WORKING GROUP ON THE ASSESSMENT OF DEMERSAL STOCKS IN THE NORTH SEA AND SKAGERRAK (WGNSSK)

Please note: Section 18 was added in September 2022; In December 2022, Executive summary, Section 11 and Annex 5, 6 and 9 were updated whilst Sections 10 and 12 were added.

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Contents

Annex 3 will be added to this report in as soon as possible.

i Executive summary

The Executive summary was updated in October 2022

The main terms of reference for the ICES Working Group for the Assessment of Demersal Stocks in the North Sea and Skagerrak (WGNSSK) were: to update, quality check and report relevant data for the working group, to update and audit the assessment and forecasts of the stocks, to produce a first draft of the advice on the fish stocks and to prepare planning for benchmarks in future years. Ecosystem changes have been analytically considered in the assessments for cod, haddock and whiting in the form of varying natural mortalities estimated by the ICES Working Group on Multi Species Assessment Methods (WGSAM).

Benchmarks in 2021/2022

Full benchmarks were conducted during 2022 for WGNSSK stocks. These were on haddock in Subarea 4, Division 6.a and Subdivision 20 and plaice in Subarea 4 and Subdivision 20. An inter-benchmark protocol (IBP) meeting took place in summer 2022 for sole in Division 7.d, to include adjustments of the assessment model configuration and tuning indices.

State of the Stocks

The main impression in recent years is that fishing pressure has been reduced substantially for many North Sea stocks of roundfish and flatfish compared to the beginning of the century. All fish stocks with agreed reference points (Category 1 stocks) are above B_{lim}, apart from cod in Subarea 4, Division 7.d and Subdivision 20. The SSBs of cod in Subarea 4, Division 7.d and Subdivision 20, sole in Subarea 4, sole in Division 7.d, and saithe in Division 3.a, Subareas 4 and 6 are below MSY $B_{trigger}$ at the beginning of 2022. Also, the SSB of witch in Division 3.a, Subarea 4, Division 7.d, estimated in the middle of the year (at spawning time) 2022 is below MSY $B_{trigger}$. Several North Sea stocks are exploited at or below F_{MSY} levels (cod in Subarea 4, Division 7.d and Subdivision 20, haddock in Subarea 4, Division 6.a and Subdivision 20, plaice in Subarea 4 and Subdivision 20, sole in Division 7.d, turbot in Subarea 4, whiting in Subarea 4 and Division 7.d); however, several others are being fished above F_{MSY} (saithe in Division 3.a, sole in Subarea 4, Subareas 4 and 6, plaice in Division 7.d, witch in Division 3.a, Subarea 4, Division 7.d). An important feature is that recruitment still remains poor compared to historic average levels for most gadoids, although there are signs of a strong recruitment for haddock and whiting in 2019 and 2020. Recruitment in 2021 continues on a high level for flatfish stocks of witch in Division 3.a, Subarea 4 and 7d and for plaice in Subarea 4 and Subdivision 20.

All *Nephrops* stocks with agreed biomass reference points (Category 1 stocks, excluding nep.fu.3-4) are currently above MSY $B_{trigger}$, apart from *Nephrops* in FU 6 (nep.fu.6). All *Nephrops* stocks with defined F_{MSY} (Category 1 stocks) are being fished below F_{MSY} in 2021, apart from *Nephrops* in FU 6 (nep.fu.6).

WGNSSK is also responsible for the assessment of several data-limited species (Category 2+ stocks) that are mainly by-catch in demersal fisheries (brill in Division 3.a, Subarea 4 and Division 7.d-e, lemon sole in Division 3.a, Subarea 4 and Division 7.d, dab in Division 3.a and Subarea 4, flounder in Division 3.a and Subarea 4, turbot in Division 3.a, whiting in Division 3.a), along with grey gurnard in Division 3.a, Subarea 4 and Division 7.d and striped red mullet in Division 3.a, Subarea 4 and Division 7.d. Annual advice is required for brill in Division 3.a, Subarea 4 and Division 7.d-e, turbot in Division 3.a as well as lemon sole in Division 3.a, Subarea 4 and Division 7.d. Biennial precautionary approach (PA) advice for striped red mullet in Division 3.a, Subarea 4 and Division 7.d and flounder in Division 3.a and Subarea 4 was provided in 2015 for the first time, and again in 2017, 2019 and 2021. Biennial advice is required on a different cycle for grey gurnard in Division 3.a, Subarea 4 and Division 7.d as well as whiting in Division 3.a, and was provided in 2022. Triennial advice is now required for dab in Division 3.a and Subarea 4 (due in 2022) and pollack in Division 3.a and Subarea 4 (due in 2024).

Biennial PA advice was provided for data-limited *Nephrops* stocks (Category 4: 10, 32, 33, 34) for the first time in 2016, subsequently in 2018, 2020 and 2022. Since 2022, advice for *Nephrops* in FU 5 was provided as a category 5 stock (after being downgraded from category 4). For *Nephrops* in 4 outside functional units biennial PA advice was produced for the first time in 2015; however, it did not make sense to have biennial advice for this unit (Category 5) misaligned with biennial advice for other data-limited *Nephrops* stocks (Category 4), so in order to achieve alignment, triennial PA advice was provided in 2017, with biennial PA advice given in 2020 in 2022 (aligned with other data-limited *Nephrops* stocks).

The summary of stock status is as follows:

1) *Nephrops*:

Category 1:

a) FU 3-4 (nep.fu.3-4): The stock size has decreased in recent years. No reference points for stock size have been defined for this FU. The estimated harvest rate for this stock is currently below F_{MSY}.

b) FU 6 (nep.fu.6): The stock size has decreased in recent years, and currently it is above MSY $B_{trigger}$. The harvest rate is currently above F_{MSY}.

c) FU 7 (nep.fu.7): The stock size is above MSY $B_{trigger}$. The harvest rate has increased since 2017 but remains below F_{MSY}.

d) FU 8 (nep.fu.8): The stock size has been above MSY $B_{trigger}$ for the entire time-series. The harvest rate decreased in 2020 and is currently below F_{MSY}. There was no survey in 2022.

e) FU 9 (nep.fu.9): The stock has been above MSY $B_{trigger}$ for the entire time-series. The harvest rate has fluctuated around F_{MSY} and is currently below F_{MSY}.

Category 4:

f) FU 32 (nep.fu.32): The stock and exploitation status are unknown, in recent years landings have been at relatively low level.

g) FU 33 (nep.fu.33): The stock and exploitation status are unknown. Landings have been on a relatively high level, since 2004 fluctuating without trend at around 1000 tonnes. The mean density of Norway lobster increased from 2019 to 2021.

h) FU 34 (nep.fu.34): The stock and exploitation status are unknown. Landings have decreased in recent years. The mean density of Norway remained stable from 2019 to 2021.

i) FU 10 (nep.fu.10): The stock and exploitation status are unknown. Landings have been at a relatively low level since 2012. The mean density of Norway lobster increased from 2014 to 2019 (Survey was not completed in 2022).

Category 5:

j) FU 5 (nep.fu.5): The stock and exploitation status are unknown. Landings have decreased in recent years. In 2022, this stock was downgraded from category 4 to category 5 due to the lack of recent survey data and information on stock trends.

k) out of FU (nep.27.4outFU): The stock and exploitation status are unknown.

2) Cod (cod.27.47d20): Spawning-stock biomass has decreased in 2016–2020, but increased since and is currently below MSY $B_{trigger}$, B_{pa} and B_{lim}. Fishing pressure has decreased since 2018, and is below F_{MSY} in 2021. Recruitment since 1998 remains poor.

3) Haddock (had.27.46a20): Spawning-stock biomass has been above MSY $B_{trigger}$ in most of the years since 2002. Currently, spawning stock size is above MSY $B_{trigger}$, B_{pa} and B_{lim}. Fishing pressure has declined since the beginning of the 2000s, but it has been above F_{MSY} for most of the entire time-series. Since 2019, fishing pressure has been below F_{MSY}. Currently, fishing pressure on the stock is below F_{MSY}, F_{pa} and F_{lim}. Recruitment since 2000 has been low with occasional larger year classes. The 2019 and 2020 year-classes are estimated to be two of the largest since 2000.

4) Whiting (whg.27.47d): Spawning-stock biomass has fluctuated around MSY $B_{trigger}$ since the mid-1980s and has been above it since 2019. Currently, spawning-stock size is above MSY $B_{trigger}$, B_{pa} and B_{lim}. Fishing pressure has been below F_{MSY} since the early 2000s. Currently, fishing pressure on the stock is below F_{MSY}, F_{pa} and F_{lim}. Recruitment has been fluctuating without trend, but the 2019 and 2020 year-classes are estimated to be the largest since 2002.

5) Saithe (pok.27.3a46): Spawning-stock biomass has mostly decreased since the early 2000s and is currently below MSY $B_{trigger}$ and between B_{pa} and B_{lim}. Fishing pressure has decreased and stabilized above F_{MSY} since 2000. Currently, fishing pressure on the stock is above F_{MSY}, but below F_{pa} and F_{lim}. Recruitment has shown an overall decreasing trend over time with lowest levels in the past 10 years.

6) Plaice (ple.27.420): The spawning-stock biomass is well above MSY $B_{trigger}$ and has markedly increased since 2008, following a substantial reduction in fishing pressure since 1999. Currently, fishing pressure on the stock is below F_{MSY}, F_{pa} and F_{lim}, and spawning-stock size is above MSY $B_{trigger}$, B_{pa} and B_{lim}. After a strong recruitment in 2019, the recruitment in 2020 is estimated to be on an average level.

7) Sole (sol.27.4): The spawning-stock biomass has fluctuated around B_{lim} since 2003, and has been estimated to be below MSY $B_{trigger}$ in 2000–2020. Currently, SSB is estimated to be below MSY $B_{trigger}$, and between B_{pa} and B_{lim}. Fishing pressure has declined since 1999. Currently, fishing pressure on the stock is above F_{MSY} and below F_{pa} and F_{lim}. Recruitment in 2019 is estimated to be one of the highest in the time series, while recruitment in 2020 and 2021 is estimated to be relatively low.

8) Sole (sol.27.7d): The spawning-stock biomass has decreased since 2014 and is estimated to be below MSY $B_{trigger}$, and between B_{pa} and B_{lim}. Fishing pressure has decreased since 2008 and is currently below F_{MSY}, F_{pa} and F_{lim}. Recruitment is estimated to be on a relatively low level since 2012.

9) Plaice (ple.27.7d): The spawning-stock biomass has increased rapidly from 2010 following a period of high recruitment between 2009 and 2019, and is now still above the MSY $B_{trigger}$, B_{pa} and B_{lim} despite a decline from 2016 to 2021. Fishing pressure has declined since the early 2000s, with an increase in the recent years to slightly above F_{pa}. Currently, fishing pressure on the stock is above F_{MSY}, but below F_{pa} and F_{lim}. Recruitment in 2020 is estimated to be the lowest value in the time series, in 2021 it is estimated to be on a relatively high level but with large uncertainty.

10) Turbot (tur.27.4): The spawning-stock biomass has increased since 2005 and has been above MSY $B_{trigger}$ since 2013. Currently, spawning stock size is above MSY $B_{trigger}$, B_{pa} and B_{lim}. Fishing pressure has decreased since the mid-1990s, and has been at or below F_{MSY} since 2012. Currently, fishing pressure on the stock is below F_{MSY}, F_{pa} and F_{lim}. Recruitment is variable without a trend. In 2021, recruitment is estimated to be below average of the time series.

11) Witch (wit.27.3a47d): Spawning-stock biomass that was below B_{lim} around 2010, has increased since then and is now above B_{lim} but below MSY $B_{trigger}$ and B_{pa}. Fishing pressure has been above F_{MSY} since the beginning of the time-series. Currently, fishing pressure on

the stock is above F_{MSY} and F_{pa}, but below F_{lim}. Recruitment has increased in recent years and is currently at high level.

12) Norway pout (nop.27.3a4): The stock size is highly variable from year to year, due to recruitment variability and a short life span. Spawning-stock biomass is estimated to have been fluctuating above B_{pa} for most of the time-series. Fishing pressure declined between 1985 and 1995 and has been fluctuating at a lower level since 1995. Recruitment in 2018, 2019, 2020 and 2022 was above the long-term average, but was estimated to be low in 2021. Currently, spawning stock size is above B_{pa} and B_{lim}; no reference points for fishing pressure or for MSY $B_{trigger}$ have been defined for this stock.

13) Category 2–6 finfish stocks: In 2022, new advice has been produced for bll.27.3a47de, gug.27.3a47d, dab.27.3a4, lem.27.3a47d, whg.27.3a (all Category 3 stocks) and tur.27.3a (Category 2). Advice was produced following the new WKLIFE X rules. Advice was not provided this year for fle.27.3a4 (Category 3) nor for mur.27.3a47d and pol.27.3a4 (Category 5).

a) Brill (bll.27.3a47de): The biomass index has been gradually increasing over the time-series until 2015, and has then decreased. Currently, fishing pressure on the stock is above $F_{MSY\ Proxy}$ and the stock size index is above $I_{trigger}$.

b) Grey gurnard (gug.27.3a47d): The available survey information indicates a decreasing trend in stock biomass in recent years. Currently, the stock size index is above $I_{trigger}$; no reference points for fishing pressure have been defined for this stock.

c) Dab (dab.27.3a4): Spawning stock biomass has decreased since 2016. Currently, the stock size index is above $I_{trigger}$. Total mortality has been fluctuating without trend over the time series, but is relatively stable in recent years. Currently, fishing pressure is below the $F_{MSY\ Proxy}$ for this stock. Since the peak in recruitment around the year 2015, there has been a decrease in recent years.

d) Lemon sole (lem.27.3a47d): Spawning-stock biomass mostly decreased from 2012 to 2018, but has recently increased. Currently, the stock size index is well above $I_{trigger}$. Currently, fishing pressure is below the $F_{MSY\ Proxy}$ for this stock.

e) Turbot (tur.27.3a): Catches peaked in the late 1970s and early 1990s and have been more stable in recent years. Relative exploitable biomass (B/B_{MSY}) declined towards 2000 with an increasing trend in recent years. Currently, spawning stock size is above MSY $B_{trigger}$. Relative fishing pressure (F/F_{MSY}) peaked in the late 1970s and early 1990s, and has been relatively low without a trend in more recent years. Currently, fishing pressure on the stock is below F_{MSY}.

f) Whiting (whg.27.3a): The biomass index has been gradually increasing in recent years. Currently, the stock size index is above $I_{trigger}$. No reference points for fishing pressure have been defined for this stock.

Summary of retrospective analysis (WKFORBIAS decision tree)

To quantify retrospective patterns in the assessments of category 1 stocks, estimates of five-year retrospective peels are produced for fishing pressure, SSB and recruitment and plotted with confidence bounds of the current assessment. The retrospective statistics (Mohn's rho) are reported as a measure of quality. The decision tree formulated by WKFORBIAS (ICES, 2020) was considered to ensure more consistency in how advice is provided. The only stock that showed significant retrospective patterns in SSB were sole in 4 (Mohn's rho above limit of 0.2). For sole, most of the retrospective peels fall outside the confidence bounds. The stock has recently undergone a benchmark and the retrospective pattern could not be solved yet. However, the target F (F_{MSY}) in the forecast for 2023 is well below the $F_{P.05}$ estimated using EqSim, therefore advice is given as usual this year.

ii Expert group information

Expert group name	Working Group on the Assessment of Demersal Stocks in the North Sea and Skagerrak (WGNSSK)
Expert group cycle	Annual
Year cycle started	2022
Reporting year in cycle	1/1
Chairs	Tanja Miethe, Germany
	Raphaël Girardin, France
Meeting venues and dates	20-29 April 2022, Copenhagen, Denmark and online (hybrid meeting), 38 participants
	13-15 September 2022, Online, *Nephrops*, 9 participants
	27 September 2022, Online, Norway pout, 6 participants

1 General

1.1 Terms of Reference

Generic ToRs for Regional and Species Working Groups

2021/2/FRSG01 The following ToRs apply to: AFWG, HAWG, NWWG, NIPAG, WGWIDE, WGBAST, WGBFAS, WGNSSK, WGCSE, WGDEEP, WGBIE, WGEEL, WGEF, WGHANSA and WGNAS.

The working group should focus on:

a) Consider and comment on Ecosystem and Fisheries overviews where available;

b) For the aim of providing input for the Fisheries Overviews, consider and comment on the following for the fisheries relevant to the working group:

  i) descriptions of ecosystem impacts on fisheries

  ii) descriptions of developments and recent changes to the fisheries

  iii) mixed fisheries considerations, and

  iv) emerging issues of relevance for management of the fisheries;

c) Conduct an assessment on the stock(s) to be addressed in 2022 using the method (assessment, forecast or trends indicators) as described in the stock annex; - complete and document an audit of the calculations and results; and produce a **brief** report of the work carried out regarding the stock, providing summaries of the following where relevant:

  i) Input data and examination of data quality; in the event of missing or inconsistent survey or catch information refer to the ACOM document for dealing with COVID-19 pandemic disruption and the linked template that formulates how deviations from the stock annex are to be reported.

  ii) Where misreporting of catches is significant, provide qualitative and where possible quantitative information and describe the methods used to obtain the information;

  iii) For relevant stocks (i.e., all stocks with catches in the NEAFC Regulatory Area), estimate the percentage of the total catch that has been taken in the NEAFC Regulatory Area in 2021.

  iv) For category 3 and 4 stocks requiring new advice in 2022, implement the methods recommended by WKLIFE X (e.g. SPiCT, rfb, chr, rb rules) to replace the former 2 over 3 advice rule (2 over 5 for elasmobranchs). MSY reference points or proxies for the category 3 and 4 stocks

  v) Evaluate spawning stock biomass, total stock biomass, fishing mortality, catches (projected landings and discards) using the method described in the stock annex;

    1) for category 1 and 2 stocks, in addition to the other relevant model diagnostics, the recommendations and decision tree formulated by WKFORBIAS (see Annex 2 of

https://www.ices.dk/sites/pub/Publication%20Reports/Expert%20Group%20Report/Fisheries%20Resources%20Steering%20Group/2020/WKFORBIAS_2019.pdf) should be considered as guidance to determine whether an assessment remains sufficiently robust for providing advice.

2) If the assessment is deemed no longer suitable as basis for advice, consider whether it is possible and feasible to resolve the issue through an interbenchmark. If this is not possible, consider providing advice using an appropriate Category 2 to 5 approach.;

vi) The state of the stocks against relevant reference points;

Consistent with ACOM's 2020 decision, the basis for Fpa should be Fp.05.

1) 1. Where Fp.05 for the current set of reference points is reported in the relevant benchmark report, replace the value and basis of Fpa with the information relevant for Fp.05

2) 2. Where Fp.05 for the current set of reference points is not reported in the relevant benchmark report, compute the Fp.05 that is consistent with the current set of reference points and use as Fpa. A review/audit of the computations will be organized.

3) 3. Where Fp.05 for the current set of reference points is not reported and cannot be computed, retain the existing basis for Fpa.

vii) Catch scenarios for the year(s) beyond the terminal year of the data for the stocks for which ICES has been requested to provide advice on fishing opportunities;

viii) Historical and analytical performance of the assessment and catch options with a succinct description of associated quality issues. For the analytical performance of category 1 and 2 age-structured assessments, report the mean Mohn's rho (assessment retrospective bias analysis) values for time series of recruitment, spawning stock biomass, and fishing mortality rate. The WG report should include a plot of this retrospective analysis. The values should be calculated in accordance with the "Guidance for completing ToR viii) of the Generic ToRs for Regional and Species Working Groups - Retrospective bias in assessment" and reported using the ICES application for this purpose.

d) Produce a first draft of the advice on the stocks under considerations according to ACOM guidelines.

i. In the section 'Basis for the assessment' under input data match the survey names with the relevant "SurveyCode" listed ICES survey naming convention *(restricted access)* and add the "SurveyCode" to the advice sheet.

e) Review progress on benchmark issues and processes of relevance to the Expert Group.
i) update the benchmark issues lists for the individual stocks in SID;
ii) review progress on benchmark issues and identify potential benchmarks to be initiated in 2023 for conclusion in 2024;
iii) determine the prioritization score for benchmarks proposed for 2023–2024;
iv) as necessary, document generic issues to be addressed by the Benchmark Oversight Group (BOG)

f) Prepare the data calls for the next year's update assessment and for planned data evaluation workshops;

g) Identify research needs of relevance to the work of the Expert Group.

h) Review and update information regarding operational issues and research priorities on the Fisheries Resources Steering Group SharePoint site.

i) If not completed in 2020, complete the audit spread sheet 'Monitor and alert for changes in ecosystem/fisheries productivity' for the new assessments and data used for the stocks. Also note in the benchmark report how productivity, species interactions, habitat and distributional changes, including those related to climate-change, could be considered in the advice.

Information of the stocks to be considered by each Expert Group is available here.

Specific WGNSSK ToRs

2021/2/FRSG19 The **Working Group on the Assessment of Demersal Stocks in the North Sea and Skagerrak** (WGNSSK), chaired by Tanja Miethe, UK, and Raphaël Girardin, France, will meet in ICES HQ, Copenhagen, Denmark, 20–29 April 2022 and by correspondence in September 2022 to:

a) Address generic ToRs for Regional and Species Working Groups.

b) Assess Norway pout assessments by correspondence.

c) Report on reopened advice as appropriate;

The assessments will be carried out on the basis of the stock annex. The assessments must be available for audit on the first day of the meeting.

Material and data relevant for the meeting must be available to the group on the dates specified in the 2022 ICES data call.

WGNSSK will report by 13 May 2022, and by 21 September 2022 (Norway pout) for the attention of ACOM.

Only experts appointed by national Delegates or appointed in consultation with the national Delegates of the expert's country can attend this Expert Group

1.1 InterCatch

1.1.1 Métier-based data call for WGNSSK (and other working groups)

The year 2012 represented a major change in the process of data collection for WGNSSK. Following an initiative launched by ICES WGMIXFISH in August 2011, it had been decided to merge the data calls and data collection of both groups WGNSSK and WGMIXFISH, on the basis of:

1. Improving the availability of métier-based data and their consistency with the stock-based data used for single-stock assessment.
2. Allowing WGMIXFISH to meet earlier in order to integrate the mixed-fisheries advice within the single-stocks advice sheets.

In 2014, data-limited stocks were included in the data call for the first time to improve the knowledge base for these stocks. With the landing obligation, these stocks become more important, and under these circumstances, discard information is a prerequisite for giving catch advice and carrying out mixed fisheries scenarios. In 2015, for the first time a joint data call for all relevant assessment working groups was launched.

The principle of the data call is to define the aggregation (métier) level for the data that individual countries should deliver following the requirements of the EU Data Collection Framework (DCF), and to use these as the basis for providing and subsequently raising data for all North Sea demersal stocks. The ICES InterCatch database was chosen as the most appropriate tool to use until the planned Regional Data Base and Estimation System (RDBES) is fully established and operational. Basic strata for the submission of catch and effort data were by country, quarter, area, métier and catch category.

In 2019, the procedure for data submission was similar to previous years, including a requirement for life-history information and length compositions for historic landings and discards for stocks identified as "DLS" (essentially Category 3 stocks) from at least the three most recent consecutive years (only the most recent year for those stock for which length frequency data were already provided in a previous data call). The data call also required reporting to four catch categories, including BMS landings (landings below minimum size for stocks under the landing obligation).

In 2020, in addition to the above procedure, coe.27.3a47de, hal.27.3a47de, and caa.27.3a47de were included to the data call to collect quarterly landings data for WGMIXFISH. An official data call was issued by ICES, with a deadline for data delivery of 1 April 2020, three weeks prior to the start of the WGNSSK meeting in Bergen. Despite delays in data submissions relative to the deadline and some errors needing to be corrected before the working group, these delays and corrections had no major impact on the work. During the meeting it was noticed that landings for Sweden for subarea 4 have not been uploaded to Intercatch. Amounts were generally low and were added manually for each affected stock to respective landings, and discards were raised using the discard ratio in area 4.

In 2021, the missing catches 2019 from Sweden have been submitted, and catch data was re-raised this year and included in the respective assessment. Due to sampling interruptions due to the Covid pandemic some reduction in samples occurred for quarters 2 to quarter 4 of 2020 and in quarter 1 and 2 of 2021. Any changes in the approaches for raising catch data in Intercatch are listed in Annex 9.

1.1.2 Data raising and allocation to un-sampled strata

Major changes occurred in recent years with the raising of data within InterCatch. Different initiatives can be mentioned here:

1. Age and length data in parallel in InterCatch

InterCatch can now work with age and length data in parallel, but it demands that length sample data have to be imported last for species with both age and length distribution data. This is due to InterCatch ignoring strata of other sample types. However, InterCatch will always take the latest imported strata without samples. Also, there is no problem with overwriting data in InterCatch as long as length data are imported latest, for stocks with both length and age samples. There is still no age-length-keys in InterCatch. It is important that when importing catches with and without age samples all strata have to be imported, all strata also have to be imported when importing catches with and without length samples.

2. Technical improvements in the InterCatch interface

- Allocation Group Setup: define a group of unsampled catch/strata for which each distribution will be calculated according to the (for the group) allocated sampled catches/strata;
- Automatic allocation ‘same’ strata: automatically find and allocate identically sampled strata from other countries to unsampled catches/strata (with the identical stratum);
- Discard Group setup: Define a group of raised discards for which each discard weight will be calculated according to the (for the group) selected landing-discard ratios;
- CATON and age/length data overviews: it is possible to examine all imported data in detail;
- Allocation overview for pivot table/matrix: all unsampled strata are shown in the first column and all sampled strata are shown as the first row, then all the selected combinations are shown in the matrix;
- Possibility to save allocation schemes.

3. Summary outputs and inspection of data before raising

The new features included in InterCatch allowed improved inspection and visualization of the data submitted by national data providers and a comparison with data from previous years. A generic R script has been developed in 2016 and improved in subsequent years by Y. Vermard (IFREMER) mapping out the raw data, through e.g. quantification of the proportion of catches covered by sampling, identification of major gaps and outliers, plot of the age distribution and discards ratio of the various strata etc.

4. Raising procedures

Based on statistical principles discussed within WKPICS, RCMs, PGCCDBS and DC-MAP etc., the suggestions for the basis on which to proceed regarding raising of age distributions and discards ratio have been revisited. In 2012, the raising and allocating was based on finding similar strata from other countries, but this was judged not fully defendable in terms of statistical integrity. In 2016, the underlying principles applied were thus:

- Main strata are supposed to be sampled. In essence one should expect that the largest share of catches should have age-based and discards information in InterCatch. Even though there may be a great number of unsampled strata, in reality these should represent only a minor part of the catches. Large strata without sampling information would need to be investigated further.
- Therefore, the suggestion was that by default, unsampled strata should be raised by all sampled strata, unless there is a good and informed reason for choosing differently after the data inspection process. Each stock coordinator has developed general principles for the allocation scheme. The main principles are mentioned in the respective report sections.

Ultimately, all these changes have triggered in-depth investigation and understanding of the data submitted, and are hopefully contributing to improved consistency and transparency in the assessment data. However, if more than one year needs to be raised, the InterCatch procedure is still very time consuming. The saving of allocations schemes does not always function, especially when the métiers differ between years, and currently, only the age allocation scheme can be copied (not the discard ratio allocation scheme). It would be beneficial to allow for more flexible automatic matching based on e.g. gear type or area only. Also the possibility of entering allocation schemes via scripts (instead of the need to click through the options and metiers) would allow for fast sensitivity checks and would make InterCatch much more user-friendly. However, there is limited scope for improvements in InterCatch, given the focus on getting RDBES (its successor) operational and fully functional in the near future.

Because of the landing obligation, new catch categories have been reported since 2016. BMS landings, observer discards and logbook recorded discards should sum up to discard data provided prior to 2016 (i.e. double-counting should be avoided), and when performing raising procedures, the raising procedure in InterCatch should be adapted as necessary to provide a robust approach, independent of how countries categorize catches when providing catch data. The general approach adopted by WGNSSK is to raise discards using only the observed discards (catch category "D" from the datacall), and to allocate discard age compositions to BMS landings (category "B" from the datacall), if reported and given a "CATON" value.

InterCatch summary data have been made available on the SharePoint, and will be investigated further during ICES WGMIXFISH.

By the end of the WG in May 2022, the status of InterCatch use was as follows:

Stock	Data Year	Working Group	Extracted	Exported	Status of Data filled in
bll.27.3a47de	2021	WGNSSK	Extracted	Exported	DataUsedForAssessment
cod.27.47d20	2021	WGNSSK	Extracted	Exported	Notfilled
dab.27.3a4	2021	WGNSSK	Extracted	Exported	DataUsedForAssessment
fle.27.3a4	2021	WGNSSK	Extracted	Exported	DataUsedForAssessment
gug.27.3a47d	2021	WGNSSK	Extracted	Exported	DataUsedForAssessment

Stock	Data Year	Working Group	Extracted	Exported	Status of Data filled in
had.27.46a20	2021	WGNSSK	Extracted	Exported	DataUsedForAssessment
hal.27.3a47de	2021	WGNSSK	No	No	Notfilled
lem.27.3a47d	2021	WGNSSK	Extracted	Exported	DataUsedForAssessment
mur.27.3a47d	2021	WGNSSK	Extracted	Exported	DataUsedForAssessment
nep.27.4outFU	2021	WGNSSK	Extracted	Exported	DataUsedForAssessment
nep.fu.10	2021	WGNSSK	Extracted	Exported	DataUsedForAssessment
nep.fu.32	2021	WGNSSK	Extracted	Exported	DataUsedForAssessment
nep.fu.33	2021	WGNSSK	Extracted	No	Notfilled
nep.fu.34	2021	WGNSSK	Extracted	Exported	DataUsedForAssessment
nep.fu.3-4	2021	WGNSSK	Extracted	No	Notfilled
nep.fu.5	2021	WGNSSK	Extracted	Exported	DataUsedForAssessment
nep.fu.6	2021	WGNSSK	Extracted	Exported	DataUsedForAssessment
nep.fu.7	2021	WGNSSK	Extracted	Exported	DataUsedForAssessment
nep.fu.8	2021	WGNSSK	Extracted	Exported	DataUsedForAssessment
nep.fu.9	2021	WGNSSK	Extracted	Exported	DataUsedForAssessment
nop.27.3a4	2021	WGNSSK	No	No	Notfilled
ple.27.420	2021	WGNSSK	Extracted	Exported	DataUsedForAssessment
ple.27.7d	2021	WGNSSK	Extracted	Exported	DataUsedForAssessment
pok.27.3a46	2021	WGNSSK	Extracted	Exported	Notfilled
pol.27.3a4	2021	WGNSSK	Extracted	Exported	DataUsedForAssessment
sol.27.4	2021	WGNSSK	Extracted	Exported	Notfilled
sol.27.7d	2021	WGNSSK	Extracted	Exported	DataUsedForAssessment
tur.27.3a	2021	WGNSSK	Extracted	No	Notfilled
tur.27.4	2021	WGNSSK	Extracted	Exported	Notfilled
whg.27.3a	2021	WGNSSK	Extracted	No	Notfilled
whg.27.47d	2021	WGNSSK	Extracted	Exported	DataUsedForAssessment
wit.27.3a47d	2021	WGNSSK	Extracted	Exported	DataUsedForAssessment

1.1.3 Treatment of BMS landings in advice sheets

There remain inconsistencies in the reporting of BMS landings between different nations, both in the official statistics (FAO) and in InterCatch. In general, WGNSSK has assumed that BMS landings are part of discards, and BMS landings are not shown separately in tables of ICES estimates given in the advice sheets; the only BMS estimates that appear in advice sheet tables are those from official statistics. The only exceptions to this treatment of BMS landings as discards is for the saithe stock (pok.27.3a46), for which the Norwegian component of BMS landings are included with the ICES estimates of landings.

1.2 General uncertainty considerations

Data or inputs used in this report are based on sampling or on census. Typical census data are landings data from sales slips representing total landing, while sampled data are random samples (design based) used to produce estimates of total, relative indices or to characterize composition (like catch at age). All sources of input may introduce error in estimates/calculations and are a limiting factor in the amount of signal in data and/or interpretation of model results. The scientist at this working group are only responsible for a modest fraction of the input data used and are relying heavily on assumptions regarding their validity and quality. The information based on sampling will contain sampling errors (random errors due to the stochastic nature of such sampling) and estimates of sampling error are generally not used by this working group. Such errors will show up in residuals (residual plots are an important diagnostic in the report), but other sources of error will also show up in the same residuals and are not easily separated from random errors. Non-random errors are either bias or model errors. Systematic bias over time is a particular concern and an example of such can be underreporting of catches, which will compromise the validity of the model results as basis for advice. Model errors may represent the use of the "wrong" equations to describe relations, but will in this report typically be linked to assumptions regarding natural mortality, the relationship between survey indices and stock size (catchability) and exploitation pattern. Some assumptions are needed since, for example, the Baranov catch equations do not have unique solutions (too many parameters to estimate).

Assessment working groups are in many ways end users of data and it would be preferable to have such information presented as point estimates together with estimates of uncertainty or confidence bands and with a description of potential sources of bias and qualitative remarks related to specific observations. InterCatch is still not fully operational in this respect.

The working group appreciates the effort made by so many supporting hands involved in creating all information needed in fish stock assessment and is dependent on the quality of information being upheld over time. An assessment working group is where information from the commercial fishery is handled together with fishery independent information to create estimates of stock status and the impact of fishing.

Demersal trawl surveys are the most used source of fishery independent information in this working group (WGNSSK). A demersal trawl survey uses a standardized procedure of trawling to create samples from a fish population. The "population" in statistical terms is the population of possible trawl stations with trawl station being the primary sampling unit. The estimates of uncertainty from a demersal trawl survey is very much dependent on the number of samples (trawl stations) and it seems that demersal trawl surveys on gadoids produces very similar estimates of uncertainty given the same number of trawl stations (ICES, 1992) regardless of the size of the area. The relationship between sample size and precision can be illustrated using the following example: If a survey of 400 trawl stations produces an estimate (for a parameter of interest) with a corresponding relative standard error of 0.1 a reduction in survey effort to 100 trawl stations is likely to produce estimates with a relative standard error of 0.2 (divide the number of stations by 4 and the relative standard error is doubled). This is also likely to hold (at least as a rule of thumb) if one looks at results from a subarea of the original (400 station) area. When estimates of relative standard error approaches 0.3, trends over time will be very difficult to detect, and with relative standard errors above 0.3, the estimator can only be used to detect sudden events. WGNSSK recommends that, along with survey index point estimates, DATRAS should also provide the uncertainty around these estimates as standard output.

1.3 Survey corrections during 2021 and 2022

New automated ALK filling methodology was introduced for DATRAS indices in early 2020. Indices for Q1 2020 and onwards are only available calculated using the new methodology. These indices are used either together with the historical index time-series historical indices will be updated during an inter-benchmark protocol or a benchmark process) or with an updated index time series using new methodology (if survey update and reference points were checked during WGNSSK).

In 2021, there was a large re-submission of IBTS data from France with many additional hauls and length information for the period 1999-2012. Until a stock undergoes an interbenchmark or benchmark, for the historical period the survey data as in WGNSSK 2020 will be used for the assessments. Only survey data for 2020-2022 have been updated.

In 2022, the IBTS Q1 survey coverage was compromised due to weather conditions and technical vessel issues with missing hauls in the central/northern North Sea and West of Scotland. Where modelling approaches are used to compute indices, spatial and vessel effects are included to account for change in coverage. Sensitivity runs were performed as appropriate to ensure data quality is sufficient.

1.4 Internal auditing

Although a very important quality assurance mechanism, internal audits do place an additional burden on group members, and it has not been possible to complete most audits during the meeting itself for a few years now. WGNSSK operates with seldom more than one scientist per stock (sometimes one scientist is responsible for two or more stocks), and there was in most cases not enough time to have the reports finalized in order to carry out the audit within the WG meeting itself. Audits had to be conducted by correspondence after the WG time, which is neither very efficient nor very motivating, given the heavy workload under which most members usually operate back in home institutes. It is hoped that the move to TAF will both make auditing easier and more transparent, and improve the quality of auditing procedures.

All WGNSSK stocks with advice in 2022 could be covered by the internal audit (Table 1.5.1). The audit results are given in Annex 4 of the report.

In 2022, new empirical rules were applied to Category 3 stocks replacing the precautionary approach (2-over-3 rule) to give advice following WKLIFE X (ICES, 2020). An external review of report sections has taken place to ensure quality control.

Model adjustments or an update of historical input data was necessary for haddock in 4, 6.a and 20, whiting in 4 and 7.d, and plaice in 7.d. Reference points were checked and updated if necessary. The working documents for these stocks (Annex 8), describing the updates, were reviewed externally at the end of the working group meeting.

Table 1.5.1. Fish stocks covered by the internal audit and external reviews.

Fish Stock	Internal Audit Spring	Internal Audit Autumn	External Audit Spring
bll.27.3a47de	X		X (WKLIFE rule)
cod.27.47d20	X		
dab.27.3a4	X		X (WKLIFE rule)
fle.27.3a4	*No new advice in 2022*		
gug.27.3a47d	X		X (WKLIFE rule)
had.27.46a20	X		X (WD)
lem.27.3a47d	X		X (WKLIFE rule)
mur.27.3a47d	*No new advice in 2022*		
nep.27.4outFU	*No advice in spring*	X	
nep.fu.10	*No advice in spring*	X	
nep.fu.32	*No advice in spring*	X	
nep.fu.33	*No advice in spring*	X	
nep.fu.34	*No advice in spring*	X	
nep.fu.3-4	*No advice in spring*	X	
nep.fu.5	*No advice in spring*	X	
nep.fu.6	*No advice in spring*	X	
nep.fu.7	*No advice in spring*	X	
nep.fu.8	*No advice in spring*	X	
nep.fu.9	*No advice in spring*	X	
nop.27.3a4	*No advice in spring*	X	
ple.27.420	X		
ple.27.7d	X		X (WD)
pok.27.3a46	X		
pol.27.3a4	*No new advice in 2022*		
sol.27.4	X		
sol.27.7d	Delayed advice (need IBP)	X	
tur.27.3a	X		
tur.27.4	X		
whg.27.3a	*X*		X (WKLIFE rule)

Fish Stock	Internal Audit Spring	Internal Audit Autumn	External Audit Spring
whg.27.47d	X		X (WD)
wit.27.3a47d	X		

1.5 Transparent Assessment Framework (TAF)

TAF is a new framework, currently in development, to organize all ICES stock assessments. Using a standard sequence of R scripts, it makes the data, analysis, and results available online, and documents how the data were pre-processed. Among the key benefits of this structured and open approach are improved quality assurance and peer review of ICES stock assessments. Furthermore, a fully scripted TAF assessment is easy to update and rerun later, with a new year of data. As of spring 2018, the first assessments have been scripted in standard TAF scripts. See http://taf.ices.dk for more information. By 2020 14 out of 30 WGNSSK stocks in varying states of completeness in TAF. Uptake has recently decreased. Stock assessors were encouraged to take part in training workshops offered by ICES to get their assessments into TAF.

1.6 Mixed Fisheries

The mixed fisheries analyses for the North Sea are performed by the Working Group for Mixed Fisheries Advice for the North Sea (WGMIXFISH), which aims to evaluate the consistency of the ICES advice for the individual stocks in a mixed fisheries context, using the Fcube model (Ulrich *et al*., 2011).

WGNSSK and WGMIXFISH have developed and issued a common data call since 2012, which has greatly improved the quality and scheduling of data delivery. WGMIXFISH meets directly after WGNSSK in June 2022 (WGMIXFISH-METH), and also in late October 2022 (WGMIXFISH-ADVICE) in order to produce mixed-fisheries advice for the North Sea (integrated into the Fisheries Overview for the North Sea). We therefore refer to the ICES WGMIXFISH reports and Fisheries Overview for any further description of the mixed-fisheries context.

However, the group continues to discuss mixed fisheries issues under the landing obligation. There is a potential problem with choke species in the North Sea, where target as well as bycatch species can become choke species for certain fleet segments. One way to deal with this is to use the recently defined ranges for F_{MSY} instead of point estimates (see e.g. ICES WKMSYREF III 2014 and ICES WKMSYREF IV 2016). Ranges can introduce the flexibility needed to minimize the discrepancies in available quotas for species in a mixed fishery, and have been introduced as part of EU MAPs, which are mixed-fishery multiannual plans for demersal stocks in the North Sea (Regulation (EU) 2018/973) and stocks in Western Waters (Regulation (EU) 2019/472). These plans allow fishing within the F_{MSY} range, but with more stringent conditions (related to the need to meet mixed fisheries objectives) for using the part of the range above F_{MSY}, referred to as the upper range. STECF undertook an evaluation of mixed-fishery multiannual plans for the North Sea (STECF EWG-15-02), following a European Commission proposal for such plans, and concluded in relation to the use of the upper range that (STECF PLEN-15-01):

→ *There is an increased risk of over-exploitation if fishing opportunities are set in line with the upper limits of the F_{MSY} ranges, particularly if several stocks in a mixed fishery are involved.*

and furthermore that:

→ *The use of the F_{MSY} range approach should only be employed when informed by objective mixed fishery advice which demonstrates that attaining F_{MSY} for the key driver species cannot be achieved simultaneously and the application of F_{MSY} ranges are necessary to better reconcile mixed fisheries issues. In the absence of such information, then fishing opportunities should be set in accordance with single species F_{MSY} advice.*

Blindly setting TACs within the upper range for all stocks should be avoided by managers. In the long-term, there is no gain to fish stocks above F_{MSY} as the yield becomes lower and the risk for the stocks increases. Selectivity in mixed fisheries should be improved instead to avoid choke effects.

The management of bycatch species (e.g. lemon sole, turbot) by TAC further complicates the situation. If the TAC management for these species continues and F_{MSY} proxies implemented, these species can become serious choke species. The inter-institutional task force on multi annual plans between the European parliament, the council and the Commission write in their agreement (EU 8529/14): "With regard to bycatch species, the co-legislators will have to determine, taking account of the available scientific advice, whether these are sufficiently covered through the management measures according to MSY for the key species". Policy has to define what sustainable exploitation means for bycatch species and it has to be evaluated by science whether MSY targets for target stocks are enough to ensure a sustainable exploitation of bycatch species.

1.7 Multispecies considerations

ICES gave advice on multi species considerations for the North Sea in 2013 for the first time to start a dialogue between ICES and its stakeholders on this topic. Simulations were carried out with the stochastic multi species model SMS to analyse F_{MSY} in a multi species context. The multi species considerations can be found under: http://www.ices.dk/sites/pub/Publication%20Reports/Advice/2013/2013/mult-NS.pdf

WGNSSK supports this step. However, the group also raised concerns about the data basis for the simulations (stomach data mainly from 1981 and 1991) and the high number of assumptions behind the model results.

Already in 2013 the group discussed the progress achieved under various initiatives such as ICES WGSAM (2011, 2012), ICES WKMTRADE (2012) and the EU project MYFISH. The group noted that a multispecies benchmark, as in the Baltic, may be needed where the North Sea SMS model and key-run settings are reviewed by external experts before a final multi species advice can be given.

There are many direct and indirect interactions between species, making it difficult to reach a single and robust best solution. Optimization scenarios carried out so far show that the result (target F) depends very much on the objectives (objective function) and SSB constraints used. The exact combination of species target F depends also on the weighting factors (e.g. price per kg when optimizing value) actually used for calculating these objectives. During a stakeholder workshop organized by ICES and MYFISH (ICES WKMTRADE 2012) it has been agreed that when offering trade-offs, ICES can provide scenarios below F_{MSY} for the exploitation of some populations. This will allow a policy choice to be made within the limits defined and explained by ICES. F_{MSY} ranges (see also under mixed fisheries) could also help here to reach consensus based on a pretty good yield concept instead of trying to reach the absolute maximum for each stock, which is impossible given the biological interactions between predator and prey.

1.8 Special requests

There were no special requests for WGNSSK to handle during the meeting.

1.9 Presentations

A presentation was given to WGNSSK in 2022 on changes in the Dutch fishing fleet since 2009, aiming to explain the impact of pulse trawls adoption on sole and plaice assessments. Since 2009, the Dutch beam trawlers started using innovative Pulse gears – which are often aimed at reduction of fuel consumption and reduction of bottom disturbance. Between 2014 and 2018, the majority of the Dutch beam trawlers have switched from traditional beam trawls (TBB) to pulse trawls (PUL) (Figure 1.1). Following the EU decision in February 2019 to revise the technical measures regulations, pulse trawling is prohibited since 30 June 2021.

The annual efforts (h) of beamtrawl fleet has been declining since 2000 (Figure 1.2). The efforts became stable since 2010, mainly with reallocation between TBB and PUL. Since 2009, TBB has been switching to PUL. In 2014-2018, majority of the beam trawlers were PUL vessels. Large number of beam trawlers are switching back to TBB since 2019 due to the pulse ban.

Switching to PUL also leads to fishing at softer fishing ground in the southern part of Division 4.c. where sole became the targeted species (Figure 1.3). In the meantime, the discards ratio for plaice has been increasing in the same period, from 40% in 2014 to 51% in 2021.

The pulse ban is expected to cause large changes in the Dutch beam trawl fleet in the coming years.

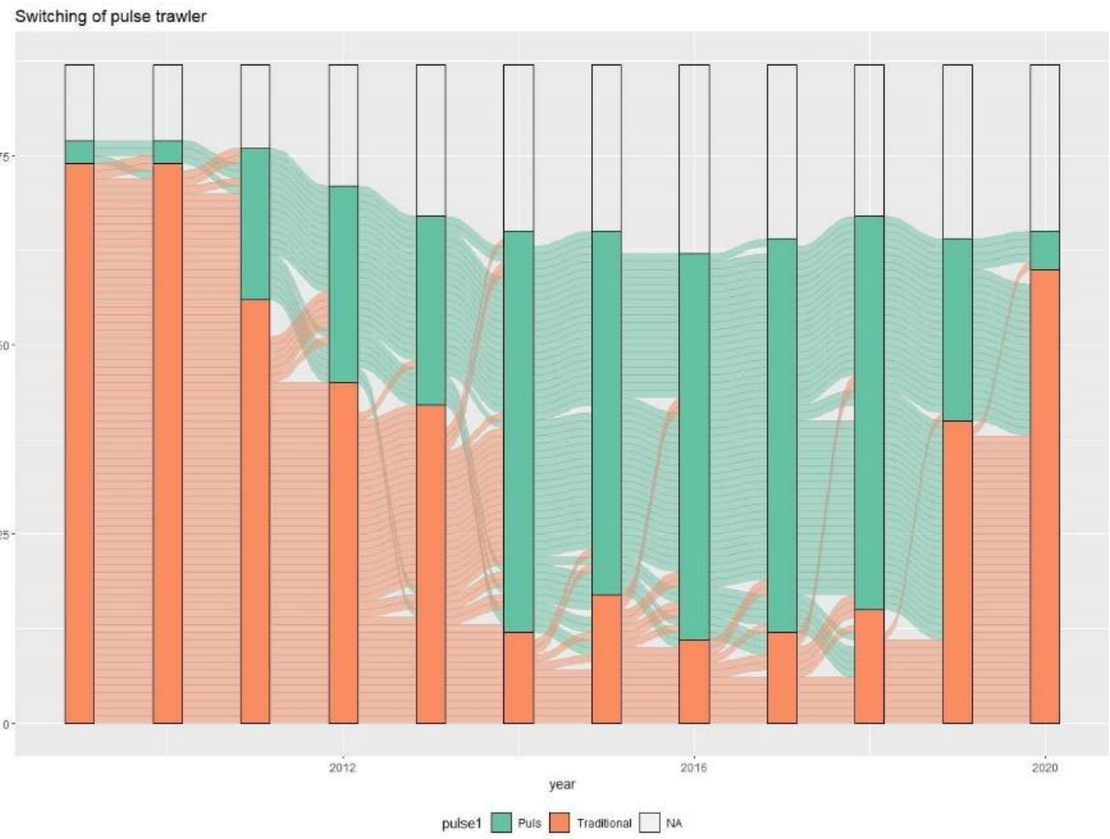


Figure 1.1. Switch between TBB and PUL in Dutch beam trawlers.

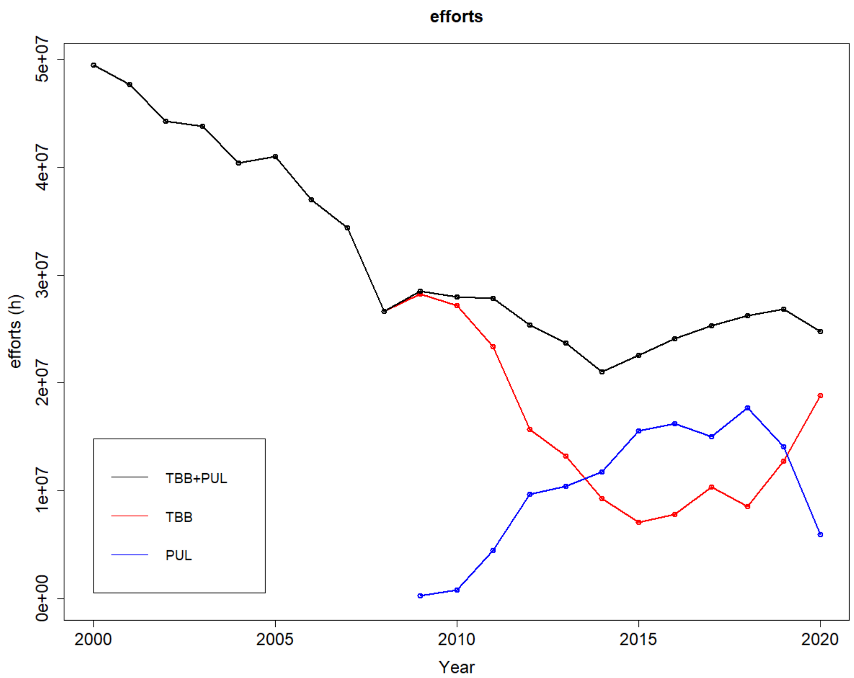
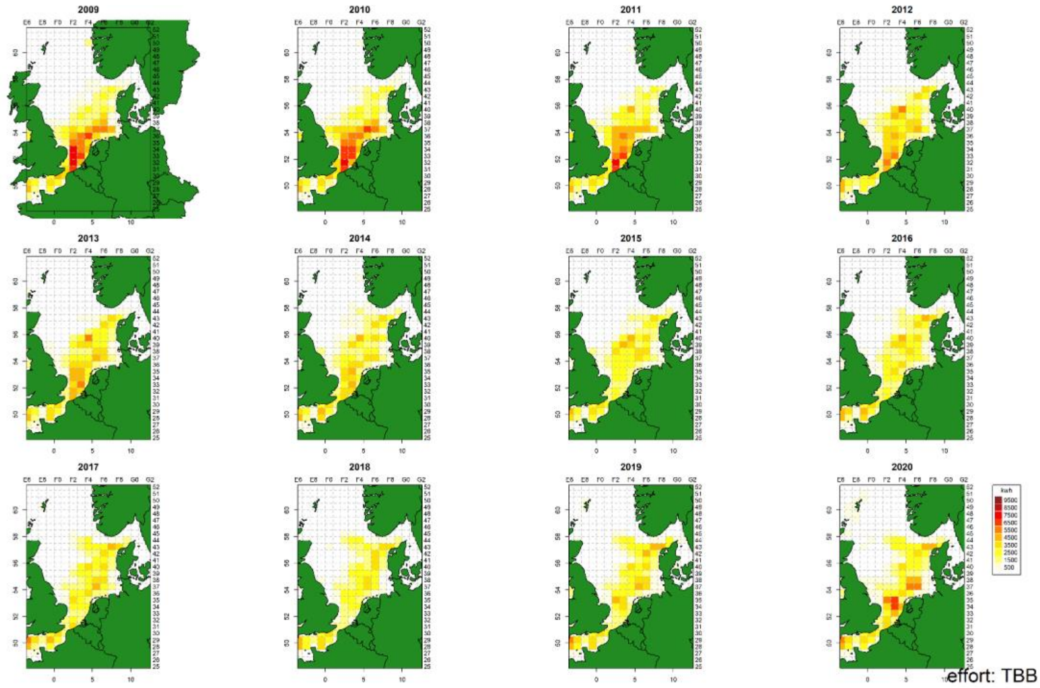


Figure 1.2. Annual fishing effort (hour) of TBB and PUL since 2000.

(a)



(b)

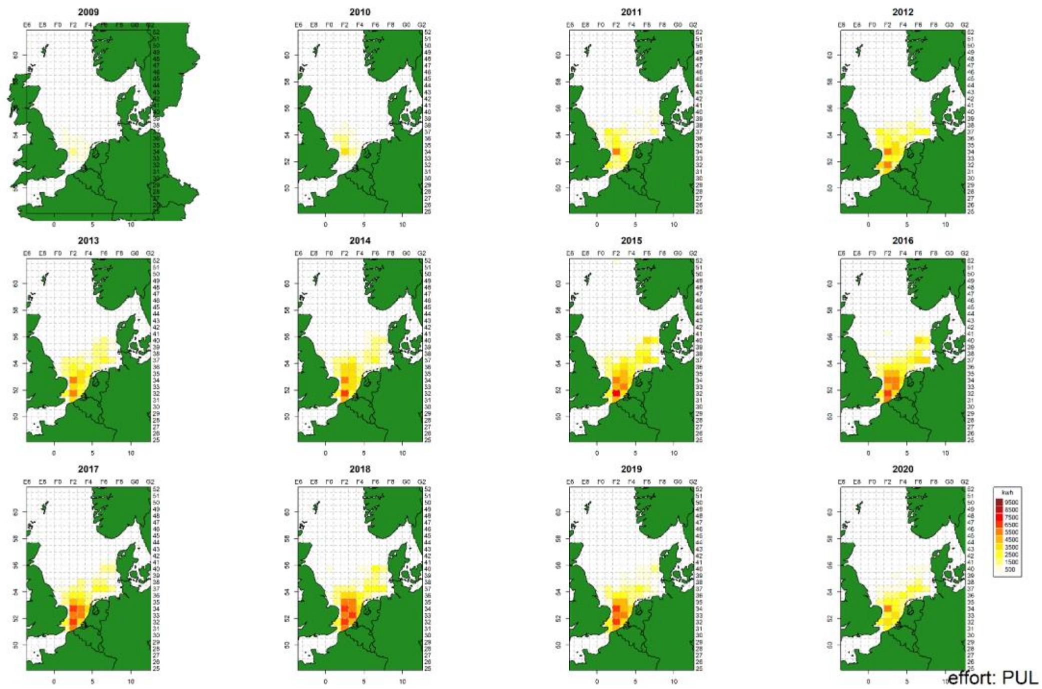


Figure 1.3. Spatial fishing effort map since 2009 for (a) TBB and (b) PUL.

1.10 References

ICES. 2020. Tenth Workshop on the Development of Quantitative Assessment Methodologies based on LIFE-history traits, exploitation characteristics, and other relevant parameters for data-limited stocks (WKLIFE X). ICES Scientific Reports. 2:98. 72 pp. http://doi.org/10.17895/ices.pub.5985

11 Norway lobster (*Nephrops* spp.) in Subarea 4 (North Sea)

This section was updated in October 2022

11.1 General comments relating to all *Nephrops* stocks

See Section 10.1.

11.2 *Nephrops* in Subarea 4

Subarea 4 contains nine FUs 5, 6, 7, 8, 9, 10, 32, 33 and 34. Management is applied at the scale of ICES Subarea through the use of a TAC and an effort regime. FU 34 (The Devil's Hole) is a relatively new functional unit having been designated in 2010 (SGNepS, 2010).

Management at ICES Subarea Level

The 2018 EC TAC for *Nephrops* in ICES Subarea 2.a and 4 was 24 518 tonnes in EC waters (plus 800 tonnes in Norwegian waters). For 2019 and 2020, EC TAC, this was decreased to 22 103 tonnes in EC waters and 600 tonnes in Norwegian waters. For 2021 the EC TAC in Norwegian waters was further decreased to 200 tonnes. COUNCIL REGULATION (EU) 2022/515 of 31 March 2022 (amending Regulation (EU) 2022/109 fixing for 2022 the fishing opportunities for certain fish stocks and groups of fish stocks applicable in Union waters and for Union fishing vessels in certain non-Union waters) sets a TAC for 2022 of 24 268 tonnes for Subarea 2.a and 4, of which 21 021 tonnes are assigned to the UK, and 3 247 tonnes are assigned to the EU. The biggest share of the EU allowance is for Belgium and Denmark, with 1 269 tonnes each.

A major change in the management of *Nephrops* fisheries in ICES Subarea 4 since 2016 has been the introduction of the landing obligation for *Nephrops* fisheries in the 80–99 mm trawl fisheries. A *de minimis* exemption for catches below the Minimum Conservation Reference Size (MCRS) of up to 6% was permitted for the fishery in Subarea 4. The application of this exemption was not clear (i.e. whether the 6% applied at a trip level or to the total annual catch). Because there was no evidence presented to the Working Group that the introduction of the landing obligation had caused any change to discarding practices for the 2017 and 2018 fishery, the catch options have been estimated assuming discarding continues according to historic patterns.

The minimum landings size (MLS) for *Nephrops* in Subarea 4 (EC) is 25 mm carapace length. Denmark and Sweden applied a national MLS of 40 mm up to 2015 but this was changed to 32 mm from 1 January 2016. Norway still has a MLS of 40 mm.

Days-at-sea regulations and recently introduced effort allocation schemes (kW*day) have reduced opportunities for directed whitefish fishing. STECF 2010 stated that the overall effort (kW*days) by demersal trawls, seines and beam trawls shows a substantial reduction since 2002. However, there have also been substantial changes in the usage of the different mesh size categories by the demersal trawls. In particular there has been a sharp reduction in usage of gears with a mesh size of between 100 mm and 119 mm (targeting whitefish), but only a gradual decline in the effort of *Nephrops* vessels (TR2).

UK legislation (SI 2001/649, SSI 2000/227) requires at least a 90 mm square mesh panel in trawls from 80 to 119 mm, where the rear of the panel should be not more than 15 m from the cod-line. The length of the panel must be 3 m if the engine power of the vessel exceeds 112 kW, otherwise a 2 m panel may be used. Under UK legislation, when fishing for *Nephrops,* the cod-end, extension and any square mesh panel must be constructed of single twine, of a thickness not exceeding 4 mm for mesh sizes 70–99 mm, while EU legislation restricts twine thickness to a maximum of 8 mm single or 6 mm double. The UK introduced emergency technical measures for UK vessels targeting *Nephrops* in the Farn Deeps in 2016 (see Section 11.4).

Under EU legislation, a maximum of 120 meshes round the cod-end circumference is permissible for all mesh sizes less than 90 mm. For this mesh size range, an additional panel must also be inserted at the rear of the headline of the trawl. UK legislation also prohibits twin or multiple rig trawling with a diamond cod end mesh smaller than 100 mm in the North Sea south of 57°30'N.

Official catch statistics for Subarea 4 are presented in Table 11.2.1. The preliminary officially reported landings in 2021 are 18 723 tonnes (including 16 tonnes of BMS landings), 37% higher than in 2020 (13 687 tonnes), 14% lower than in 2019 (21 808 tonnes), and 24% lower than the peak observed in 2009 (24 597 tonnes). The main contributing countries increased their landings in 2021 compared to 2020. The UK remains the main producer country (reporting 83.0% of the total landings in 2021), followed by Netherlands (6.8%), Belgium (3.9%) and Denmark (2.1%).

Table 11.2.2 shows landings by FU as reported to the WG for 2021. The most productive functional units are 7 (51% of the total landings), followed by 6 (11%), 8 (10%) and 33 (7%). A small but significant proportion of the landings from Subarea 4 come from outside the defined *Nephrops* FUs. This value increased to nearly 10% of the total in 2009 and as a response, a new Functional Unit at the Devil's Hole (FU 34) was designated in 2011. Landings from outside the Functional Units exceeded 1000 tonnes in 2017 but have been below 800 tonnes since then.

11.3 Botney Cut (FU 5)

11.3.1 The fishery in 2021

Nephrops Functional Unit 5 is an offshore stock that encompasses an area of 1850 km^2 in Division 27.4.b (Central North Sea) and Division 27.4.c (Southern North Sea).

There is no creeling in the area, and *Nephrops* are caught through trawling by five countries: Netherlands is the main producer, in recent years usually followed by the Belgium, Germany, and the UK. Danish landings have been negligible between 2015 and 2020. However, in 2021, Danish landings exceeded UK landings, which have been decreasing since 2016. Although *Nephrops* are caught throughout the year, the main activity takes places during the summer (predominantly Q3).

The highest landings from FU 5 were reached in 2016, with a value on record of 2535 tonnes (Figure 11.3.1). The landings in 2017 were also high at 2109 tonnes, but decreased in 2018 to a more representative value of 1004 tonnes, primarily due to a 76% decrease in UK landings compared with 2017. In 2019, especially Dutch and German landings increased again, with total annual landings of 1172 tonnes. The total international landings in 2020 were 540 tonnes, the lowest recorded value since 1994, most likely due to the restrictions and reduced market during the Covid-19 pandemic. In 2021, international landings almost doubled compared to the previous year, with a total of 1067 tonnes.

ICES advice in 2020

FU 5 is assessed every two years, with the last advice given in 2020:

"ICES advises that when the precautionary approach is applied, catches in each of the years 2021 and 2022 should be no more than 1570 tonnes, assuming recent discard rates.

To protect the stock in this functional unit (FU) from continued overexploitation, management should be implemented at the functional unit level."

11.3.2 Data Available

Commercial landings

Landings by country for FU 5, including Belgium, Denmark, Germany, Netherlands, and the UK, are available since 1991 (Table 11.3.1 and Figure 11.3.1). Landings increased from around 800 tonnes in the early 1990s to around 1200 tonnes in the early 2000s, reaching 1443 tonnes in 2001. Then followed a period of general decline, with a low of 729 tonnes in 2009. From there, landings have increased again to over 2000 tonnes in 2016 and 2017. In 2018, 2019, and 2021, landings decreased again to more long-term representative values of 1004, 1172, and 1067 tonnes, respectively. In 2020, landings were uncharacteristically low due to the Covid-19 pandemic.

Between 1991 and 1995, the Belgian fleet took more than 75% of the international *Nephrops* landings from this functional unit. Since then, Belgian landings have declined drastically, and since 2006 there has been no directed *Nephrops* fishery by Belgian operated vessels. Some Belgian owned vessels operating as Dutch vessels have a directed fishery and increased the landings between 2010 and 2017 by a factor of 7.5. Danish landings have been sporadic since 2006, with almost no landings between 2015 and 2020. In the most recent years, the Netherlands and the UK have accounted for most of the landings from this functional unit, the large increase in 2014–2015 being driven entirely by these two fleets. The sharp jump in landings in 2016 was dominated by increases from the UK, Belgium and Germany, with lesser increases from the Netherlands. Since 2017, the UK reduced their participation in the fishery, catching only 2.4% of the total landings in 2020, and 1.1% in 2021. The strong decline in landings in 2020 was mainly due to reduced landings by the Netherlands, Germany, and the UK, while Belgian landings remained the same at just over 190 tonnes. In 2021, landings returned to the more typical level of 2018 and 2019.

Length composition

The length composition of landings by sex has been provided by The Netherlands since 2004. Data were not available for 2013 as the sample rate was considered insufficient to raise the distributions. Since 2015, Netherlands has also provided the unsexed length composition of their discards.

The intensity of the Dutch catch sampling programme is highly variable (Figure 11.3.2). In 2015 and 2017, the number of animals measured in landings were 4000 and 5600 individuals per year, respectively. In the other years since 2016, the annual number of length measurements has been at or below 2000, with no landings sampling in 2020. Annual length measurements in discards have been at least 4000 since 2015, with the exception of 2020, when 1500 animals were measured.

The proportion of Dutch landings that is represented by the Dutch catch sampling programme is also highly variable (Figure 11.3.3). Overall, the best sampling year was 2015, where a relatively high number of measurements represented 62% of the landings. By contrast, the even higher number of measurements in 2017 only represented 7% of the landings. In 2019, 32% of the landings were represented by just below 2000 measurements, and in 2021, 90% of the landings were represented by 2000 measurements. As there were no length measurements in landings in 2020, the individual mean weight in landings for this year’s advice update is calculated based on 2019 and 2021 sampling.

Natural mortality, maturity at age and other biological parameters

In previous analytical assessments (see e.g. WGNEPH, 2003), natural mortality was assumed to be 0.3 for males of all ages and in all years. Natural mortality was assumed to be 0.3 for immature females, and 0.2 for mature females. Discard survival was assumed to be 0.25 for both males and females (after Gueguen and Charuau, 1975; and Redant and Polet, 1994).

Growth parameters are as follows:

Males: L_∞ = 62 mm CL, k = 0.165.

Immature females: L_∞ = 62 mm CL, k = 0.165.

Mature females: L_∞ = 60 mm CL, k = 0.080, Size at 50% maturity = 27 mm CL.

Growth parameters have been assumed to be similar to those of Scottish *Nephrops* stocks with similar overall size distributions of the landings (see e.g. WGNEPH, 2003). Female size at 50% maturity was taken from Redant (1994).

Commercial effort data

Until the previous advice update in 2020, *Nephrops* directed effort was calculated for all English and Welsh vessels landing outside the UK, together with all UK vessels (including also Scottish and Northern Irish vessels) landing into England and Wales. This was done because, in this functional unit, more detailed information about *Nephrops* targeting vessels is available for the English and Welsh fleet, than for the fleets of other nations.

The relative contribution of UK landings to the total international landings has fluctuated over time and has generally decreased from the highest value of 53% in 2008, to the lowest value of 12% in 2019 (ignoring the unusual situation during the Covid-19 pandemic in 2020 and 2021; Table 11.3.1 and Figure 11.3.1). The UK landings component during recent years has not been high enough to be able to calculate an effort or LPUE measure that would be representative of the entire fleet targeting this functional unit. Therefore, until the UK component increases again, an estimate of annual directed effort will be determined based on the data uploaded to InterCatch.

Nephrops directed effort is estimated by taking into account only the OTB_CRU_70-99_0_0_all metier. For all countries, except the Netherlands, this is equivalent to TR2 gear. The TR2 class is defined as containing Otter trawl gears (codes OT (unspecified), OTB (bottom trawls), OTT (twin trawls)), as well as *Nephrops* bottom trawls (TBN), with mesh sizes of 70–99 mm. The Netherlands associate TR2 landings either with a crustacean (CRU), or with a demersal fish (DEF) target assemblage, depending on the catch composition.

Although the total international effort in 2021 has increased slightly compared with 2020, it remains low compared with previous years (Figure 11.3.4). The main changes were significant increases in Dutch and Belgium effort, and a decrease in German effort.

UWTV survey

There were no new surveys in FU 5 since 2012. Details of the 2010 and 2012 surveys are given in the 2013 WGNSSK report.

11.3.3 InterCatch

The ICES InterCatch database has been used as the main data submission tool for *Nephrops* from 2011 onwards, whereby all countries participating in the fishery within a particular functional unit submit at least quarterly landings by fleet.

Annual discard data have been available since 2015 from the Dutch self-sampling program. Discard data were available for the Belgian *Nephrops* fleet for the period 2002–2005, but in the absence of a directed fishery since 2006, there has been no data collection from the Belgian *Nephrops* landings. In addition, the Netherlands has provided length distributions for landings and discards by fleet where available. As discussed in Section 11.3.2, the Dutch sampling effort is highly variable from one year to the next. However, the sampling in 2019 and 2021 is deemed sufficient to update mean individual weights and discard rates for the calculation of the most recent harvest rate, which is required for the advice update.

11.3.4 Quality of assessment

The data available to assess FU 5 are limited, and consequently the assessment is not robust enough to determine the status of the stock.

The assessment is based upon the assumptions that the length composition of catch, and the discard pattern, are the same for all fleets and are sufficiently well estimated by Dutch sampling. The 2012 survey estimate considered in this advice (0.7 burrows m^{-2}) is relatively high compared with most Norway lobster stocks in the North Sea. However, the large interannual variability in density that is seen in neighboring functional units, such as FU 6, indicates that a single survey is insufficient to provide a reliable abundance estimate. For the advice given in 2022, it was therefore decided to downgrade this functional unit from a Category 4 to a Category 5 stock.

11.3.5 Status of stock

The status of this stock is uncertain, although there are signs that the fishing yield of this stock has decreased over the years. The number of UK vessels fishing in FU 5 has generally decreased over time. Due to the small contribution of UK vessels to the total international landings, and in the absence of detailed information about the other national fleets, an LPUE estimate has not been calculated since 2018. Pooled landings and discards length distributions were determined for 2019 and 2021. No landings samples are available for 2020.

Following the procedure outlined in Section 10.1.2, an estimate of all *Nephrops* grounds was used to give a likely envelope for the total abundance of *Nephrops* in this functional unit, and to estimate the harvest rate. Discard survival was set to zero in line with the protocol for data limited *Nephrops* stocks. The 2012 survey shows that density is relatively high on this ground at 0.7 burrows per m^2. Estimating the harvest rate since then is associated with two main sources of uncertainty. One is the inevitable change in abundance, the other is the lack of adequate sampling data to establish reliable estimates of individual mean weights in landings. Therefore, to increase confidence in at least the qualitative evolution of recent harvest rates, two different scenarios were considered (Figure 11.3.5). For both scenarios, the individual mean weights in landings and discards from 2018, 2019 and 2021 were used. For the years 2017–2021, discard rates by number were calculated as three-year averages ending in a given year. In the first scenario, the abundance was assumed to be constant since 2012. In the second scenario, the abundance from FU 6 was used, scaled to the FU 5 abundance in 2012. Based on both scenarios, the harvest rate steadily declined between 2017 and 2020. In 2021, it increased again but remains well below the precautionary MSY proxy of 7.5%. The qualitative changes in harvest rate are predominantly driven by changes in landings, rather than the abundance.

11.3.6 Short term forecasts

The short-term forecasts and the quota advice for this stock are updated every two years. Catch and landing predictions for 2023 and 2024 were estimated for WGNSSK 2022 and are given in the table below when the ICES framework for Category 4 *Nephrops* stocks was applied. This assumes that the absolute abundance estimate made in 2012 is relevant to the stock status for 2023 and 2024.

However, at the ADGNEPH 2022, it was decided that due to the lack of recent survey estimates or trends to downgrade this stock from category 4 to category 5. There is no indication of harvest rate relative to proxies, stock size in relation to reference points is unknown and there are no marked positive trends for this FU. Therefore, catch advice for 2023 and 2024 are based on the latest catch advice and a precautionary buffer of -20% was applied. Based on the advice approach, catches in 2023 and 2024 should be no more than 1256 tonnes, assuming recent discards rates (50.5%, average in 2019, 2019, 2021)

***Nephrops* FU 5. Category 4 advice catch options assuming discarding continues at recent average. All weights are in tonnes. Harvest rates in percent are calculated for a range of densities, with values above the MSY proxy of 7.5% highlighted in grey.**

Basis	Total Catch	Projected landings	Projected discards	Range of potential densities (*Nephrops* m^{-2})								
				0.05	0.1	0.2	0.3	0.4	0.5	0.6	0.7 *	0.8
0.5 x average landings (2019–2021)	709	463	246	24.3	12.1	6.1	4.0	3.0	2.4	2.0	1.7	1.5
0.5 x average landings (2012–2021)	1045	683	362	35.8	17.9	8.9	6.0	4.5	3.6	3.0	2.6	2.2
Advice for 2021 and 2022 -20%	1212	792	420	41.5	20.8	10.4	6.9	5.2	4.2	3.5	3.0	2.6
Average landings (2019–2021)	1418	926	492	48.6	24.3	12.1	8.1	6.1	4.9	4.0	3.5	3.0
Advice for 2021 and 2022	1578	1031	547	54.1	27.0	13.5	9.0	6.8	5.4	4.5	3.9	3.4
Advice for 2021 and 2022 +20%	1894	1237	657	64.9	32.4	16.2	10.8	8.1	6.5	5.4	4.6	4.1
Average landings (2012–2021)	2089	1365	724	71.6	35.8	17.9	11.9	8.9	7.2	6.0	5.1	4.5
Average landings (2012–2021) +20%	2507	1638	869	85.9	43.0	21.5	14.3	10.7	8.6	7.2	6.1	5.4
MSY proxy harvest rate	3064	2002	1062		52.5	26.3	17.5	13.1	10.5	8.8	7.5	6.6
Maximum landings	3880	2535	1345		66.5	33.2	22.2	16.6	13.3	11.1	9.5	8.3

*** Density assumed for this stock.**

11.3.7 Issues for a future benchmark

The lack of updated abundance estimates since 2012 significantly reduces the reliability of estimates of the current harvest rate. This makes it difficult to determine whether the landings advice can be increased from the previous year, according to the advice rules for Category 4 *Nephrops* stocks. Currently, there are no UWTV surveys planned within FU 5. It might therefore become necessary to re-classify this functional unit as a Category 5 stock and provide landings only advice, as for the outside-FU parts of Subarea 4.

At that time, it could also be considered whether the area covered by FU 5 should be redefined, possibly in connection with the introduction of a new functional unit. This is suggested by an analysis of the spatial distribution of recent landings from the outside-FU area (for a description, see Section 11.12).

11.3.8 Management considerations for FU 5.

The North Sea TAC is not thought to be restrictive for the fleets exploiting this stock, as the landings between 2014 and 2017 were significantly higher than the catch advice. Although since then landings have been broadly in line with the advice, given the paucity of metrics available for assessing stock development, the exploitation of this stock should be monitored closely.

11.4 Farn Deeps (FU 6)

11.4.1 Fishery in 2020 and 2021

Nephrops Functional Unit 6 is situated in Division 27.4.b (Central North Sea), off the northeast coast of England.

Since the beginning of the time-series, the UK fleet has accounted for virtually all landings (≥ 98%) from the Farn Deeps (Table 11.4.1 and Figure 11.4.1). The Farn Deeps fishery is essentially a winter fishery commencing in September and running through to March. The most recent data from 2021 therefore comprise the end of the 2020–2021 fishery and the start of the 2021–2022 fishery.

The total international landings in 2021 were 2022 tonnes, significantly lower than the unusually high landings of 4364 tonnes in 2019, and within the range of landings during the 2016–2018 period and in 2020 (Table 11.4.1 and Figure 11.4.1). While the combined relative contribution to total international landings from English, Welsh, and Northern Irish vessels has continued to increase from 79% in 2019 to 89% in 2021, the contribution from Scottish vessels has decreased from 20% to 11%.

The discard rates (estimated as percentage of biomass) during 2017—2019 were between 9.1—9.4%. During the years of the Covid-19 pandemic, they increased to 14.0% in 2020 and 17.2% in 2021. As described in Section 11.4.4, there is a greater uncertainty around the estimation of discards in 2020 and 2021, due to the reduced sampling at sea.

In 2016, the UK implemented a suite of technical measures in response to the continued poor state of the stock. The measures commenced in April 2016 for UK vessels fishing in Farn Deeps (99% of the fleet in the stock unit). These measures were as follows:

- A minimum mesh size of 90 mm using single twine of 5 mm.
- Only single-rig vessels of 350 kW (476 hp) or less are permitted to fish within 12 nm of the coast.
- Multi-rig vessels (vessels with three or more rigs) are prohibited from operating within the Farn Deeps. Twin rig vessels are permitted to operate outside 12 nm.

- No vessel can use gear with more than one cod end per rig

ICES updated advice in November 2021

"ICES advises that when the MSY approach is applied, and assuming that discard rates and fishery selection patterns do not change from the average of the years 2018–2020, catches in 2022 should be no more than 1940 tonnes.

To ensure that the stock in Functional Unit (FU) 6 is exploited sustainably, management should be implemented at the functional unit level. Any substantial transfer of the current surplus fishing opportunities from other FUs to FU 6 could rapidly lead to overexploitation."

Management of the fishery is at the ICES Subarea level as described in Section 10.1.

11.4.2 Assessment

Review of the 2022 assessment

"The forecast has been performed correctly with no deviations from the standard procedure for this stock."

11.4.3 Data available

Landings and discards sampling

The two types of sampling on *Nephrops* in FU 6 are the UK vessel observer programme, determining the sex-specific length distributions in landings and discards, and the Cefas shore sampling programme, determining sex-specific length distributions in unsorted catches. The catch length distributions from the shore sampling programme are separated into landings and discards by means of a sigmoidal discard probability curve that is fitted to the vessel observer size-dependent discard rates. For the years 2006—2019, the results are shown in Figure 11.4.2. Due to the Covid-19 pandemic, in 2020 and 2021, there were too few observer trips during which both landings and discards were sampled. For those two years, length distributions are primarily based on data from the shore sampling programme.

Discarding practice varies considerably between vessels in any given period, but there are no significant trends in the two fitted parameters of the discard probability curve (Figure 11.4.2). A fixed discard probability curve has therefore been used since 2002 to separate catch samples into landings and discards.

The Benchmark meeting in 2013 concluded that the historical assumption of 0% discard survival was no longer applicable, as a significant proportion of catch sorting now takes place at sea. For day-boats, the first haul of the day will generally be sorted on the fishing grounds, whilst the second haul will be sorted whilst steaming back to port (and therefore passing over habitat unsuitable for *Nephrops)*. Discarding practice for multi-day boats will generally result in discards returning to suitable sediment. The conclusion was therefore that although the full 25% survival assumed in other FUs was not likely to be applicable, a 15% survival rate was a reasonable estimate for this functional unit.

Changes in length distribution

There is a clear change in length frequencies around 2007, with much lower contributions from the smaller (discarded) size classes (Figure 11.4.3). This may reflect an improvement in selectivity by the fleet. A bi-modal length frequency distribution for landed females was observed between 2009–2014, becoming more pronounced throughout that period. This could be the result of a large year class, but a similar phenomenon is not observed in the male part of the population. In fact, the mean size in the males decreased in 2012 and 2013 (Table 11.4.2). Additionally, the mean annual increment of the larger female mode of around 2 mm is considerably lower than the annual growth that would be expected based on the growth parameters available for this stock. A high year class strength is therefore unlikely to be the cause of this phenomenon. The predominance of large females in the catches means they were foraging for food, at a time when they would be expected to be brooding within their burrows. Given that there are very few males of similar size appearing in the catches, it is possible that there is a physical size differential constraint in mating patterns of *Nephrops*. This may either be an inability of the males to successfully transfer spermatophores, or alternatively large females may be able to resist the (usually quite aggressive) approaches of the smaller males when they try to mate with large females.

The reduction in the bi-modal nature of the female length distribution since 2015 implies a lower relative availability of females at larger sizes and may indicate a better spawning success. The high abundance observed in the UWTV survey in 2018 and 2019 (continuing the increase since 2015), and the small animals observed in the catch for those years, support this hypothesis (assuming that recruits enter the fishery between age 3 and 4, and they are seen in the survey from age 2).

The mean carapace length of large females (≥ 35 mm) in the landings have gradually increased over the period 2000–2017 (Figure 11.4.1). Since 2017, the mean length of large females as declined again. For large males, the mean length increased over the period 2002–2013, and has generally decreased since, although there was an increase in 2021. The mean lengths of small females and males (< 35 mm) in the landings do not show any clear temporal pattern.

Effort and LPUE

The way in which data regarding both landings and effort were collected within the UK changed in 2006, when the "Buyers & Sellers" legislation from 2005 came into effect, which resulted in a noticeable change in the level of reported metrics. A comparison between the periods before and since 2006 is therefore inadvisable.

Historically the fishery has been prosecuted by a combination of local English boats (smaller vessels undertaking day–trips) and larger vessels from Scotland with occasional influxes of Northern Irish vessels. The total number of vessels in the fishery (which land into England and Wales) has fluctuated between ~100 and ~250 since 2006 (Figure 11.4.4), but overall the fleet size declined until 2018. A temporary increase in 2019, resulting in more than doubling of the landings of the previous year, was then followed by a decline in the active fleet size in 2020, back to the 2018 level. The fleet size increased again in 2021, due to an increase in the number of small and intermediate vessels, while the number of vessels longer than 15 m continued to decline. Generally, however, most of the fluctuation in fleet size is due to changes in the above 15 m fleet, which experienced an influx of vessels from Scotland and Northern Ireland for the period between 2011–2014, and again in 2019. In contrast, the size fleet for the 10–15 m sector has remained fairly constant since 2006, with the exception of a temporary increase in the number of active Scottish vessels in 2019. The size of the under-10 m sector has generally declined since 2006.

Directed effort is calculated taking into account only TR2 gear, with a *Nephrops* catch component of ≥ 25%. The TR2 class is defined as containing Otter trawl gears (codes OT (unspecified), OTB (bottom trawls), OTT (twin trawls)), as well as *Nephrops* bottom trawls (TBN), with mesh sizes of 70–99 mm. On the basis of available data for this functional unit, effort is calculated for all English and Welsh vessels landing outside the UK, together with all UK vessels (including also Scottish and Northern Irish vessels) landing into England and Wales. The unit of fishing effort is kWd.

Fishing effort calculated in this fashion for vessels ≤ 15 m has been fairly consistent since 2006 (Figure 11.4.1). The main changes in total landings – including the sharp decline between 2006–2008, the intermittently high values in 2012–2014, and the high value in 2019 – were driven primarily by fluctuations in the fishing effort of the > 15 m fleet (Figure 11.4.1). Directed effort is highest in quarters one and four, without a consistent relative fishing intensity between these quarters (Figure 11.4.5). A notable exception is the relatively high effort in the summer (Q3) of 2016. Landings per unit effort (LPUE) of males tend to be highest during the winter months, whereas LPUE of females is typically highest in quarter three.

The use of LPUE as an index of stock abundance is confounded by changes in availability of *Nephrops* to fishing gears, depending upon environmental factors such as tide and light levels, plus changes to emergence behaviour induced by mating and predator avoidance. Therefore, the temporal trend of LPUE can only be used as an indicator of trends of abundance, if the catchability of *Nephrops* is assumed to be constant over the years.

LPUE for the entire directed *Nephrops* fleet, as defined above, has fluctuated between 0.6–1.0 kg/kWd since 2006, without any consistent trends over periods of more than 3 years (Table 11.4.3).

Traditionally, males tend to predominate the landings, averaging about 70% (with a range of 64%–79%) by biomass in the period 1992–2005. Towards the end of the fishing season (February–March) there is usually an increase in female availability as mature females emerge from their burrows having released their eggs. There has been a marked change in the seasonal pattern of sex-ratio (in catches by number) for Farn Deeps *Nephrops* since the winter of 2005. Prior to this, the ratios were generally steady, with small (~10%) seasonal fluctuations. Since then, there have been significant interannual swings, with whole years being dominated by landings of females (2006, 2010, 2013–2014, Figure 11.4.6). The sex ratio since 2015 returned to a generally male dominated fishery, which can be explained by the lack of large females in catches (Figure 11.4.3). However, in 2019, for the first time since 2013, a larger number of females was caught in the fourth quarter, followed by an even larger proportion in the first quarter of 2020. Due to the poor sampling situation since then, sex-ratios in landings are uncertain. However, based on the available data, quarter one and four landings in 2021 had a high proportion of males.

UWTV

Underwater TV (UWTV) surveys of the Farn Deeps grounds have been conducted at least once in each year from 2001 onwards.

A time series of indices is given in Table 11.4.4 and Figure 11.4.7. The procedure used to work up the UWTV survey has been changed in 2007. The original survey design was a random-stratified design, where the ground was split into regular boxes with stations randomly placed within. At a later stage, additional stations were inserted into areas of high density to better define them. However, this was not accounted for in the process of estimating overall abundance, and therefore the higher density of stations in high-density *Nephrops* areas biased the estimate upwards. In addition, the distance covered by the UWTV sledge was determined by assuming a straight-line between the start and finish positions of the vessel. Since 2007, GPS logging of the position of the vessel and the sledge (via a Hi-Pap beacon) at short intervals (~5 seconds) has enabled the determination of a considerably more robust estimate of viewed distance. The abundance estimate is now obtained through a geostatistical procedure, in which the burrow density estimates are first fitted by a semi-variogram model. Then, an interpolated surface of burrow density is created using Kriging on a 500 m by 500 m grid. Uncertainty estimation of the overall abundance estimate is performed by bootstrapping the counts, re-fitting the semi-variogram, and re-estimating the surface. Uncertainty estimates are typically 2%, much lower than the previous estimates which ignored spatial structure to a large degree. Since 2013, the survey takes place during the summer instead of the autumn, in order to avoid the fishing vessels working in the area and disturbing the sediment.

The total abundance at the beginning of the time series was higher than 1000 million of individuals, reaching 1685 million in 2001. From 2008 to 2015, the abundance gradually declined, attaining the lowest value of 578 million in 2015. The UWTV survey in 2009 was hampered by a period of poor weather and low visibility, which coincided with the surveying of the areas traditionally associated with the highest densities. From 2015 until 2019, mean density and total abundance have increased again, with values of 0.37 individuals per m^2 (a total of 1163 million individuals, ±26 million 95% CI) in 2019. However, the UWTV surveys since then indicate that total abundance has steadily decreased to a value of 878 million individuals (±20 million 95% CI) in 2022, with a density of 0.28 individuals per m^2. The lower bound of the confidence interval is now at the MSY biomass trigger point of 858 million. The turning point in the abundance trend coincides with the unusually high landings in 2019.

The spatial pattern of burrow density is similar through time with the highest density ground running along the western edge of the mud-patch (Figure 11.4.8).

11.4.4 InterCatch

In 2021, landings data by fleet were provided via the ICES InterCatch database by England, Scotland, the Netherlands, Belgium, Denmark, and Sweden. Discard data were provided by England and Scotland. Length distributions for landings and discards by fleet and quarter were provided by England and Scotland. There were no reported BMS landings.

As in previous years, unreported discards for the reported landings were calculated in InterCatch based on the UK discard ratios. Following this procedure, 282 tonnes of discards were raised for 2021, which was unusually high compared with the 137 tonnes of reported discards. The reason for the high raised discards is the lack of discard data for Q1 in 2021. However, the total discards of 419 tonnes (reported plus raised) are between the values of 2019 (453 tonnes) and 2020 (310 tonnes).

The length distributions imported by England and Scotland for 2021 represented 34% of the landings, which is less than half the proportion of sampled landings for the period 2015--2020. The main reason for that is the lack of samples in Q1 of 2021. All reported discards were sampled. Length frequencies for unsampled landings, or strata without reported discards, were generated from the pooled sampling data. Strata are defined by quarter and metier.

11.4.5 Biological parameters

Biological parameter values, such as natural mortality and maturity at age, are included in the Stock Annex which was updated at the 2013 benchmark.

11.4.6 Exploratory analyses of RV data

A comprehensive review of the use of UWTV surveys for *Nephrops* stock assessment was undertaken by WKNeph (ICES, 2009). This covered the range of potential biases resulting from factors including edge effects, species mis-identification, and burrow occupancy. The cumulative bias-correction factor estimated for FU 6 was 1.2, meaning that the raw counts from the UWTV survey are likely to overestimate densities of *Nephrops* by 20%. The correction factor is therefore applied to the raw counts to arrive at the absolute abundance index. Estimates of absolute burrow density and total abundance estimates (with confidence estimates) are given in Table 11.4.4.

For the purposes of advising on management for the next year, the UWTV survey from the assessment year is assumed to be representative of the fishing opportunities for the forecast year. The UWTV survey for FU 6 is typically undertaken between late May and July and is therefore available for the updated advice in autumn. The validity of using the UWTV survey to determine advice for the following year was explored by looking at how the UWTV survey predicts metrics such as catch rate and landings in the following year. Significant relationships exist between UWTV abundances and LPUE, Effort and Landings in the following year (Figure 11.4.9), whereas there are no significant relationships when using the UWTV survey in the same year as the fishery metrics. This suggests that, for FU 6, the UWTV survey is a valid predictor of fishery activity the following year.

Final Assessment

The estimated abundance in 2022 was 878 million individuals (±20 million 95% CI, Table 11.4.4), a 10.6% decrease from 2021, and the lower bound of the confidence interval is at the 2007 estimate of 858 million, which is used as MSY $B_{trigger}$. The estimated harvest rate for 2021 was 11.9% (up from 9.6% in 2020; Table 11.4.5) and therefore remains above the MSY proxy level of 8.1%.

11.4.7 Historical stock trends.

The time series of UWTV surveys covers the time period from 2001 onwards, although the new geostatistical method has only been applied retrospectively to 2007. Whilst a small over-estimation of abundance using the previous technique is expected, it is likely that the reduction in stock abundance observed between the two periods of estimation procedure is real.

Estimates of historical harvest rate (the proportion of the stock which is removed) range from 5.9% in 2008 to 24.3% in 2006 (Table 11.4.5, Figure 11.4.10). The harvest rate jumped from around 11% in 2004–2005 to the historical maximum in 2006, when the new reporting legislation came into effect. Since 2001, the harvest rate has only been below the MSY level once, during the historical minimum in 2008.

11.4.8 MSY considerations

Considerations for setting harvest rates associated with proxies for F_{MSY} for *Nephrops* are described in ICES, WGNSSK, 2010, Section 10.1.

- Average density in the stock is at a medium level, above the level of FU 7, but below that of FU 8.
- Density has varied through time but does not appear to undergo large scale interannual fluctuations. Spatially, there is a good degree of consistency in the pattern of high and low density between the years.
- Estimated growth rates are at a moderate level, although the data supporting them are quite old. Natural mortality estimates are standard.
- The fishery in the Farn Deeps is a winter fishery (October–March) with typically male dominated catches. The intra-annual pattern of sex ratio in the catches has fluctuated widely between 2005 and 2014, with periods of high female catch ratios during the winter. This might be due to sperm limitation or ovary resorption, leading to more mature but unfertilised females becoming available to the fishery.
- Although the time series of observed harvest rates is relatively short, there has been a fair degree of fluctuation (6–24%). The observed harvest rate is, of course, confounded by the change in reporting levels considered to have occurred around 2006.

The following table shows the mean F, implied harvest rate and resulting spawner per recruit values (expressed as percentage of a virgin stock) for the range of F_{MSY} proxies suggested for *Nephrops*. These values were last recalculated in 2013 using a length cohort analysis model (SCA, see ICES, WKNEP 2009) on the combined length frequencies for 2010–2012. The model fit to the data (Figure 11.4.11) is reasonable, but the increasing bi-modality of the length frequency observed in the females for 2009–2014 does violate model assumptions, and the model under-predicts the landings of larger females.

		F_{bar} 20–40 mm		Harvest Rate	% Virgin Spawner per Recruit (SpR)	
		Female	Male		Female	Male
F0.1	Comb	0.09	0.09	8.7%	47.52%	32.11%
F0.1	Female	0.16	0.16	14.0%	32.63%	18.26%
F0.1	Male	0.07	0.07	7.1%	53.02%	38.50%
F35%	Comb	0.12	0.12	11.1%	39.98%	24.50%
F35%	Female	0.17	0.17	15.2%	34.82%	16.64%
F35%	Male	0.16	0.16	8.1%	57.17%	34.88%
Fmax	Comb	0.17	0.17	15.3%	34.58%	16.48%
Fmax	Female	0.29	0.29	21.6%	22.22%	9.47%
Fmax	Male	0.12	0.12	11.6%	44.70%	23.73%

The default harvest rate suggested for *Nephrops* is the combined sex F35%SpR. The effects of sperm limitation appear to have been a factor in the recent development of this stock. There are signs that this stock may have been in a period of lower productivity for a number of years, and so a harvest rate which gives greater protection to the spawning potential of males would be advisable. The Working Group adopted the F_{MSY} proxy to be the harvest rate equivalent to F35% on males for this stock (8.1%).

WGNSSK suggests the absolute abundance index of 858 million individuals from the 2007 UWTV survey (i.e., the first year when the stock was considered to be depleted in the recent series) should become a proxy for $B_{trigger}$.

11.4.9 Short term forecasts

Catch and landing predictions for 2023 are given in the table below. These predictions include the latest abundance estimate from the 2022 UWTV survey.

In November 2016, ICES advised on fishing opportunities assuming that discarding would only occur below the minimum conservation reference size (MCRS). Observations from the fishery since then indicate that discarding above the MCRS continues, and practices have not changed markedly (Figure 11.4.3). Consequently, ICES has provided advice based on average discard rates observed over the last three years, which is considered to be a more realistic assumption than zero discards above MCRS. A table with the catch and landing predictions assuming zero discards is also presented for comparison.

A deviation from the normal procedure was agreed during WGNSSK 2021, to address the reduced sampling level in quarters two to four of 2020 due to Covid-19 restrictions. For *Nephrops* stocks, the adopted procedure calculates the average mean individual weights in landings and discards during the period 2017–2019, scaled such that the quarter one values of the three-year reference period are identical to those in quarter one of 2020. In FU 6, the commercial activity in 2019 was unusual not only by the magnitude of annual landings, but also by uncharacteristically high discard rates by weight in quarters two and three. As the unusual discarding practice in 2019 might have affected the length sampling for FU 6, in contrast with the other *Nephrops* stocks, it was decided to calculate averages for the reference period 2016–2018 and scale those to quarter one values in 2020. As usual, discard rates by number were calculated from landed and discarded numbers, given by the total landed and discarded weights divided by the respective mean individual weights.

In 2021, discard and length sampling data were only available for Q4. Despite reduced sampling during the two years of the pandemic, discards in 2020—2021 were within the range of values of the ten years preceding the pandemic (Table 11.4.5). Also, a comparison between quarterly mean weights of females and males in landings and discards has shown that the values in 2020—2021 are not outliers (Figure 11.4.11). An adjustment of discards and mean weights, as in the previous year, was therefore not deemed to be necessary. This would require a deviation from the stock annex, would have to be done outside of InterCatch, would therefore reduce transparency and potentially introduce more uncertainty into the results.

The ICES MSY approach dictates that, where the stock status is above the trigger point, the maximum advised fishing rate should be the MSY rate. Applying this approach, catches in 2023 that correspond to MSY are 1604 tonnes. This value is considered precautionary when applying the ICES advice rule.

***Nephrops* in FU 6. The basis for the catch scenarios**

Variable	Value	Notes
Stock abundance	878	Underwater TV survey 2022; individuals in millions
Mean weight in projected landings	25.53	Average 2019–2021; grammes
Mean weight in projected discards	10.82	Average 2019–2021; grammes
Projected discard rate (total)	26.7	Average 2019–2021; percentage by number of the total catch
Discard survival rate	15	Percentage by number of the discards
Dead projected discard ratio	23.7	Percentage by number of the total catch

***Nephrops* in FU 6. Catch options assuming discarding continues at recent average. All weights are in tonnes.**

Basis	Total catch	Dead removals	Projected landings	Projected dead discards	Projected surviving discards	% harvest rate*
	PL + PDD + PSD	PL+PDD	PL	PDD	PSD	for PL+PDD
MSY approach	1604	1572	1390	183	32	8.12
$F_{MSY\ lower}$	1383	1355	1198	157	28	7.00
$F_{MSY\ upper}$	1604	1572	1390	183	32	8.12
F_{2021}	2345	2298	2031	267	47	11.87
$F_{2019–2021}$	2478	2428	2146	282	50	12.54
F35% Male	1604	1572	1390	183	32	8.12
F35% Female	3001	2941	2599	341	60	15.19
F35% Combined	2201	2157	1906	250	44	11.14
F0.1 Male	1405	1377	1217	160	28	7.11
F0.1 Female	2770	2714	2399	315	56	14.02
F0.1 Combined	1715	1681	1485	195	34	8.68
Fmax Male	2292	2246	1985	261	46	11.60
Fmax Female	4268	4182	3696	486	86	21.60
Fmax Combined	3023	2962	2618	344	61	15.30

*** Calculated for dead removals.**

***Nephrops* in FU 6. Catch options assuming zero discard rates. All weights are in tonnes.**

Basis	Total catch	Wanted catch	Unwanted catch**	% harvest rate *
MSY approach	1540	1334	206	8.12
FMSY lower	1328	1150	178	7.00
FMSY upper	1540	1334	206	8.12
F2021	2251	1949	301	11.87
F2019–2021	2378	2060	318	12.54
F35% Male	1540	1334	206	8.12
F35% Female	2881	2495	386	15.19
F35% Combined	2113	1830	283	11.14
F0.1 Male	1348	1168	180	7.11
F0.1 Female	2659	2303	356	14.02
F0.1 Combined	1646	1426	220	8.68
Fmax Male	2200	1906	294	11.60
Fmax Female	4097	3548	548	21.60
Fmax Combined	2902	2513	388	15.30

*** Calculated for dead removals.**

**** Represents the amount that otherwise would have been discarded but is now landed under the landing obligation.**

11.4.10 BRPs

Suggestions for proxies of biological reference points are shown in the catch option table and discussed in 11.4.8.

11.4.11 Quality of the assessment

Changes to the legislation regarding the reporting of catches in 2006 means that the levels of reported landings from this point forward are considered to better reflect the true landings and hence effort input into this fishery. This does mean that comparison of LPUE with previous years is inadvisable.

There was an issue with the UK official database in 2017 and 2018, and some fishing trips were missed. These trips were made by non-Scottish vessels that sold their catch to Scottish buyers. In order to associate the missing landings with a functional unit, it was assumed the vessels (all of them under 10 m length) fished near the landing port. Consequently, vessels landing *Nephrops* in North Shields, Amber, Hartlepool, Blyth, North Sunderland and Boulmer (England) were assumed to fish in Farn Deeps during those missing trips.

The addition of these missing landings for 2017 resulted in an increase of 151 tonnes compared with the value submitted in 2017. It also caused an increase of the estimated discard and harvest rate, and a decrease of the mean weight and size of the catch for that year. The fishing effort and LPUE for English vessels were also updated.

Normally, the length and sex compositions arising from the land-based catch sampling programme are considered to be representative of the fishery. Estimates of discarded and retained length frequencies arising from the vessel observer sampling programme are also normally considered robust. However, the unusual situation in 2020 resulted in missing sampling data in quarters two to four. These data gaps have been filled in according to the procedure described in Section 11.4.9. The impact on the assessment due to missing sampling data is unknown.

The UWTV survey in this area has a high density of survey stations compared to other surveys, and the abundance estimates are generally considered robust. There is greater uncertainty in the index for 2009 due to the absence of stations in the higher density areas which may result in an over-estimate of the magnitude of the decline for this year. The spatial distribution of the 2022 survey abundance continues the spatial pattern observed in previous years, with the spine of high density on the western edge of the ground, but with overall reduced density compared with the previous three years.

11.4.12 Status of stock

The 2022 UWTV survey indicates that the size of the stock has continued to decrease since 2019. The abundance remains above the MSY $B_{trigger.}$ However, the lower bound of the confidence interval is now at the biomass trigger point.

The harvest rate by number, estimated as the proportion of the stock that has been fished (including dead discards), significantly increased from 2018 to 2019. Although in 2020 the harvest rate decreased again to between the values of 2017–2018, it remained above the $F_{MSYtrigger}$ and has increased again in 2021.

The turning point in abundance in 2019 coincided with the unusually high reported landings during that year. However, population biomass is also affected by reproductive success, in addition to fishing. Recruitment is affected by many environmental factors and has so far not been assessed for this stock.

11.4.13 Management considerations

The WG, ACFM and STECF have repeatedly advised that management should be at a smaller scale than the ICES Subarea 4 level, and management at the functional unit level could provide the controls to ensure that catch opportunities and effort were compatible and in line with the scale of the resource.

Catches generally have been well above ICES advice in Farn Deeps, highlighting the issue that current management arrangements are not sufficient to contain the fishery within the sustainable limits determined by ICES, and that management should be implemented at the functional unit level.

It is expected that, under the EU landing obligation, below minimum size individuals that would formerly have been discarded would now be reported as below minimum size (BMS) landings in logbooks. However, BMS landings reported to ICES may be lower than expected for several reasons: minimum size individuals could either not have been landed and not recorded in logbooks, or have been landed but not recorded as BMS. Furthermore, BMS landings recorded in logbooks may not have been reported to ICES. Only insignificant amounts of *Nephrops* (463 kg in 2020, on the order of one permille of the reported discards) were recorded as below MCRS (BMS category) in FU 6, despite catches having been observed below the MCRS.

11.5 Fladen Ground (FU 7)

11.5.1 Ecosystem aspects

The Fladen Ground (Functional Unit 7) is located towards the centre of the Northern North Sea off the east coast of Scotland (Figure 10.1.1). This region is characterised by an extensive area of mud and muddy sand, and hydrographic conditions include a large-scale seasonal gyre which develops in the late spring over a dome of colder water.

Owing to its burrowing behaviour, the distribution of *Nephrops* is restricted to areas of mud, sandy mud and muddy sand. Within the Fladen Ground FU these substrates are distributed more or less continuously over a very large area (approx. 30 000 km^2). Figure 11.5.5 shows the distribution of sediment in the area. Sandy mud and muddy sand are the dominant sediment types, with patches of mud in the south west area of the FU. Numerous fish species occur in the same area as *Nephrops* with demersal fish more prevalent in the northern area. In the softest areas of mud, *Pandalus borealis* is also found.

11.5.2 The Fishery in 2021

The *Nephrops* fishery at Fladen is the largest in the North Sea and is mainly prosecuted by UK (Scotland) vessels (total landings of 9559 tonnes in 2021), with Denmark taking 80 tonnes, and England 2 tonnes (Table 11.5.1). Around 90 vessels participated in the Fladen fishery at various times throughout the year. The majority are Scottish vessels fishing out of and landing to Fraserburgh and Peterhead. Catch consisted of *Nephrops*, haddock, whiting, cod, monkfish and megrim. A number of vessels have installed freezer capabilities to enable longer trips, but the average trip is around seven days. The fishery is seasonal and the fleet nomadic, moving between Fladen, Moray Firth, Firth of Forth, Devil's Hole, Farn Deeps and west coast of Scotland according with the time of the year and catch rates. Some vessels spent time fishing in the Farne Deeps (FU 6) and Devil's Hole (FU 34). The Covid-19 pandemic had a significant impact in the 2020 *Nephrops* fishing season with vessels having to deal with strict requirements from shellfish processors (buyers) in terms of amounts landed, grade sizes and demand abroad. These restrictions were not observed in 2021 and the fishery resumed its normal activity with a clear increase in landings. Most vessels fishing in FU 7 traditionally have used twin rigs with 80/90 mm mesh.

Recently, to reduce catches of whitefish (e.g. cod), mandatory measures implied that any vessel using gear with a mesh size of less than 100 mm (TR2) in Area 4.a in the North Sea must fish exclusively with any of the Highly Selective Gears (HSGs). Examples of these are the Gamrie Bay Trawl or Faithlie Cod Avoidance Panel. This made the majority of the fleet to switch to TR1 gears with mesh size combinations of 100–109 mm/120 mm, as they can target both *Nephrops* and fish. This confirms the information on the TR1/TR2 split which shows that in recent years, vessels fishing in Fladen have become more dual purpose in the sense that the large majority are now using larger mesh sizes and no longer solely dependent on *Nephrops*. This implies that these vessels have to buy both quota and days. Further general information on the fishery can be found in the Stock Annex.

11.5.3 Advice in 2021

The ICES advice in 2021 (for 2022) (Single-stock exploitation boundaries) was as follows:

MSY approach

"ICES advises that when the MSY approach is applied, and assuming that discard rates and fishery selection patterns do not change from the average of the years 2018–2020, catches in 2022 should be no more than 14 803 tonnes.

To ensure that the stock in Functional Unit (FU) 7 is exploited sustainably, management should be implemented at the functional unit level. The catch in FU 7 has been lower than advised in recent years, and if the difference is transferred to other FUs, this could result in non-precautionary exploitation of those FUs.

ICES notes the existence of a management plan, developed and adopted by one of the relevant management authorities for Subarea 4. ICES considers this plan to be precautionary when implemented at the functional unit level."

11.5.4 Management

Total Allowable Catch (TAC) management is at the ICES Subarea level. Historically most *Nephrops* vessels used to operate TR2 gears (≥ 70 and < 100 mm) which were subject to the effort regulations of the cod recovery plan. In recent year there has been a shift to using TR1 gears in Fladen allowing vessels to target *Nephrops* and fish simultaneously.

11.5.5 Assessment

Approach in 2022

The assessment of *Nephrops* in 2022 is based on examining trends in the UWTV survey data (1992–2021) and utilising an extensive series of commercial fishery data and follows the process defined by the benchmark WG 2009. The assessment approach is further described in the stock annex.

The provision of advice in 2022 followed the process of 2021, and attempts to incorporate decisions taken at WKFRAME (2010) for the provision of MSY advice. The approach was developed based on inter-sessional work carried out by participants of the benchmark and involved collaboration between WGNSSK and WGCSE. The UWTV based assessments have derived predicted landings by applying a harvest rate approach to populations described in terms of length compositions from the trawl component of the fishery. Considerations for setting Harvest Ratios (HR) associated with proxies for F_{MSY} for *Nephrops* are described in the WGNSSK 2010 report.

It was decided by ICES prior to the 2022 WG meeting that the advice for North Sea *Nephrops* stocks would be delayed until autumn after the summer surveys. The assessment presented in this report was concluded in September 2022 and incorporates the most recent *Nephrops* UWTV survey (2022).

11.5.6 Data available

Commercial catch and effort data

Landings from this fishery are predominantly reported from Scotland, with small contributions from Denmark and England, and are presented in Table 11.5.1 and Figure 11.5.1. Total international landings (as reported to the WG) in 2021 were 9559 tonnes (72% increase in comparison with the 2020 total), consisting mostly of Scottish landings with 82 tonnes landed by other countries (England and Denmark). *Nephrops* is one of the species in the North Sea under the landing obligation. No landings below the minimum conservation reference size (BMS) or logbook registered discards were reported for FU 7 in 2021.

In previous years, concerns were expressed over the reliability of the effort figures provided for Scottish *Nephrops* trawlers; effort figures were unrealistically low in some areas, particularly Fladen. Investigation of the issue revealed a problem in the MSS Marine Laboratory database, where only the effort expended in the first statistical rectangle visited by a vessel during a trip was being output. This did not affect landings. An extraction of effort data by the Marine Scotland data unit in Edinburgh covering the four main trawl gears landing *Nephrops* into Scotland produced higher Figures which capture all the effort. At the present time, these revised data cover the period 2000 to 2021 and only annual summaries are available.

Trends in Scottish effort of *Nephrops* trawlers and LPUE are shown in Figure 11.5.1 and Table 11.5.2. From 2015, effort data for this stock is expressed both in days fishing and kW days (there are no major differences in effort trends between those different units). Effort has been relatively stable from 2002 to 2010 but fell markedly in 2011–2012 because of poor fishing and part the fleet relocating to other areas. The spatial contraction of the fishery was further confirmed by the VMS distribution of otter trawlers fishing in Fladen (2010–2021) shown in Figure 11.5.8. In this period, a decreasing number of trips have been taking place in FU 7 and in 2015-2017, the south of the ground was the area where most fishing took place. From 2018, vessels seem to have returned to the northern areas of the Fladen grounds (Figure 11.5.8). In 2021 there was a slight increase in effort for Scottish trawlers. LPUE has gradually increased since 2000 to a peak of over 620 kg/day in 2009. It has fallen since then until 2015 to values similar to those observed in the early 2000s (~200 kg/day). In 2019, the Scottish LPUE increased markedly and is currently at a similar level to that observed in the late 2010s. Danish LPUE data (1991–2021) are presented in Table 11.5.3. Effort has generally decreased over the time whilst LPUE has gradually increased to its highest value in 2009 followed by a dramatic decrease as *Nephrops* became mostly a bycatch species for the Danish fleet in recent years. In 2021, the Danish LPUE showed a marked increase to 0.3 kg/kwd. This is in agreement with the trend observed in the Scottish LPUE which also seems to support a higher availability of *Nephrops* in the Fladen grounds.

Males consistently make the largest contribution to the landings (Figure 11.5.2). This is likely to be due to the varying seasonal pattern in the fishery and associated relative catchability (due to different burrow emergence behaviour) of male and female *Nephrops*. This is confirmed by the quarterly landings as shown in Figure 11.5.2. From 2012, landings were generally lower in the second quarter of the year, a period when females would be expected to be more available for capture. In recent years landings were larger in the third and fourth quarters although quarter 1 in 2021 was relatively higher than what has been observed in the last five years. Figure 11.5.7 shows the quarterly sex ratio by number from 2000. The seasonality of *Nephrops* emergency behaviour is apparent with males dominating catches, in particular during winter time (quarters 1 and 4). In quarters 2 and 3, females become more active and are more available to the fishery, although in FU 7 (unlike FU 8 and 9) the sex ratio is less seasonal and male percentages in catches (by number) have varied between 40–80%. In 2013–2016 the male proportion in quarter 2 was higher than previously observed. This may have been related with sampling noise associated with the recent decrease in landings (and sampling opportunities) in that quarter. Sex ratio data does not seem to show an overall increase of female proportion in catches in the time series, except for the period 2013–2015 where male percentage in catches decreased to less than 50%. Increased female catchability has been associated with stocks which are in a poor state (females may remain more active as they have been unable to mate due to lack of males in the population). It is unclear if this was the case in FU 7 but sex ratio monitoring in catches will continue to inform on potential shifts in the balance of the population.

Discarding of undersized and unwanted *Nephrops* has occurred in this fishery, and quarterly discard sampling has been conducted on the Scottish *Nephrops* trawler fleet since 2000. In 2021 due to the Covid-19 pandemic and the suspension of the on-board observer programme, discards were not sampled in quarter 1. The discarding rate average from 2000 is approximately 6% by number in this FU. From 2011 to 2016, discard rates dropped below the long-term average and were close to zero. This reduction in discard rate appears to be due to a change in the discard pattern with lower numbers of small individuals being caught and could also signal reduced recruitment and a tendency towards the use of larger mesh gears (see below on length compositions). From 2017 catches increased in FU 7 but discarding remained at a relatively low level. The discard rate in 2021 was estimated at 1.7% by number.

It is likely that some *Nephrops* survive the discarding process. An estimate of 25% survival has been assumed in order to calculate dead removals (landings + dead discards) from the population.

Intercatch

Scottish 2021 data (official landings and sampled data for landings and discards) were successfully uploaded into Intercatch. National data co-ordinators for other countries (England and Denmark) also uploaded landings data to Intercatch ahead of the 2022 WG. Output data for landings and discards were produced and extracted following the same raising procedure used in previous years to obtain length compositions in formats suitable for running the assessment. In 2021 there were no discard data imported for quarter 1. Discard rates and allocations for length frequencies in quarter 1 were based in the available data for quarter 4. No BMS or logbook registered discard data were reported for this FU in 2021. Since 2017, observer sampling from the Scottish-Science observer sampling scheme was extended to include *Nephrops* catches in FU 7. In 2021, all discard sampling data available for this FU were collected by industry observers.

Length compositions

Length compositions of landings and discards are obtained during monthly market sampling and quarterly on-board observer sampling respectively. Although assessments based on detailed catch data analysis are not presently possible for this species, examination of length compositions can provide a preliminary indication of exploitation effects.

Figure 11.5.3 shows a series of annual length frequency distributions for the period 2000 to 2021. Catch (removals) length compositions are shown for each sex with the mean catch and landings lengths shown in relation to MLS (25 mm) and 35 mm. In both sexes, the mean sizes have been generally stable over time until 2011 when a noticeable shift in the length distribution and an increase in the mean size has been observed for males and to a lesser extent, females. In 2017, length distributions in both sexes showed a marked decrease in the mean size in catches to similar values as those observed prior to 2011. In 2021, length distributions were generally similar to 2017–2020. In 2018 and 2020, a second peak (mode) was detected in the length distribution of females, implying possibly a large cohort moving through the population. Figure 11.5.1 and Table 11.5.4 show the series of mean sizes of larger *Nephrops* (>35 mm) in the landings. This parameter might be expected to reduce in size if overexploitation were taking place but there is no evidence of this. The mean size of smaller animals (<35 mm) in the catch is fairly stable through time until 2010 when an increase is noticeable which may be associated with lower recruitments combined with the increasing use of more selective gears. In 2017, the mean size in catches <35 mm decreased sharply followed by an increase in 2018–2021 and is now around 31 mm CL for females and 32 mm CL for males. The discard rate in 2021 was estimated to have decreased from the 2017 high value (4.4%) and is now 1.7% by number. Quantitative information on trends in gear changes is not currently available but a shift from TR2 to TR1 gears was observed from 2010. No major gear changes were noted in recent years suggesting the current reduced mean sizes in catches may be related with a strong recruitment in 2016–2017. A further difficulty in the interpretation of these size observations is that the ground extends over a wide area and the distributional pattern of fleet activity is known to vary over time. This may lead to exploitation of subareas within the ground, where size compositions may be slightly different.

Mean weights in the landings through time (1990–2021) are shown in Figure 11.5.4 and Table 11.5.5. The variability in mean size is greater in FU 7 (and FU 34) than in other areas. In 2021, the mean weight in landings remained stable at approximately 36 g and were similar to the values observed in the early 2010's.

Natural mortality, maturity at age and other biological parameters

Biological parameter values are included in the Stock Annex.

Research vessel data

Underwater TV (UWTV) surveys using a stratified random design are available for FU 7 since 1992 (missing survey in 1996). UWTV surveys of *Nephrops* burrow density and distribution reduces the problems associated with traditional trawl surveys that arise from variability in burrow emergence of *Nephrops*.

The numbers of valid stations used in the final analysis in each year are shown in Table 11.5.6. On average, approximately 66 stations have been considered valid each year. There were 70 stations completed in the 2022. Data are raised to a stock area of 28 153 km^2 based on the stratification (by sediment type). General analysis methods for UWTV survey data are similar for each of the Scottish surveys, and are described in more detail in the Stock Annex.

Previous review groups have noted that the UWTV survey did not cover the stock distribution. The survey stations are randomly distributed within strata and therefore the actual location of the survey stations varies from year to year and in some years, particular regions of the main part of the ground may not be surveyed. There is an additional small patch of mud to the north of the ground which it is not possible to survey (due to time constraints and distance to survey ground) and therefore the estimated absolute abundance is likely to be slightly underestimated by the UWTV survey.

11.5.7 Data analyses

Exploratory analyses of survey data

Table 11.5.7 shows the basic analysis (corrected to absolute values) for the three most recent UWTV surveys conducted in FU 7. The table includes estimates of abundance and variability in each of the strata adopted in the stratified random approach. The ground has a range of mud types from soft silty clays to coarser sandy muds (<40% silt and clay) and the latter predominates.

Most of the variance in the survey is associated with the coarse sediment which surrounds the main centres of abundance.

Figure 11.5.5 shows the distribution of stations in recent UWTV surveys (2011–2022) with the size of the symbol reflecting the *Nephrops* burrow density. The abundance in 2022 decreased 12% from 2021. Abundance is generally higher in the soft and intermediate sediments located to the centre and south east of the ground. Table 11.5.6 and Figure 11.5.6 show the time series estimated abundance for the UWTV surveys (U6028), with 95% confidence intervals on annual estimates. Following the low UWTV estimated densities in the period 2011–2015 and the apparent *Nephrops* fleet preference for the fishing grounds located to the south of Fladen (Figure 11.5.8), the WG looked closely at the spatial distribution of the UWTV survey in the last decade. It was suggested (as a hypothesis) that the north of the ground has been more affected by the recent decline (from 2009) in abundance than the areas in the south where most fishing took place in recent years. The TV surveys from 2009–2022 were re-worked by sediment type, splitting the ground in two areas, north and south of the 58.75 N latitude line. Results seem to support that the areas mostly affected by the fluctuations in the mean *Nephrops* burrow density from 2009 were in fact located in the south, especially those made of finer sediments located in the central south region (Figure 11.5.9). In the north of Fladen, where coarser sediments (<40% silt and clay) dominate, a decrease in density was observed in the period 2011–2015 but to a lesser extent when compared with those in the south. This analysis also shows that even during the period of lowest abundance in FU 7, the mean densities in the south remain on average higher than those in the north. The density increase recorded from 2016 occurred across the different strata but is more evident in the three finer sediments (F, MF and MC) in the south and in the medium fine (MF) and medium coarse (MC) sediments in the north (Figure 11.5.9).

The use of the UWTV surveys for *Nephrops* in the provision of advice was extensively reviewed by WKNEPH (ICES, 2009). A number of potential biases were highlighted including those due to edge effects, species burrow misidentification and burrow occupancy. The cumulative bias correction factor estimated for FU 7 was 1.35 meaning that the raw UWTV survey is likely to overestimate *Nephrops* abundance by 35%. In order to convert the raw UWTV survey abundance to an absolute abundance the raw data are divided by 1.35.

Final assessment

The UWTV survey is again presented as the best available information on the Fladen *Nephrops* stock. This survey provides a fishery independent estimate of *Nephrops* abundance. At present it is not possible to extract any length or age structure information from the survey and it therefore only provides information on abundance over the area of the survey.

The latest UWTV survey data shows that the abundance has decreased 12% in 2022. The stock is above the average abundance over the time series and is well above the biomass trigger. The harvest ratio in 2021 (4.7%, calculated as dead removals/TV abundance) is below F_{MSY}. The effort by *Nephrops* trawlers and respective LPUE declined from 2010 until 2015 and this appears to be consistent with the abundance trends from the UWTV survey. The LPUE increased markedly in 2019 and is currently approximately at the same high level as recorded in 2011–2012. The low LPUEs observed prior to 2006 may be due the under-reporting of landings before the introduction of 'Buyers and Sellers' legislation. The relatively high LPUEs calculated for the period 2009–2011, after the stock have declined could also be explained by the fishing fleet targeting areas where the density of *Nephrops* is higher. The mean size of individuals >35 mm in the catch remains relatively stable. The discard rate in catches has increased and the mean size of individuals below 35 mm decreased in 2017. This suggests a period of lower recruitment between 2010 and 2015 followed by a strong recruitment event in 2016–2017. In 2019–2021, the observed recruitment pulse seems to be moving up in the length distributions as suggested by a decrease in the discard rate and an increase in the mean sizes of catches below 35 mm CL from 2017.

Historical Stock trends

The UWTV survey estimates of abundance for *Nephrops* in FU 7 suggest that the population has fluctuated over the 30-year period of the surveys. From 1997 to 2008, the abundance has generally increased and reached a peak of 7360 million individuals in 2008. The abundance has fallen subsequently and was below the $B_{trigger}$ in 2012 and 2015. In 2016–2017, the abundance continued to increase sharply from the lowest point in the time series. In 2022, the abundance remains at a relatively high level estimated to be 5550 million (Table 11.5.8).

Table 11.5.8 also shows the estimated harvest ratios from 1992–2021. These range from 1.4–10% over this period and are all below F_{MSY}. It is unlikely that prior to 2006, the estimated harvest ratios are representative of actual harvest ratios due to under-reporting of landings. In 2021, landings and abundance increased by 72% and 38% respectively, as such, the harvest ratio has increased slightly and was estimated to be at 4.7% (3.7% in 2020), well below the F_{MSY} proxy (7.5%).

In addition to the discard rate, Table 11.5.8 shows the dead discard rate which is the quantity of dead discards as a proportion (by number) of the removals (landings + dead discards). Discards were estimated to be 1.7% by number in 2021.

11.5.8 Recruitment estimates

Recruitment estimates from surveys are not available for this FU. However, the increase in mean size of small animals <35 mm (i.e. a lower proportion of small animals in this component of the catch) observed in recent years may be indicative of lower recruitments in the period 2010–2015. The recent increase in abundance suggests a good recruitment in 2016–2017.

11.5.9 MSY considerations

F_{MSY} proxies for *Nephrops* are obtained from the per-recruit analysis as documented in the WGNSSK 2015 report. The most recent analysis used 2012–2014 catch-at-length data, to account for the apparent changes in the discard pattern in this fishery. Length frequency data in Fladen have shifted towards larger animals since 2010 (see Section 11.5.5 and Figure 11.5.3) suggesting a different selection pattern in the fishery. In addition, the discard rate has shown generally a declining trend over the last 10 years due to a combination of low recruitments, a shift to larger meshes (TR1) and the increase in the use of the use of Highly Selective Gears for reducing fish bycatch. The biological parameters used in the analysis can be found in the Stock Annex. The complete range of the per-recruit F_{MSY} proxies is given in the table below and the basis for choosing an appropriate F_{MSY} proxy remains the same and is described in WGNSSK 2010 report.

WGNSSK 2015		**F_{bar}(20–40 mm)**		**HR (%)**	**SpR (%)**		
		M	**F**		**M**	**F**	**T**
$F_{0.1}$	M	0.07	0.07	6.4	47.4	58.3	51.9
	F	0.14	0.15	10.6	33.3	40.8	36.4
	T	0.08	0.09	7.5	43.0	53.1	47.2
F_{max}	M	0.21	0.22	13.8	26.6	31.6	28.7
	F	0.44	0.46	21.2	17.5	18.7	18.0
	T	0.27	0.29	16.4	22.8	26.1	24.2
$F_{35\%SpR}$	M	0.13	0.13	10.0	34.8	42.9	38.1
	F	0.18	0.19	12.6	29.0	34.9	31.4
	T	0.15	0.16	11.2	31.9	39.0	34.8

*** M = males, F = females, T = combined**

For this FU, the absolute density observed on the UWTV survey remains low (average just below 0.2 m^{-2}) suggesting the stock may have low productivity. In addition, the expansion of the fishery in this area is a relatively recent phenomenon and as a result the population has not been well-studied and biological parameters are considered particularly uncertain. Furthermore, historical harvest ratios in this FU have been below that equivalent to fishing at $F_{0.1}$. For these reasons, it is suggested that a conservative proxy is chosen for F_{MSY} such as $F_{0.1(T)}$.

The F_{MSY} proxy harvest ratio is 7.5%.

The $B_{trigger}$ point for this FU (lowest observed absolute UWTV abundance, 1992–2010) is calculated as 2767 million individuals.

11.5.10 Short-term forecasts

A catch prediction for 2023 was made for the Fladen Ground (FU 7) using the approach agreed at the Benchmark Workshop in 2009 and outlined in the introductory section of the 2010 WGNSSK report. The table below shows catch predictions at various harvest ratios, including a selection of those equivalent to the per-recruit reference points discussed in Section 11.5.9 of this report and the harvest ratio in 2021 using the input parameters agreed at WKNEPH (ICES, 2009). The catch prediction is calculated following the procedure outlined in the stock annex (section: short term projections).

To account for the landing obligation coming into force for *Nephrops* in 2016, the projected amount of discards (now referred to as projected discards) have been added to the catch options table. The advice given in 2022 considers that *Nephrops* discarding is allowed to continue as in previous years. Under this scenario the harvest rate is assumed to include landings (projected landings) plus dead discards (Projected dead discards). The catch options table includes projected surviving discards (discards survival for *Nephrops* in FU 7 is assumed to be 25%). Projected discards (by number) are calculated using data from the on-board observer sampling programme. This value is multiplied by the mean weight in discards to obtain the projected discard weight. There is a *de minimis* exemption in place for *Nephrops* in the UK waters of the North Sea (ICES division 2.a and Subarea 4) with certain gears. The forecast includes an extra catch options table assuming a discard ban for 2023. The main difference in this scenario is that there is no survival assumed for the projected discards.

The advice for Category 1 stocks (where assessment includes landings and discards data) is based on catches. The prediction for 2023 is that catches should be no more than 13679 tonnes, assuming recent discard rates. This represents a 7.6% decrease from the advice given for 2022. It should be noted that the F_{MSY} proxy harvest ratio for Fladen is based on a combined Length Cohort Analysis (data 2012–2014) using dead removals (landings + dead discards). A discussion of F_{MSY} reference points for *Nephrops* is provided in Section 11.5.9.

The inputs to the landings forecast were as follows:

FU 7 basis for the catch options

Variable	Value	Notes
Stock abundance (2023)	5550	Underwater TV (UWTV) survey 2022; individuals in millions
Mean weight in projected landings	33.08	Average 2019-2021; grammes
Mean weight in projected discards	12.75	Average 2019-2021; grammes
Projected total discard rate	1.80	Average 2019-2021; percentage by number of the total catch
Discard survival rate	25	Percentage by number of the discards

Catch scenarios assuming recent discard rates

Basis	Total catch	Dead removals	Projected landings	Projected dead discards	Projected surviving discards	Harvest rate * for PL+PDD	% advice change **
	PL + PDD + PSD	PL + PDD	PL	PDD	PSD		
ICES advice basis							
MSY approach	13679	13655	13583	72	24	7.5	-7.6
Other scenarios							
$F_{2019–2021}$	8390	8375	8331	44	15	4.6	-43
F_{2021}	8530	8515	8470	45	15	4.7	-42
F_{MSY} lower	12037	12016	11953	63	21	6.6	-18.7
F_{MSY} upper***	13679	13655	13583	72	24	7.5	-7.6
$F_{35\%SpR}$	20427	20391	20284	107	36	11.2	38
F_{max}	29910	29858	29701	157	52	16.4	102

Catch scenarios assuming zero discards

Basis	Total catch	Projected landings	Projected discards ^	Harvest rate * for PL + PD	% advice change **
	PL + PD	PL	PD		
ICES advice basis					
MSY approach	13618	13522	96	7.5	-8.0%
Other scenarios					
$F_{2019–2021}$	8352	8293	59	4.6	-44%
F_{2021}	8492	8432	60	4.7	-43%
F_{MSY} lower	11983	11899	84	6.6	-19.1%
F_{MSY} upper***	13618	13522	96	7.5	-8.0%
$F_{35\%SpR}$	20335	20192	143	11.2	37%
F_{max}	29776	29567	209	16.4	101%

^ Represents the amount that otherwise would have been discarded but is now landed under the landing obligation.
*** Calculated for dead removals.**
**** Advice basis values for 2023 relative to the 2022 advice values (14803 tonnes).**
***** $F_{MSY\ upper}$ = F_{MSY} for this stock.**

Biological Reference points

Biological reference points have not been defined for this stock.

11.5.11 Quality of assessment

The length and sex composition of the landings data is considered to be well sampled. Discard sampling has been conducted on a quarterly basis for Scottish *Nephrops* trawlers in this fishery since 2000, and is considered to represent the fishery adequately. Discard sampling in 2020-2021 was impacted by the Covid-19 pandemic and there were some missing samples (quarters 2 and 3 in 2020 and quarter 1 in 2021). The proportion of landings with discards associated (same strata) is 71% in 2021 (71% of the discards were imported and 29% were raised discards).

The quality of landings (and catch) data is likely to have improved in recent years following the implementation of 'the registration of buyers and sellers' legislation in the UK in 2006, but because of concerns over the accuracy of earlier years, the final assessment adopted is independent of official statistics.

Underwater TV surveys have been conducted for this stock since 1992, with a continuous annual series available since 1997. The number of valid stations in the survey has remained relatively stable throughout the time period. Confidence intervals are relatively small.

The UWTV survey is conducted over the main part of the ground, representing an area of around 28 200 km^2 of suitable mud substrate (the largest ground in Europe). The Fladen Functional Unit contains several patches of mud to the north of the ground which are fished, bringing the overall area of substrate to 30 633 km^2. This area is not surveyed but would add to the abundance estimate. The absolute abundance estimate for this ground is therefore likely to be underestimated by the current methodology.

The Fishers' North Sea stock survey suggests that moderate or high amounts of recruits were apparent in Area 1 (which Fladen FU lies largely within) in 2011 compared to 2009. The time series of perceived abundance in Area 1 increases up to 2011. Opinion on discards appears to be split fairly evenly between lower, higher and no change. There are no Fishers' North Sea survey data available for 2013–2021.

11.5.12 Status of the stock

The stock has declined in the period 2008–2015 to the lowest point in the time series, and increased in the following years with the current abundance being close to the highest value recorded in 2008. The stock abundance is well above the MSY $B_{trigger}$ level. Landings taken from this FU in 2021 (9559 tonnes) were lower than the 2020 total catch advice (for 2021) of 9579 tonnes. The harvest rate increased in 2021 (in relation to the previous year) to 4.7% but remains below F_{MSY}. Length frequencies in the caches have evolved towards larger animals, suggesting a selectivity change and/or lower recruitment in the period 2010–2015. In 2017, length distributions in catches showed a decrease in the mean size and discard rates (previously estimated to be zero) increased. In the last two years, there is again some evidence of larger animals in the length distributions with increases recorded in the mean size and mean weight of catches.

11.5.13 Management considerations

The WG, ACOM and STECF have repeatedly advised that management should be at a smaller scale than the ICES division level. Management implemented at the Functional Unit level could provide controls to ensure that catch opportunities and effort were in line with the scale of the resource and that other FUs do not suffer from displacement from unused catch options from this FU.

Nephrops fisheries have a bycatch of cod. The Scottish industry is implementing improved selectivity measures in gears which target *Nephrops* with a view to reducing unwanted by-catch of cod and other species.

The increase in abundance registered in recent years points to a high recruitment event. Most of these small individuals only became available to the fishery in 2017 given the increase in selectivity recently observed for this FU. The selectivity of the survey is >17 mm carapace length (CL), the current MCRS is 25 mm CL. This stock is considered to be lightly exploited, and the difference between advice and catches may be transferred to other FUs in the North Sea which could result in non-precautionary exploitation of those FUs.

This stock is under the landings obligation although there is a *de minimis* exemption in place for *Nephrops* in the UK waters of the North Sea (ICES division 2.a and Subarea 4) with certain gears, according to the Marine Management Organization (MMO, 2021). The exemption applies to catches of Norway lobster below the minimum conservation reference size, which shall not exceed 2% of the total annual catches of that species. In 2021, no *Nephrops* were recorded as below the minimum size (BMS) in FU 7. This is consistent with the discard rates estimated for this FU which have been low.

References:

MMO, 2021. Fishing gear requirements and Landing Obligation exemptions 2022. Applicable to the Nephrops Fishery in UK waters of the North Sea. Document No.: V1. Date of Issue: December 2021.

11.6 Firth of Forth (FU 8)

11.6.1 Ecosystem aspects

The Firth of Forth Functional Unit 8 is located in the south-west of the Northern North Sea and is an inshore ground just off the east coast of Scotland (Figure 10.1.1.). In common with other firths around the Scottish coast, the area is characterised by a wide entrance to seaward, narrowing towards the coast with river basins draining into the area. Sandy mud and muddy sand deposits are widespread throughout the area covering an area of 915 km^2, the coarsest muds being found offshore beyond the Isle of May.

Owing to its burrowing behaviour, the distribution of *Nephrops* is restricted to areas of mud, sandy mud and muddy sand. Figure 11.6.4 shows the distribution of sediment in the area. There is some evidence of *Nephrops* larval drift from grounds to the south of the area but most larvae appear to be produced locally and the population is characterised by high density and generally small size. Although this area was historically important for fish catches, this area has now declined and *Nephrops* is the main commercial species. The recruits of numerous demersal fish species occasionally aggregate in the area and small pelagics (sprat and juvenile herring) are seasonally abundant. Important seabird colonies occur in the area and the 'Wee Bankie' gravel area, important for sandeel is located further offshore to the north and east of the Firth.

11.6.2 The fishery in 2021

The *Nephrops* fishery in the Firth of Forth is dominated by UK (Scotland) vessels with low landings reported by other UK nations (Table 11.6.1). In recent years, around 40 vessels worked regularly in the Firth of Forth. Most vessels are under 12 m in length with about 10 in 12–15 m category and a few above 15 m. Engine power ranges from just under 100 kw to around the 300 kw. The trip length for most of the fleet is one day. In the winter, most vessels fish from around dawn till 16:00–19:00. In spring/summer, vessels switch to nights, working from around 19:00 to 07:00–10:00. The few larger vessels (over 15 m) fishing in FU 8, undertake trips of around 2–3 days. The overall number of boats operating varies seasonally as vessels move around the UK in response to varying catch rates. In recent years some large Fraserburgh boats, which usually operate in FU 7, moved into the area, fishing mostly to the east grounds of the Firth. Visitor boats come generally from the Northeast of Scotland (FU 7 and FU 9) in periods of poor fishing in those grounds but tend to land to harbours in the northeast of Scotland. A few English vessels also visited FU 8 with landings from the rest of UK estimated at 9 tonnes in 2021. The low market price for *Nephrops* was an issue faced by the fishery in 2020 when prices have, to an extent, crashed compared to previous years. In 2021 prices improved compared with 2020 and remained stable throughout the year. Fuel prices have been reported as similar to previous years. The predominant trawl gear mesh sizes are 80 mm and 95 mm with several vessels working with twin rigs. The fishery continues to be characterised by catches of small *Nephrops* which often leads to higher discard rates than in other east coast Functional Units. There were only 2 tonnes of *Nephrops* landings by creel vessels in FU 8 in 2021 – typically, the main target species of these vessels are crabs and lobsters.

Further general information on the fishery can be found in the Stock Annex.

11.6.3 Advice in 2021

The ICES advice in 2021 (for 2022) (Single-stock exploitation boundaries) was as follows:

MSY approach

"ICES advises that when the MSY approach is applied, and assuming that discard rates and fishery selection patterns do not change from the average of the years 2018–2020, catches in 2022 should be no more than 3216 tonnes.

To ensure that the stock in Functional Unit (FU) 8 is exploited sustainably, management should be implemented at the functional unit level.

ICES notes the existence of a management plan, developed and adopted by one of the relevant management authorities for Subarea 4. ICES considers this plan to be precautionary when implemented at the functional unit level."

11.6.4 Management

Management is at the ICES Subarea level as described in Section 10.1.

11.6.5 Assessment

Approach in 2022

The assessment in 2022 is based on a combination of examining trends in fishery indicators and underwater TV using an extensive data series for the Firth of Forth Ground FU 8. The assessment of *Nephrops* through the use of the UWTV survey data and other commercial fishery data follows the process defined by the benchmark WG 2009 and described in the stock annex.

The provision of advice in 2022 followed the process of 2021, and attempts to incorporate decisions taken at WKFRAME (2010) for the provision of MSY advice. The approach was developed based on inter-sessional work carried out by participants of the benchmark and involving collaboration between WGNSSK and WGCSE. The UWTV based assessments have derived predicted landings by applying a harvest rate approach to populations described in terms of length compositions from the trawl component of the fishery. Considerations for setting Harvest Ratios (HR) associated with proxies for F_{MSY} for *Nephrops* are described in the WGNSSK 2010 report.

It was decided by ICES prior to the 2022 WG meeting that the advice for North Sea *Nephrops* stocks would be delayed until autumn after the summer surveys. The assessment presented in this report was concluded in September 2022 and incorporates the most recent *Nephrops* UWTV survey (2022). The assessment presented in this report was re-run in September 2022 but it only incorporates survey data up to 2021 given the fact that a FU 8 Nephrops UWTV survey was not carried out in 2022. The 2021 survey was used in the catch forecasts for 2023.

Data available

Commercial catch and effort data

Landings from this fishery are predominantly reported from Scotland, with very small contributions from England, and are presented in Table 11.6.1 and Figure 11.6.1. Most of the landings are made by trawlers with creels generally accounting for less than 1% of the total (only 2 tonnes of creel landings were recorded in 2021). Reported landings rose from 1100 to over 2650 tonnes between 2003 and 2009 and have fluctuated since then around 2000 tonnes. The value for 2021 of 1835 tonnes represents a 3% increase from 2020 and is below the ten-year average (2130 tonnes). *Nephrops* is one of the species in the North Sea under the landing obligation. In 2021 there were 15 tonnes landed below the minimum conservation reference size (BMS) and no logbook registered discards were reported in FU 8.

In previous years, concerns were expressed over the reliability of the effort figures provided for Scottish *Nephrops* trawlers; effort Figures were unrealistically low in some areas. Investigation of the issue revealed a problem in the MSS Marine Laboratory database, where only the effort expended in the first statistical rectangle visited by a vessel during a trip was being output. This did not affect landings. An extraction of effort data by the Marine Scotland data unit in Edinburgh covering the 4 main trawl gears landing *Nephrops* into Scotland produced higher figures which capture all the effort. At the present time, these revised data cover the period 2000 to the present and only annual summaries are available.

Trends in Scottish effort and LPUE are shown in Figure 11.6.1 and Table 11.6.2. Effort data is expressed both in days fishing and kW days (only small differences in recent years are noticeable between these different units). Effort has shown a gradual decline over the time period. Some of this is recently attributable to the EU effort management regime although, as part of the Scottish conservation credits scheme, *Nephrops* vessels have been eligible for effort 'buy-backs'. LPUE rose in the early 2000s, stabilised at a relatively high level from 2006 to 2016 and increased again in recent years reaching the highest level of the time series in 2018.

Males consistently make the largest contribution to the landings by weight (Figure 11.6.2), although the sex ratio does vary. In 2011–2013, more females recorded in the catches moved the ratio closer to 1:1. This may be due to the changes in seasonal effort distribution in the late 2000s with greatest effort in the 3rd quarter when females are likely to be more available to the fishery (compared with a more evenly distributed seasonal effort pattern in previous years, Figure 11.6.2). Figure 11.6.6 shows the quarterly sex ratio by number from 2000. The seasonality of *Nephrops* emergency behaviour is evident with males dominating catches during winter time. In quarters 2 and 3, females become more active and are more available to the fishery. These data suggest a gradual increase of female proportion in catches up to 2015, in particular during quarters 2 and 3. Increased female catchability has also been associated with stocks which are in a poor state (females may remain more active as they have been unable to mate due to lack of males in the population). This problem usually manifests itself at times of the year when females would normally be reduced in the catches. This does not appear to be the case here.

Discarding of undersized and unwanted *Nephrops* occurs in this fishery, and quarterly discard sampling has been conducted on the Scottish *Nephrops* trawler fleet since 1990. In 2021 due to the Covid-19 pandemic and the suspension of the on-board observer programme, discards were only sampled in quarter 4. Historically, discard rates have been higher in this stock than the more northerly North Sea FUs for which Scottish discard estimates are also available. This could arise from the fact that the use of larger meshed nets is not so prevalent in this fishery (80–95 mm is more common) and in addition, the population appears to consist of smaller individuals due to slower growth. Discarding rates in this FU have varied between 7% and 55% of the catch by number (2012–2021 average is 20%). In 2021, the discard rate was recorded at 13%. It is likely that some *Nephrops* survive the discarding process, an estimate of 25% survival is assumed in order to calculate dead removals (landings + dead discards) from the population.

InterCatch

Scottish 2021 data (official landings and sampled data for landings and discards) were successfully uploaded into InterCatch. National data co-ordinators for other countries (England) also uploaded landings data to InterCatch ahead of the 2022 WG. Output data for landings were produced and extracted following the same raising procedure used in previous years to obtain length compositions in formats suitable for running the assessment. In 2021 there were only discard data imported for quarter 4. Analyses were carried out to visualize the relationship between discard rates and season – this showed that discard rates in FU8 are highly variable with no clear seasonality patterns. As such, discard rates and allocations for length frequencies in quarters 1-3 were estimated as follows: calculations were performed to obtain the mean discard rate (and mean length frequency distributions for males and females separately) in the last 3 years (2017-2019) for quarters 1-3 (avQ1-3) and quarter 4 (avQ4); then, the 2021 discard rates for Q1-3 were estimated according with the formula: avQ1-3*(Q4_2021/avQ4). This results in a mean discard length distribution for each of quarters 1, 2 and 3 which is scaled to the 2021 Q4 estimate (the only available for 2021). Borrowing discard rates from previous years is not a feature allowed in Intercatch, as such the method described above was performed outside Intercatch. This procedure follows that which was implemented in the previous year with the difference being that in 2020 discards were only available for quarter 1. In 2021 there were 15 tonnes of BMS recorded but no logbook registered discard data reported for this FU.

Length compositions

Length compositions of landings and discards are obtained during monthly market sampling and quarterly on-board observer sampling respectively. Although assessments based on detailed annual catch data analysis are not presently possible, examination of length compositions may provide an indication of exploitation effects.

Figure 11.6.3 shows a series of annual length frequency distributions for the period 2000 to 2021. Size information on catches (removals) are shown for each sex with the mean catch and landings lengths shown in relation to MLS and 35 mm. There is little evidence of change in the mean size of either sex over time and examination of the tails of the distributions above 35 mm shows no evidence of reductions in relative numbers of larger animals.

The observation of relatively stable length compositions is further confirmed in the series of mean sizes of larger *Nephrops* (>35 mm) in the landings shown in Figure 11.6.1 and Table 11.6.3. This parameter might be expected to reduce in size if overexploitation were taking place but over the last 30 years has in fact been quite stable. The mean size in the catch in the <35 mm category (Figure 11.6.1) also shows no particular trend. There was a slight shift to the right in the length distributions in 2020, implying a higher relative number of large animals present in the catches (Figure 11.6.3). In 2021, the length distribution was very similar to that observed in 2019 and the previous 5 years. The observation of a larger mean size in landings in 2020 coincides with an increase in the mean size of animals below 35 mm (Figure 11.6.1) and a decrease in the discard rate. However, given the limited discard sampling in 2020 (only quarter 1 coverage) caution should be taken in the interpretation of these results and this does not necessarily imply clear recruitment changes in FU 8, particularly given that discard rates are known to be variable throughout the year. In 2021 the mean size below 35 mm decreased and is close to that observed in 2019.

Mean weight in the landings is shown in Figure 11.5.4 and Table 11.5.5 and this shows no systematic changes over the time series. The mean weight recorded for 2021 decreased from 2020 (28.8 g) and is currently estimated at 24.8 g.

Natural mortality, maturity at age and other biological parameters

Biological parameter values are included in the Stock Annex.

Research vessel data

Due to operational limitations the 2022 FU 8 UWTV survey was not carried out. TV surveys using a stratified random design are available for FU 8 since 1993 (missing surveys in 1995, 1997 and in the current year, 2022). Underwater television surveys of *Nephrops* burrow number and distribution, reduce the problems associated with traditional trawl surveys that arise from variability in burrow emergence of *Nephrops*.

The numbers of valid stations used in the final analysis in each year are shown in Table 11.6.4. On average, about 44 stations have been considered valid each year. In recent years the aim of the survey is to sample 50 stations. The last survey in FU 8 was completed in 2021, however, due to limitations related with the Covid-19 pandemic and the research vessel's availability, the 2021 survey was carried out in June (it is normally conducted in August) together with other Functional Units to the west of Scotland (FU 11, FU 12 and FU 13) and in the North Sea (FU 7, FU 9 and FU 34). Abundance data are raised to a stock area of 915 km^2. General analysis methods for underwater TV survey data are similar for each of the Scottish surveys, and are described in the Stock Annex.

A further non-surveyed area of sediment (Lunan Bay) exists just north of the Firth of Forth FU. There is a small *Nephrops* fishery in this area (off Arbroath), but the area is only surveyed on an irregular basis and therefore is not included in any estimates of abundance. The WG wishes to emphasise that this area is out-with the Firth of Forth functional unit, is considered as part of the 'other' North Sea *Nephrops* area and hence not further considered in this section.

Data analyses

Exploratory analyses of survey data

Table 11.6.5 shows the basic analysis for the three most recent TV surveys conducted in FU 8. The table includes estimates of abundance and variability in each of the strata adopted in the stratified random approach. The ground is predominantly of coarser muddy sand. Depending on the year, high variance in the survey is associated with different strata and there is no clear distributional or sedimentary pattern in this area. Densities observed in this FU are typically higher than those of the more northerly FUs in the North Sea.

Figure 11.6.4 shows the distribution of stations in TV surveys, with the size of the symbol reflecting the *Nephrops* burrow density. Abundance is currently higher towards the western parts of the ground and around the Isle of May. Table 11.6.4 and Figure 11.6.5 show the time series of estimated abundance for the TV surveys (U6028), with 95% confidence intervals on annual estimates. The use of the UWTV surveys for *Nephrops* in the provision of advice was extensively reviewed by WKNEPH (ICES, 2009). A number of potential issues were highlighted including those arising from edge effects, species burrow mis-identification and burrow occupancy. To take account of these effects, a cumulative correction factor of 1.18 was estimated for FU 8 and this is applied to raw counts in order to derive the absolute abundance.

Final assessment

The underwater TV survey is again presented as the best available information on the Firth of Forth *Nephrops* stock. This survey provides a fishery independent estimate of *Nephrops* abundance. At present it is not possible to extract any length or age structure information from the survey, and it therefore only provides information on abundance over the area of the survey.

The UWTV abundance was relatively high in the period 2003 to 2008 but has shown a decreasing trend in 2008–2014. The stock has increased again in recent years and in 2020 reached the highest point of the time series. The 2022 UWTV survey was not carried out, as such, the most recent abundance estimate available for this stock is from 2021(837 million). The stock is currently above the average abundance over the time series and remains well above the biomass trigger. The calculated harvest ratio in 2021 (dead removals/TV abundance) increased but continues to be below F_{MSY}. This is the result of a 25% decrease in stock abundance (in 2021) and landings in 2021 remaining at approximately the same level in relation to 2020. The mean size of individuals >35 mm in the catch shows no strong trend in recent years. The mean size of individuals below 35 mm has shown an increasing trend since 2009. Larger square mesh panels and new, more selective TR2 gears implemented from 2010 as part of the Scottish Conservation Credits scheme may have improved the exploitation pattern. The effect of these changes are not however, as evident as those observed in FU 7 and generally with the exception of 2020, length frequencies in recent years remain relatively stable in the Firth of Forth.

11.6.6 Historical stock trends

The TV survey estimate of abundance for *Nephrops* in the Firth of Forth suggests that the population decreased between 1993 and 1998 and then began a steady increase up to 2008 followed by a further decrease until 2014. Abundance is estimated to have increased in the years since then. The abundance estimates from 1993–2021 are shown in Table 11.6.6. The stock is currently estimated to consist of 837 million individuals.

Table 11.6.6 also shows the estimated harvest ratios over this period. From 2003 (the period over which the survey estimates have been revised) these range from 6–29% with the upper range being the value for 2014 (estimated harvest ratios prior to 2006 may not be representative of actual harvest ratios due to under-reporting of landings before the introduction of 'Buyers and Sellers' legislation). The estimated harvest rate in 2021 is 10.8% which has increased from the 2020 value (6.1%, the lowest harvest rate in the time series) but is still below the estimated value at F_{MSY} (16.3%).

In addition to the discard rate, Table 11.6.6 also shows the dead discard rate which is calculated as the quantity of dead discards as a proportion (by number) of the removals (landings + dead discards).

11.6.7 Recruitment estimates

Survey recruitment estimates are not available for this stock.

11.6.8 MSY considerations

A number of potential F_{MSY} proxies were obtained from the per-recruit analysis for *Nephrops* as documented in the WGNSSK 2010 report. The most recent analysis (in 2011) used 2008–2010 catch-at-length data, to account for the apparent changes in the discard pattern in this fishery. The biological parameters used in the analysis can be found in the Stock Annex. The complete range of the per-recruit F_{MSY} proxies is given in the table below and the process for choosing an appropriate F_{MSY} proxy is described in WGNSSK 2010 report.

WGNSSK 2011		F_{bar}(20–40 mm)		HR (%)	SpR (%)		
		M	F		M	F	T
F0.1	M	0.14	0.06	7.7	40.8	62.3	49.9
	F	0.31	0.13	15.2	20.5	40.7	29
	T	0.17	0.07	9.4	34.6	56.6	43.9
Fmax	M	0.25	0.11	12.7	25.3	46.8	34.4
	F	0.64	0.28	26.7	9.1	22.9	14.9
	T	0.34	0.14	16.3	18.8	38.5	27.1
F35%SpR	M	0.17	0.07	9.4	34.6	56.6	43.9
	F	0.39	0.17	18.3	16	34.5	23.9
	T	0.25	0.11	12.7	25.3	46.8	34.4

For this FU, the absolute density observed in the UWTV survey is relatively high (average of ~ 0.7 m^{-2}). Harvest ratios (which are likely to have been underestimated prior to 2006) have mostly been well above F_{max} and in addition there is a long time series of relatively stable landings (average reported landings ~ 2000 tonnes, well above those predicted by currently fishing at F_{max}) suggesting a productive stock. For these reasons, it is suggested that the sexes combined $F_{max(T)}$ is chosen as the F_{MSY} proxy.

The F_{MSY} proxy harvest ratio is 16.3%.

The $B_{trigger}$ point for this FU (lowest observed absolute UWTV abundance) is calculated as 292 million individuals.

11.6.9 Short-term forecasts

A catch prediction for 2023 was made for the Firth of Forth (FU 8) using the approach agreed at the Benchmark Workshop in 2009 and outlined in the introductory section of the 2010 WGNSSK report. The table below shows catch predictions at various harvest ratios, including a selection of those equivalent to the per-recruit reference points discussed in Section 11.7.8 of this report and the harvest ratio in 2020 using the input parameters agreed at WKNEPH (ICES, 2009). The catch prediction is calculated following the procedure outlined in the stock annex (section: short term projections).

Recently, to account for the landings obligation coming into force for *Nephrops* in 2016, the projected amount of discards (now referred to as projected discards) have been added to the catch options table. The advice given in 2022 considers that *Nephrops* discarding is allowed to continue as in previous years. Under this scenario the harvest rate is assumed to include landings (projected landings) plus dead discards (Projected dead discards). The catch options table includes projected surviving discards (discards survival for *Nephrops* in FU 8 is assumed to be 25%). Projected discards (by number) are calculated using data from the on-board observer sampling programme. This value is multiplied by the mean weight in discards to obtain the projected discard weight. There is a *de minimis* exemption in place for *Nephrops* in the UK waters of the North Sea (ICES division 2.a and Subarea 4) with certain gears. The forecast includes an extra catch options table assuming a discard ban for 2023. The main difference in this scenario is that there is no survival assumed for the projected discards.

The advice for Category 1 stocks (where assessment includes landings and discards data) is based on catches. There was no survey carried out for the Firth of Forth in 2022, as such, the 2021 value was used as the most recent abundance estimate in FU 8. The prediction for 2023 is that catches should be no more than 3201 tonnes, assuming recent discard rates. This represents a

0.5% decrease from the advice given for 2022. It should be noted that the F_{MSY} proxy harvest ratio in the Firth of Forth is still based on a combined Length Cohort Analysis (data 2008–2010) using dead removals (landings + dead discards). A discussion of F_{MSY} reference points for *Nephrops* is provided in Section 11.7.8.

The inputs to the landings forecast were as follows:

FU 8 basis for the catch options

Variable	Value	Notes
Stock abundance (2023)	837	Underwater TV (UWTV) survey 2021 (no survey available in 2022); millions
Mean weight in projected landings	24.78	Average 2019-2021; grammes
Mean weight in projected discards	10.09	Average 2019-2021; grammes
Projected total discard rate	14.9	Average 2019-2021; percentage by number of the total catch
Discard survival rate	25	Percentage by number of the discards

Catch scenarios assuming recent discard rates

Basis	Total catch	Dead re-movals	Projected landings	Projected dead discards	Projected surviving discards	Harvest rate * for PL+PDD	% advice change **
	PL + PDD + PSD	PL + PDD	PL	PDD	PSD		
ICES advice basis							
MSY approach	3201	3148	2988	160	53	16.3	-0.47
Other scenarios							
$F_{0.1}$	1846	1815	1723	92	31	9.4	-43
F_{MSY} lower	2082	2047	1943	104	35	10.6	-35
F_{2021}	2123	2088	1982	106	35	10.8	-34
$F_{2019–2021}$	2298	2260	2145	115	38	11.7	-29
$F_{35\%SpR}$	2493	2452	2328	124	41	12.7	-22
F_{MSY} upper***	3201	3148	2988	160	53	16.3	-0.47

Catch scenarios assuming zero discards

Basis	Total catch PL + PD	Projected landings PL	Projected discards ^ PD	Harvest rate * for PL + PD	% advice change **
ICES advice basis					
MSY approach	3082	2877	205	16.3	-4.2
Other scenarios					
$F_{0.1}$	1777	1659	118	9.4	-45
F_{MSY} lower	2004	1871	133	10.6	-38
F_{2021}	2044	1908	136	10.8	-36
$F_{2019–2021}$	2212	2065	147	11.7	-31
$F_{35\%SpR}$	2402	2242	160	12.7	-25
F_{MSY} upper***	3082	2877	205	16.3	-4.2

^ Represents the amount that otherwise would have been discarded but is now landed under the landing obligation.

*** Calculated for dead removals.**

**** Advice basis values for 2023 relative to the 2022 advice values (3216 tonnes).**

***** $F_{MSY\ upper}$ = F_{MSY} for this stock.**

Biological Reference points

Biological reference points have not been defined for this stock.

11.6.10 Quality of assessment

There were no UWTV survey data available for FU 8 in 2022, therefore the stock size indicator is unknown for 2022. The assessment and advice were based on the 2021 UWTV survey along with 2019-2021 catch mean weights and discard rates. UWTV surveys have been conducted for this stock since 1993, with a continual annual series available between 1998 and 2021. The number of valid stations in the survey has remained relatively stable throughout the time period.

The length and sex composition of the landings data is considered to be well sampled. Discard sampling has been conducted on a quarterly basis for Scottish *Nephrops* trawlers in this fishery since 1990, and is considered to represent the fishery adequately. Discard sampling in 2020-2021 was impacted by the Covid-19 pandemic and only samples for quarter 1 (2020) and quarter 4 (2021) were available with discard rates and length distribution for the missing quarters being borrowed from years 2017–2019. The proportion of landings with discards associated (same strata) is 27% in 2021 (27% of the discards were imported and 73% were raised discards).

There are concerns over the accuracy of historical landings (pre-2006) due to misreporting and because of this the final assessment adopted is independent of officially reported data.

The Fishers' North Sea Stock survey does not include specific information for the Firth of Forth. Area 3 shows a perception of decreased abundance over the period 2007–2012, but this covers the Firth of Forth and parts of the Devil's Hole in addition to the Moray Firth. There are no Fishers' North Sea survey data available for 2013–2021.

11.6.11 Status of the stock

The stock has shown an increasing trend since 2014 and is above the average abundance and well above the MSY $B_{trigger}$ level. The abundance value calculated for 2021 is 837 million. Landings taken from this FU in 2021 (1835 tonnes) were lower than the 2020 total catch advice (for 2021) of 3931 tonnes. The harvest rate increased in 2021 to 10.8% (a combination of a decrease in stock abundance and stable landings in 2021) but remains below F_{MSY}. Length frequencies in the catches have been relatively stable.

11.6.12 Management considerations

Catches in 2018 increased to levels above ICES advice for 2018, highlighting the issue that current management arrangements are not sufficient to contain the fishery within the sustainable limits determined by ICES. The WG, ACOM and STECF have repeatedly advised that management should be at a smaller scale than the ICES Division level. Management at the Functional Unit level could provide the controls to ensure that catch opportunities and effort were compatible and in line with the scale of the resource.

Nephrops discard rates in this Functional Unit are relatively high in comparison to other Functional Units and there is a need to reduce these and to improve the exploitation pattern. An additional reason for suggesting improved selectivity in this area relates to bycatch. It is important that efforts are made to ensure that other fish are not taken as unwanted bycatch in this fishery which mainly uses 80 mm mesh. Larger square mesh panels and new, more selective TR2 gears should help to improve the exploitation pattern for some species such as haddock and whiting and small cod.

Although the persistently high estimated harvest rates in the past do not appear to have adversely affected the stock, in recent years they have occasionally been equivalent to fishing at a rate greater than F_{MSY} and therefore it would be unwise to allow effort to increase in this FU.

This stock is under the landings obligation although there is a *de minimis* exemption in place for *Nephrops* in the UK waters of the North Sea (ICES Division 2.a and Subarea 4) with certain gears, according to the Marine Management Organization (MMO, 2021). The exemption applies to catches of Norway lobster below the minimum conservation reference size, which shall not exceed 2% of the total annual catches of that species. In 2021, only 15 tonnes of *Nephrops* were recorded as below the minimum size (BMS) in FU 8 despite relatively high amounts of catches have been observed below the MCRS and this being a Functional unit that historically have shown high discard rates.

References:

MMO, 2021. Fishing gear requirements and Landing Obligation exemptions 2022. Applicable to the Nephrops Fishery in UK waters of the North Sea. Document No.: V1. Date of Issue: December 2021.

11.7 Moray Firth (FU 9)

11.7.1 Ecosystem aspects

The Moray Firth Functional Unit is located in the east of the Northern North Sea and is an inshore ground just off the east coast of Scotland (Figure 10.1.1). In common with other firths around the Scottish coast, the area is characterised by a wide entrance to seaward, narrowing towards the coast with river basins draining into the area. Muddy sand deposits are the most widespread sediment, particularly towards the outer areas of the Firth, with smaller areas of sandy mud. Overall the ground covers an area of 2195 km^2. In the inner parts of the Firth the sediment is patchier and there are several areas of sand and of gravel.

Owing to its burrowing behaviour, the distribution of *Nephrops* is restricted to areas of mud, sandy mud and muddy sand. Figure 11.7.4 shows the distribution of sediment in the area. It is thought that most larvae are produced locally although some drift from the Fladen may occur. The population is characterised by medium densities of *Nephrops*. Although the Moray Firth was historically important for whitefish fisheries, catches declined and *Nephrops* is the main commercial species with squid catches important in some years. The recruits of numerous demersal fish species occasionally aggregate in the area and small pelagics (sprat and juvenile herring) are seasonally abundant. The area is important for marine mammals (seals and cetaceans).

11.7.2 The fishery in 2021

The Moray Firth *Nephrops* fishery is essentially a Scottish fishery with only occasional landings made by vessels from elsewhere in the UK (Table 11.7.1). Vessels targeting this fishery typically conduct day trips from the nearby ports along the Moray Firth coast. Around 20–25 local vessels (all single riggers) regularly fish in Moray Firth area, mostly out of Burghead and Buckie. The majority of the Moray Firth fleet is under 10 m. Most vessels over 10 m are using 250 mm square mesh panels and reporting better catches than when they used HSGs. Square mesh panels of 160 mm and 200 mm were introduced for under 10 m vessels in the end of 2017. The fleet have been consistent in their grounds throughout the years, with smaller vessels fishing locally from Burghead and larger and more powerful vessels venturing further out. Occasionally larger vessels fish the outer Moray Firth grounds on their way to/from the Fladen or in times of poor weather. These larger twin riggers (typically over 15 m) fished in the outer areas of the Firth during the winter months and unlike the smaller local vessels, they can continue to operate in periods of poor weather. In 2012, a voluntary code of conduct for *Nephrops* trawlers (Moray Firth Prawn Agreement) has been agreed amongst fishermen for the Inner Moray Firth so as to protect the viability of smaller vessels based in the area. The agreement proposes that an area in the most westerly part of the Moray Firth be reserved for vessels under 300 HP with a further small area reserved for vessels under 400 HP. In 2020, *Nephrops* fleet had to deal with the effects of the Covid-19 pandemic. The majority of shellfish processors did not purchase *Nephrops* between April and May 2020, leaving the fleet tied up in this period. Markets returned to a more normal status in 2021 with no restrictions on landings imposed by buyers and a slight increase in *Nephrops* prices, although not to pre-Covid/Brexit levels. Anecdotal evidence suggests some bycatch of monkfish and haddock occurred but vessels under 10 m, which make most of the fleet, are generally limited by quota restrictions. *Nephrops* creeling in the Moray Firth is not common (only 4 tonnes landed in 2021) as grounds are in open water and gear conflicts with trawl vessels are likely to happen. A squid fishery took place as usual in the Moray Firth in the late summer, starting in the Southern Trench when squid moves inshore. The majority of the local fleet participated in the squid fishery between September and October, returning to *Nephrops* fishing in November. A number of vessels from other districts joined the Moray Firth *Nephrops* fishery towards the end of the year after the squid fishery season was over. Further general information on the fishery can be found in the Stock Annex.

11.7.3 Advice in 2021

The ICES advice in 2021 (for 2022) (Single-stock exploitation boundaries) was as follows:

MSY approach

"ICES advises that when the MSY approach is applied, and assuming that discard rates and fishery selection patterns do not change from the average of the years 2018–2020, catches in 2022 should be no more than 2062 tonnes.

To ensure that the stock in Functional Unit (FU) 9 is exploited sustainably, management should be implemented at the functional unit level.

ICES notes the existence of a management plan, developed and adopted by one of the relevant management authorities for Subarea 4. ICES considers this plan to be precautionary when implemented at the functional unit level."

11.7.4 Management

Management is at the ICES Subarea level as described in Section 10.1.

11.7.5 Assessment

Approach in 2021

The assessment in 2022 is based on a combination of examining trends in fishery indicators and UWTV using an extensive data series for the Moray Firth FU 9. The assessment of *Nephrops* through the use of the UWTV survey data and other commercial fishery data follows the process defined by the benchmark WG 2009 and described in the stock annex.

The provision of advice in 2022 followed the process of 2021, and attempts to incorporate decisions taken at WKFRAME (2010) for the provision of MSY advice. The approach was developed based on inter-sessional work carried out by participants of the benchmark and involved collaboration between WGNSSK and WGCSE. The UWTV based assessments have derived predicted landings by applying a harvest rate approach to populations described in terms of length compositions from the trawl component of the fishery. Considerations for setting Harvest Ratios (HR) associated with proxies for F_{MSY} for *Nephrops* are described in the WGNSSK 2010 report.

It was decided by ICES prior to the 2022 WG meeting that the advice for North Sea *Nephrops* stocks would be delayed until autumn after the summer surveys. The assessment presented in this report was concluded in September 2022 and incorporates the most recent *Nephrops* UWTV survey (2022).

Data available

Commercial catch and effort data

Landings from this fishery are predominantly reported from Scotland, with very small contributions from England, and are presented in Table 11.7.1. Total landings (as reported to the WG) in 2021 for Scotland were 1221 tonnes (an increase of 21% in relation to 2020). Landings in recent years (post 2006) are more reliable due to the introduction of 'buyers and sellers' legislation. The long-term landings trends are shown in Figure 11.7.1. *Nephrops* is one of the species in the North Sea under the landing obligation. No landings below the minimum conservation reference size (BMS) or logbook registered discards were reported for FU 9 in 2021.

In previous years, concerns were expressed over the reliability of the effort Figures provided for Scottish *Nephrops* trawlers; effort Figures were unrealistically low in some areas. Investigation of the issue revealed a problem in the MSS Marine Laboratory database, where only the effort expended in the first statistical rectangle visited by a vessel during a trip was being output. This did not affect landings. An extraction of effort data by the Marine Scotland data unit in Edinburgh covering the four main trawl gears landing *Nephrops* into Scotland produced higher figures which capture all the effort. At the present time, these revised data cover the period 2000 to the present and only annual summaries are available.

Trends in Scottish effort and LPUE are shown in Figure 11.7.1 and Table 11.7.2. From 2015, effort data for this stock is expressed both in days fishing and kW days (there are no major differences in effort trends between those different units). Effort has shown a gradual decline over the time period although an increase was recorded in 2017 to the same level as that estimated for the mid-2000s. Some of this is attributable to the EU effort management regime although *Nephrops* vessels have generally been allocated exemptions. LPUE rose in the early 2000s and since 2006 it has fluctuated. In 2021 there was a sharp increase in LPUE to the second highest value observed in the time series as a result of increasing landings and reduced effort.

Males generally make the largest contribution to the landings by weight (Figure 11.7.2), although in 2011 and 2015 the proportion of females was higher than in the recent past. In 2016–2021, males dominate again. The high contribution of females previously recorded appears to be due to a much higher proportion of the fishery taking place in the second and third quarter when females are more available. This observation has been made a number of times before in the Moray Firth (particularly for example in 1994 when female catches exceeded those of males). Figure 11.7.6 shows the quarterly sex ratio by number from 2000. The seasonality of *Nephrops* emergency behaviour is evident with males dominating catches during winter time. In quarters 2 and 3, females become more active and are more available to the fishery. These data suggest a fairly stable sex ratio in quarterly catches throughout the time series. Increased female catchability has also been associated with stocks which are in a poor state (females may remain more active as they have been unable to mate due to lack of males in the population). This problem usually manifests itself at times of the year when females would normally be reduced in the catches. This is not the case here.

Discarding of undersize and unwanted *Nephrops* occurs in this fishery, and quarterly discard sampling has been conducted on the Scottish *Nephrops* trawler fleet since 1990. In 2020 due to the Covid-19 pandemic and the suspension of the on-board observer programme, discards were only sampled in quarter 1 and in 2021 there were no discard data collected in FU 9. As such, discard rates calculated for 2021 were based on averages from 2017 to 2019 when sampling levels in the fishery were higher. Discarding rates in this FU appear to be highly variable with rates over the time series of 1% to 54% of the catch by number. In 2020 the observed rate by number (based on quarter 1 only) was at a low level, approximately 5.5% by number, suggesting that recruitment to the fishery is likely to be at a low level. Discards rates were generally higher in the past and in recent years appear to be lower but with occasional high annual levels which may be associated with sporadic high recruitments (e.g. 2002, 2004, 2010 and 2014–2016). It is likely that some *Nephrops* survive the discarding process, an estimate of 25% survival is assumed in order to calculate dead removals (landings + dead discards) from the population.

InterCatch

Scottish 2021 data (official landings and sampled data for landings) were successfully uploaded into InterCatch. There were no landings uploaded from other countries in 2021. In 2021 there were no discard data imported for this FU. Discard rates and allocations for length frequencies in 2021 were based on averages from years 2017-2019. Borrowing discard rates from previous years is not a feature allowed in Intercatch, as such the method described above was performed outside Intercatch. Output data for landings and discards were produced and extracted following the same raising procedure used in previous years to obtain length compositions in formats suitable for running the assessment. No BMS or logbook registered discard data were reported for this FU in 2021.

Length compositions

Length compositions of landings and discards are obtained during monthly market sampling and quarterly on-board observer sampling respectively. Although assessments based on detailed catch analysis are not presently possible, examination of length compositions may provide an indication of exploitation effects.

Figure 11.7.3 shows a series of annual length frequency distributions for the period 2000 to 2021. Catch (removals) are shown for each sex with the mean catch and landings lengths shown in relation to MLS and 35 mm. There is little evidence of change in the mean size of either sex over time and examination of the tails of the distributions above 35 mm shows no evidence of reductions in relative numbers of larger animals. Occasional large year classes can be observed in these length frequency data (2002, 2004 and more recently, 2016). This is consistent with the occasional high discard rates observed for this FU.

The observation of relatively stable length compositions is further confirmed in the series of mean sizes of larger *Nephrops* (>35 mm) in the landings shown in Figure 11.7.1 and Table 11.7.3. This parameter might be expected to reduce in size if overexploitation were taking place, but it appears to be stable throughout the time series. In 2013–2015, length frequencies seem to suggest a slight increase in the retention of larger males, which given the larger male contribution to the catches, caused an increase in the mean weight in the landings (Figure 11.5.4 and Table 11.5.5).

The mean size in the catch in the <35 mm category (Figure 11.7.1) shows no particular trend over the time series. This parameter is however slightly above average over the last five years, which is consistent with the recent decrease in the discard rate and that is likely related with the trend found in the length frequency distributions (Figure 11.7.3) suggesting a series of poor recruitment in recent years.

Natural mortality, maturity at age and other biological parameters

Biological parameter values are included in the Stock Annex.

Research vessel data

Underwater TV (UWTV) surveys of *Nephrops* burrow number and distribution reduce the problems associated with traditional trawl surveys that arise from variability in burrow emergence of *Nephrops*.

The numbers of valid stations used in the final analysis in each year are shown in Table 11.7.4. The UWTV survey did not cover FU 9 in 2020 due to a decreased sampling schedule caused by limited time at sea available related with the Covid-19 pandemic. In 2021 a TV survey was carried out but the timing of the survey was changed from August into June, due to limitations related with the research vessel's availability. In 2022 the FU 9 survey was carried out as normally in August/September. On average, 43 stations have been considered valid each year and 45 stations were sampled in 2022. Abundance data are raised to a stock area of 2195 km^2. General analysis methods for UWTV survey data are similar for each of the Scottish surveys, and are described in the Stock Annex.

Data analyses

Exploratory analyses of survey data

Table 11.7.5 shows the basic analysis for the three most recent UWTV surveys conducted in FU 9. The table includes estimates of abundance and variability in each of the strata adopted in the stratified random approach. The ground is predominantly of coarser muddy sand and typically, the variance in the survey is higher in the west and east muddy sand strata and lower in central muddy sand and sandy mud strata. The densities typically observed in this FU are lower than those observed in FU 8.

Figure 11.7.4 shows the distribution of stations in UWTV surveys (U6028), with the size of the symbol reflecting the *Nephrops* burrow density. In recent years the abundance appears to be highest at the southwestern inshore and to the east of the FU, with lower densities in the central areas. Table 11.7.4 and Figure 11.7.5 show the time series of estimated abundance for the UWTV surveys, with 95% confidence intervals on annual estimates. With the exception of 2003, the confidence intervals have been fairly stable in this survey.

The use of the UWTV surveys for *Nephrops* in the provision of advice was extensively reviewed by WKNEPH (ICES, 2009). A number of potential biases were highlighted including those due to edge effects, species burrow mis-identification and burrow occupancy. The cumulative bias correction factor estimated for FU 9 was 1.21 meaning that the TV survey is likely to overestimate

Nephrops abundance by 21%. In order to convert the raw UWTV survey abundance to an absolute abundance the raw data are divided by 1.21.

Final assessment

The UWTV survey is again presented as the best available information on the Moray Firth *Nephrops* stock. This survey provides a fishery independent estimate of *Nephrops* abundance. At present it is not possible to extract any length or age structure information from the survey and it therefore only provides information on abundance over the area of the survey.

The abundance in the Moray Firth has declined markedly in 2005 having remained stable around 400 million until 2019. In 2021 the abundance increased sharply but decreased again in 2022 and is now estimated at 396 million, a 40% reduction compared with the 2021 value. The stock is currently below the average abundance over the time series but remains above the biomass trigger. The calculated harvest ratio in 2021 (dead removals/TV abundance) is 6.4% which is now below F_{MSY} (previously above F_{MSY}). The mean size of individuals >35 mm in the catch shows no strong trend in recent years. The mean size of individuals below 35 mm has shown an increase in 2017–2018 which, together with the low discard rate observed in the last 5 years suggests a recent low recruitment period in relation to 2014–2016. Larger square mesh panels and new, more selective TR2 gears implemented from 2010 as part of the Scottish Conservation Credits scheme may have improved the exploitation pattern as shown by a small increase in the proportion of large males in caches in 2013–2015. The effect of these changes are not however, as evident as those observed in FU 7 and length frequencies in recent years remain relatively stable in the Moray Firth.

11.7.6 Historical stock trends

The UWTV survey estimate of abundance for *Nephrops* in the Moray Firth suggests that the population increased in 1997–2005 and has gradually fallen until 2012. In recent years abundance has remained at a relatively low level with the exception of 2021 when a sharp increase (75%) in abundance was observed (there was no survey in 2020). The abundance estimates from 1993–2022 are shown in Table 11.7.6 and Table 11.7.6 shows the estimated harvest ratios. These range from 6–33% over this period. Estimated harvest ratios prior to 2006 may not be representative of actual harvest ratios due to under-reporting of landings before the introduction of 'Buyers and Sellers' legislation.

In addition to the discard rate, Table 11.7.6 also shows the dead discard rate which is calculated as the quantity of dead discards as a proportion (by number) of the removals (landings + dead discards).

11.7.7 Recruitment estimates

Survey recruitment estimates are not available for this stock, although the length frequency distributions and highly variable discard rates suggest that this FU may be characterised by occasional large year classes.

11.7.8 MSY considerations

A number of potential F_{MSY} proxies were obtained from the per-recruit analysis for *Nephrops* as documented in the WGNSSK 2010 report. The analysis was updated in 2011 using 2008–2010 catch-at-length data, to account for the apparent changes in the discard pattern in this fishery and since previous estimates were derived several years before. An update was not performed this year. The complete range of the per-recruit F_{MSY} proxies is given in the table below and the process for choosing an appropriate F_{MSY} proxy is described in WGNSSK 2010 report.

		F_{bar}(20–40 mm)		HR (%)	SpR (%)		
		M	F		M	F	T
F0.1	M	0.13	0.07	7.16	42.35	61.48	49.89
	F	0.24	0.12	11.61	27.45	47.01	35.16
	T	0.14	0.07	7.84	39.46	58.93	47.13
Fmax	M	0.26	0.13	12.31	25.80	45.16	33.42
	F	0.68	0.36	23.82	11.42	25.16	16.83
	T	0.34	0.18	14.92	20.79	39.10	28.01
F35%SpR	M	0.17	0.09	9.11	34.69	54.48	42.48
	F	0.41	0.22	17.12	17.62	34.83	24.40
	T	0.24	0.13	11.79	27.02	46.53	34.71

The changes in the selection and discard patterns, and relative availability of females as estimated by the LCA result in slight decreases in the estimated MSY harvest ratio proxies compared to those calculated previously. (See stock annex for previously calculated values used at WGNSSK 2010).

Moderate absolute densities are generally observed on the UWTV survey of this FU (average of ~ 0.2 m^{-2}). Harvest ratios (which are likely to have been underestimated prior to 2006) appear to have been above $F_{35\%SpR}$ and in addition there is a long time series of relatively stable landings (average reported landings ~ 1300 tonnes, above those predicted by currently fishing at $F_{35\%SpR}$). For these reasons, it is suggested that $F_{35\%SpR(T)}$ is used as the F_{MSY} proxy.

The F_{MSY} proxy harvest ratio is 11.8%.

The $B_{trigger}$ point for this FU (lowest observed UWTV abundance) is calculated as 262 million individuals.

11.7.9 Short-term forecasts

A catch prediction for 2023 was made for the Moray Firth (FU 9) using the approach agreed at the Benchmark Workshop in 2009 and outlined in the introductory section of the 2010 WGNSSK report. The table below shows catch predictions at various harvest ratios, including a selection of those equivalent to the per-recruit reference points discussed in Section 11.7.8 of this report and the harvest ratio in 2020 using the input parameters agreed at WKNEPH (ICES, 2009). The catch prediction is calculated following the procedure outlined in the stock annex (section: short term projections).

Recently, to account for the landing obligation coming into force for *Nephrops* in 2016, the projected amount of discards (now referred to as projected discards) have been added to the catch options table. The advice given in 2022 considers that *Nephrops* discarding is allowed to continue as in previous years. Under this scenario the harvest rate is assumed to include landings (projected landings) plus dead discards (Projected dead discards). The catch options table includes projected surviving discards (discards survival for *Nephrops* in FU 9 is assumed to be 25%). Projected discards (by number) are calculated using data from the on-board observer sampling programme. This value is multiplied by the mean weight in discards to obtain the projected discard weight. There is a *de minimis* exemption in place for *Nephrops* in the UK waters of the North Sea (ICES division 2.a and Subarea 4) with certain gears. The forecast includes an extra catch options table assuming a discard ban for 2023. The main difference in this scenario is that there is no survival assumed for the projected discards.

The advice for Category 1 stocks (where assessment includes landings and discards data) is based on catches. The prediction for 2023 is that catches should be no more than 1249 tonnes, assuming recent discard rates. This represents a 39% decrease from the advice given for 2022. It should be noted that the F_{MSY} proxy harvest ratio in the Moray Firth is still based on a combined Length Cohort Analysis (data 2008–2010) using dead removals (landings + dead discards). A discussion of F_{MSY} reference points for *Nephrops* is provided in Section 11.7.8.

The inputs to the landings forecast were as follows:

FU 9 basis for the catch options

Variable	Value	Notes
Stock abundance (2023)	396	Underwater TV (UWTV) survey 2022; individuals in millions
Mean weight in projected landings	27.06	Average 2019-2021; grammes
Mean weight in projected discards	9.29	Average 2019-2021; grammes
Projected total discard rate	3.0	Average 2019-2021; percentage by number of the total catch
Discard survival rate	25	Percentage by number of the discards

Catch scenarios assuming recent discard rates

Basis	Total catch PL + PDD + PSD	Dead re-movals PL + PDD	Projected landings PL	Projected dead discards PDD	Projected surviving discards PSD	Harvest rate * for PL+PDD	% advice change **
ICES advice basis							
MSY approach	1249	1246	1236	10	3	11.8	-39
Other scenarios							
F_{2021}	675	673	668	5	2	6.4	-67
$F_{0.1}$	826	824	817	7	2	7.8	-60
F_{MSY} lower	964	961	953	8	3	9.1	-53
$F_{2019–2021}$	1006	1003	995	8	3	9.5	-51
F_{MSY} upper***	1249	1246	1236	10	3	11.8	-39
F_{max}	1576	1572	1560	12	4	14.9	-24

Catch scenarios assuming zero discards

Basis	Total catch PL + PD	Projected landings PL	Projected discards ^ PD	Harvest rate * for PL + PD	% advice change **
ICES advice basis					
MSY approach	1240	1227	13	11.8	-40
Other scenarios					
F_{2021}	670	663	7	6.4	-68
$F_{0.1}$	820	811	9	7.8	-60
F_{MSY} lower	956	946	10	9.1	-54
$F_{2019-2021}$	997	987	10	9.5	-52
F_{MSY} upper***	1240	1227	13	11.8	-40
F_{max}	1565	1549	16	14.9	-24

^ Represents the amount that otherwise would have been discarded but is now landed under the landing obligation.
*** Calculated for dead removals.**
**** Advice basis values for 2023 relative to the 2022 advice values (2062 tonnes).**
***** $F_{MSY\ upper}$ = F_{MSY} for this stock.**

Biological Reference points

Biological reference points have not been defined for this stock.

11.7.10 Quality of assessment

The length and sex composition of the landings data is considered to be relatively well sampled. Discard sampling has been conducted on a quarterly basis for Scottish *Nephrops* trawlers in this fishery since 1990, and is considered to represent the fishery adequately. Discard sampling in 2020-2021 was impacted by the Covid-19 pandemic and only samples for quarter 1 are available in 2020 and no samples were collected for 2021. The proportion of landings with discards associated (same strata) is 0% in 2021. As there were no discards imported, averages from years 2017-2019 were used to estimate discard rates and length frequencies in 2021.

There are concerns over the accuracy of landings (pre 2006) and effort data and because of this the final assessment adopted is independent of official statistics.

UWTV surveys have been conducted for this stock from 1993 to 2019 (no surveys in 1995 and 2020). The number of valid stations in the survey has remained relatively stable throughout the time period.

The Fishers' North Sea stock survey does not include specific information for the Moray Firth. Area 3 covers the Moray Firth, Firth of Forth and areas of the Devil's Hole and there appears to be some inconsistencies between the report in 2011 and 2012. In 2011, the report documented a perceived increase in the *Nephrops* abundance in this area since 2008; however, the 2012 report appears to show a perceived decrease since 2008. There are no Fishers' North Sea survey data available for 2013–2021.

11.7.11 Status of the stock

The evidence from the UWTV survey suggests that following a continuous decrease from 2007 to 2012 the abundance has fluctuated around 400 million until 2020. The abundance has increased 75% in 2021 and decreased again in 2022 (to 396 million) and is approximately at the same level as in the late 2000s. The stock size is above the MSY $B_{trigger}$ level. Landings taken from this FU in 2021 (1221 tonnes) were higher than the 2020 total catch advice (for 2021) of

1180 tonnes. The harvest rate decreased in 2021 to 6.4% and is now below F_{MSY} (11.8%). Length frequencies in the catches have been relatively stable.

11.7.12 Management considerations

Catches in 2021 were above ICES advice in 2020 (for 2021), highlighting the issue that current management arrangements are not sufficient to contain the fishery within the sustainable limits determined by ICES. The WG, ACOM and STECF have repeatedly advised that management should be at a smaller scale than the ICES Division level. Management at the Functional Unit level could provide the controls to ensure that catch opportunities and effort were compatible and in line with the scale of the resource.

There is a by-catch of other species in the Moray Firth area. It is important that efforts are made to ensure that unwanted bycatch is kept to a minimum in this fishery. Current efforts to reduce discards and unwanted bycatches include the implementation of larger meshed square mesh panels.

The estimated harvest rates have been fluctuating around F_{MSY} but the abundance (as estimated by the UWTV survey) in recent years is just above the MSY $B_{trigger}$, therefore it would be unwise to allow effort to increase in this FU.

This stock is under the landings obligation although there is a *de minimis* exemption in place for *Nephrops* in the UK waters of the North Sea (ICES division 2.a and Subarea 4) with certain gears, according to the Marine Management Organization (MMO, 2021). The exemption applies to catches of Norway lobster below the minimum conservation reference size, which shall not exceed 2% of the total annual catches of that species. In 2021, no *Nephrops* were recorded as below the minimum size (BMS) in FU 9 despite catches having been observed below the MCRS and this being a Functional unit that historically have shown occasional high discard rates.

References:

MMO, 2021. Fishing gear requirements and Landing Obligation exemptions 2022. Applicable to the Nephrops Fishery in UK waters of the North Sea. Document No.: V1. Date of Issue: December 2021.

11.8 Noup (FU 10)

11.8.1 Ecosystem aspects

The Noup is a small area of muddy sand located to the west of Orkney. The area is exposed to the open Atlantic to the west and strong tidal currents occur in the area. The surrounding coarser grounds are important brown crab fishing areas and fish populations (mixed demersal species) are important in the locality.

11.8.2 The fishery in 2020 and 2021

The Noup currently supports a relatively small fishery. Few vessels target *Nephrops* regularly in this area. In Orkney there are currently only one part-time vessel fishing seasonally for *Nephrops* (mostly around summer) as most of the local fleet targets crabs and lobsters. *Nephrops* boats from Orkney spend most of the year fishing in the Moray Firth (FU 9). In recent years, vessels from Scrabster landing *Nephrops* use 120 mm mesh twin rigs (targeting whitefish). Landings from Noup have decreased steadily since 2002 and in 2021, only 14 tonnes of *Nephrops* were landed (Table 11.8.1). Further general information on the fishery can be found in the Stock Annex.

11.8.3 Advice in 2020

The advice provided in 2020 was biennial and valid for 2021 and 2022.

"ICES advises that when the precautionary approach is applied, catches in each of the years 2021 and 2022 should not exceed 46 tonnes, assuming recent discard rates.

To ensure the stock in Functional Unit (FU) 10 is exploited sustainably, management should be implemented at the functional unit level."

Data available

Commercial catch and effort data

Landings from this fishery are reported only from Scotland and are presented in Table 11.8.1 and Figure 11.8.1. Total landings (as reported to the WG) in 2021 were 14 tonnes, an increase of 4 tonnes from 2020. *Nephrops* are almost exclusively landed by 'non-*Nephrops*' vessels. This supports the anecdotal information received from the fishing industry that this area is rarely fished by *Nephrops* vessels due to the high catch rates of whitefish in the area.

In previous years, concerns were expressed over the reliability of the effort figures provided for Scottish *Nephrops* trawlers; effort figures were unrealistically low in some areas. Investigation of the issue revealed a problem in the MSS Marine Laboratory database, where only the effort expended in the first statistical rectangle visited by a vessel during a trip was being output. This did not affect landings. An extraction of effort data by the Marine Scotland data unit in Edinburgh covering the four main trawl gears landing *Nephrops* into Scotland produced higher figures which capture all the effort. At the present time, these revised data cover the period 2000 to the present and only annual summaries are available.

Trends in Scottish effort and LPUE are shown in Figure 11.8.1 and Table 11.8.2. Effort has declined over the time period and this is more marked than on other *Nephrops* grounds owing to the presence of demersal fish in the area. In the last years the LPUE have been stable.

Length compositions

Levels of market sampling are low and discard sampling is not available. Mean sizes in the landings in previous years are shown in Figure 11.8.1 and Table 11.8.3. There were no sampling data available for 2015, 2018 and 2020, two sampling trips in 2016, and one trip in each of 2017, 2019 and 2021. The low levels of sampling for this fishery mean it is not realistic to draw conclusions from changes in size composition or sex ratio.

InterCatch

Scottish data for 2021 were successfully uploaded into InterCatch prior to the 2022 WG meeting according with the deadline proposed. The 2021 data provided by Scotland was raised based on length frequencies collected in quarter 3. Careful must be taken when interpreting this information due to the low levels of sampling.

Natural mortality, maturity at age and other biological parameters

No data available.

Research vessel data

An underwater TV (UWTV) survey of this FU has been conducted sporadically (1994, 1999, 2006, 2007 and 2014). In 2019, Noup was re-visited by the summer Scotia UWTV survey after five years past the previous survey. Figure 11.8.3 shows the distribution of stations in the UWTV surveys, with the size of the symbol reflecting the *Nephrops* burrow density. In 2019, 11 stations were successfully surveyed. The most recent survey gives an estimate of population size of 90 million

(0.22 burrows/m^2) similar to that found in 1999 which is significantly higher than the previous survey (51 million, 0.13 burrows/m^2). All of these are lower than the very high value observed in 1994. The results of the UWTV surveys are shown in Figure 11.8.4 and Table 11.8.4. There were no surveys carried out in FU 10 in 2020-2022.

11.8.4 Historical stock trends

The TV survey estimate of abundance for *Nephrops* in the Noup suggests that the population declined from the first survey in 1994 and remained at a lower level on the following surveyed years until 2019 when the abundance increased again. Landings fluctuated between 200 and 400 tonnes between 1995 and 2002, and declined markedly from then. Recent landings for this FU have been low, 11 tonnes in 2020 and 14 tonnes in 2021.

11.8.5 Recruitment estimates

There are no recruitment estimates for this FU.

11.8.6 Short-term Forecasts

The advice guidance and category classification for data-limited stocks (DLS) was addressed at WKLIFE2 (ICES 2012). The methodology for DLS *Nephrops* stocks is further described in the 2013 Benchmark report (ICES 2013). Following the procedure outlined (Section 10.1), the spatial extent of the *Nephrops* grounds were estimated (based on BGS sediment maps) to provide a likely envelope for the total abundance of *Nephrops* in FU 10 (see table below). UWTV survey information on the mean density of *Nephrops* (0.22 *Nephrops*/m^2), from the 2019 survey, was used together with discard percentages, and mean weights taken from FU 9 (Moray Firth). The same advice as provided in 2020 of 46 tonnes (catch) results in a harvest ratio of 1.93%. The stock appears to be very lightly exploited. Providing the harvest rate is less than 7.5%, the default basis for advice is the average landings of the last ten years (2012–2021), subject to the application of the uncertainty cap to restrict annual advice change to less than 20%. The ten-year average corresponds to 14 tonnes of advised catch which implies a 70% reduction from the 2020 advice. Therefore, the chosen advice option was the 2020 advice – 20% corresponding to catches of 37 tonnes, assuming recent discard rates, obtained from the neighbouring FU 9. The current advice option results in a harvest rate of 1.55%. This is well below the range of maximum sustainable yield (MSY) harvest rates in the North Sea (between 7.5% and 16%), which is considered conservative. The precautionary buffer was applied in 2020 and its application has, therefore, not been considered again. Stock size in relation to reference points is unknown and the stock has not increased significantly. Additional options including a medium term (10 year) average and a recent (3 year) average projected landings were also included in the table. Assuming the 2019 survey density, all the options (with the exception of the time series maximum landing value) result in a harvest ratio lower or equal to 7.5%, reflecting the low exploitation level in recent years in FU 10. In line with the advice for other stocks, total catches, projected landings and projected discards expected under the landing obligation policy were added to the table. For data limited stocks the discard survival is assumed to be zero.

Basis for the catch scenarios.

Variable	Value	Notes
Stock density (2023)	0.22	Underwater TV (UWTV) survey 2019 (UWTV was not completed in 2022); density in numbers m-2
Mean weight in projected landings (2023)	27.06	Average 2019-2021 (from FU 9); grammes
Mean weight in projected discards (2023)	9.29	Average 2019–2021 (from FU 9); grammes
Projected total discard rate (2023)	3.0	Average 2019–2021 (from FU 9); percentage by number of the total catch
Discard survival rate (2023)	0	Discard survival is assumed to be zero
Surface area estimate	409	Benchmark estimate WKNEPHTV (ICES, 2007); km2

Nephrops FU 10. Catch options assuming discarding continues at recent average. All weights are in tonnes. Harvest rates in percent are calculated for a range of densities, with values above the MSY proxy of 7.5% highlighted in grey.

Basis	Total Catch	Projected landings	Projected discards	Range of potential densities (*Nephrops* m^{-2})									% advice change**
				0.05	0.1	0.15	0.2	0.22 *	0.3	0.4	0.6	0.8	
Advice for 2021 and 2022 −20% cap (Precautionary approach)^	**37**	**37**	**0**	6.8	3.4	2.3	1.71	**1.55**	1.14	0.85	0.57	0.43	**-20**
Average landings (2012–2021)	14	14	0	2.6	1.31	0.88	0.66	0.60	0.44	0.33	0.22	0.164	-70
Recent average landings (2019–2021)	15	15	0	2.9	1.43	0.95	0.71	0.65	0.48	0.36	0.24	0.179	-67
Advice for 2021 and 2022 −20% cap	37	37	0	6.8	3.4	2.3	1.71	1.55	1.14	0.85	0.57	0.43	-20
Advice for 2021 and 2022	46	46	0	8.5	4.2	2.8	2.1	1.93	1.41	1.06	0.71	0.53	0
Advice for 2021 and 2022 +20% cap (Precautionary approach)	55	54	1	10.1	5.1	3.4	2.5	2.3	1.69	1.27	0.84	0.63	20
MSY proxy harvest rate (HR)	179	177	2	33	16.5	11.0	8.2	7.5	5.5	4.1	2.8	2.1	289
Maximum landings	499	494	5	92	46	31	23	21	15.3	11.5	7.7	5.8	984

***Most recent abundance estimate (2019 UWTV survey). Harvest rates are calculated for dead removals and applied to total catch.**

**** Advice basis values for 2023 and 2024 relative to the advice value for 2021 and 2022 (catch advice of 46 tonnes).**

^ The average landings (2012–2021) option results in a -70% advice change, therefore, a -20% cap was applied.

11.8.7 Quality of the assessment

The time-series of UWTV survey data is incomplete, and the last survey was conducted in 2019. Given the low number of vessels involved in the fishery and the fact that some vessels were not targeting *Nephrops*, caution should be exercised when interpreting the effort data for this FU and the resulting landings per unit of effort (LPUE).

There is no recent discard information for this fishery. Discard percentages and mean weights have been taken from the closest inshore functional unit (FU 9). The catch options presented in recent years were based on a calculation of potential landing options and harvest rates, given the known surface area of Norway lobster habitat and observed densities of the functional unit.

11.8.8 Status of the stock

The current state of the stock is unknown.

11.8.9 Management considerations

The WG, ACOM and STECF have repeatedly advised that management should be at a smaller scale than the ICES Division level. Management at the Functional Unit level could provide the controls to ensure that catch opportunities and effort were compatible and in line with the scale of the resource.

The Noup area supports a mixed fishery in which *Nephrops* are taken mainly by demersal trawlers targeting fish. It is important that efforts are made to ensure that unwanted bycatch is kept to a minimum in this fishery.

This stock is under the landings obligation although there is a survivability exemption in place for *Nephrops* in the UK waters of the North Sea (ICES division 2.a and Subarea 4) with certain gears, according to the Marine Management Organization (MMO, 2021).

References:

ICES. 2012. Report of The Workshop to Finalize the ICES Data-limited Stock (DLS) Methodologies Documentation in an Operational Form for the 2013 Advice Season and to make Recommendations on Target Categories for Data-limited Stocks (WKLIFE II), 20–22 November 2012, Copenhagen, Denmark. ICES CM 2012/ACOM:79. 46 pp.

ICES. 2013. Report of the Benchmark Workshop on *Nephrops* Stocks (WKNEPH), 25 February–1 March 2013, Lysekil, Sweden. ICES CM 2013/ACOM:45. 230 pp.

MMO, 2021. Fishing gear requirements and Landing Obligation exemptions 2022. Applicable to the Nephrops Fishery in UK waters of the North Sea. Document No.: V1. Date of Issue: December 2021.

11.9 Norwegian Deep (FU 32)

11.9.1 Ecosystem aspects.

See stock annex (Section A.3).

11.9.2 The fishery in 2020 and 2021

The annual spatial distribution of the Danish and Norwegian fisheries in FU 32 are shown in figures 11.9.1, 11.9.2 and 11.9.3. The Danish fishery is still largely confined to the southernmost part of the functional unit. The Norwegian large vessel trawl fisheries (large mesh bottom trawl and small mesh shrimp trawl) with *Nephrops* as bycatch declined from 2012 to 2013. In 2013–2015, these trawl fisheries were confined to the southernmost part of the functional unit as well as an area just west of the city Stavanger, while from 2016 onwards trawling has again taken place along the western rim of the Norwegian Trench. The Norwegian creel fishery is concentrated in outer coastal areas from Stavanger to Bergen.

The total landings from FU 32 in 2021 were 216 tonnes, an increase of 20% from 2020. Denmark landed 129 tonnes, which was an increase from 2020 (81 tonnes), while Norway landed 80 tonnes, a decrease from 2020 (94 tonnes).

See also stock annex (Section A.2) and Section 11.9.5.

11.9.3 Advice in 2020

Advice for *Nephrops* in FU 32 is biennial and was last updated in 2020. This advice applied for 2021 and 2022 (single-stock exploitation boundaries). The stock is not subject to the reopening procedure.

"ICES advises that when the precautionary approach is applied, catches in each of the years 2021 and 2022 should be no more than 381 tonnes. If this stock is not under the Norwegian discard ban in 2021 and 2022, and discard rates do not change from the recent average, this implies landings of no more than 379 tonnes."

ICES did not remark on the state of the stock in 2020, as an abbreviated advice was issued due to the COVID-19 disruption.

11.9.4 Management

An overview of the management of *Nephrops* in FU 32 is given in the stock annex (Section A.2). There is a minimum mesh size of 120 mm for large mesh bottom trawls in Norwegian waters in the North Sea (area 04-N). MLS is 40 mm CL in Norwegian waters. The EU fisheries are managed by a separate TAC for the Norwegian EEZ, decided by the annual Norway–EU negotiations. The TAC for EU vessels has decreased from 1300 tonnes in 2008 to 200 tonnes in 2021-2022 (Table 11.9.1). The EU quota of *Nephrops* in Norwegian waters is mainly allocated to Denmark (app. 95%) with a small fraction of app. 5% to UK. There is no quota restriction currently for the Norwegian fishery. Since 1st January 2022, discarding of *Nephrops* in the Norwegian waters in the North Sea has been prohibited.

11.9.5 Assessment

Data available

Landings data for all fleets in 2021 have been uploaded using InterCatch. Estimated discards exist only for the Danish landings (Figure 11.9.4). Previously, length data were only presented for the Danish catches, but in 2022 all Norwegian length data back in time have been compiled. Only the Danish length data have been uploaded to Intercatch (Figure 11.9.5). A fishery independent biomass index exists from a Norwegian bottom trawl survey.

Catch

International landings from the Norwegian Deep increased from less than 20 tonnes in the mid–1980s to 1190 tonnes in 2001 (Table 11.9.1, Figure 11.9.6). Since then, landings declined due to a reduction of Danish landings, to only 137 tonnes in 2018, the lowest figure since 1990. Since 2019 total landings have increased again. The decreased Danish landings can be explained by increasing fuel costs, fewer vessels, and *Nephrops* catches now occurring mainly as bycatch in mixed fisheries. Danish vessels used to take 80–90% of the total landings, while in 2018, Denmark landed only 25% of the total landings. In 2021, due to Danish landings being almost four times higher than in 2018, Denmark landed 60% of the total landings. Norwegian landings decreased from 2008 to 2014 (62 tonnes), but increased thereafter. In 2017–2018, 90% of Norwegian landings were from creels. Norwegian trawl landings increased in 2019-2021, while creel landings decreased, resulting in 68% creel landings in 2021.

Since 2003, the Danish at-sea-sampling programme has provided discard estimates (Table 11.9.1) and length measurements. In 2017, only a small number of *Nephrops* was length measured (stock annex, Section B.1). The 2017 observer data were considered not representative and were therefore not used as part of the information going into the harvest rate table used in the 2020 advice (see below). Danish sampling was also low in both 2020 and 2021, and there was no discard sampling in 2020 and no landings sampling in 2021.

Danish discards are low due to the legislated 120 mm mesh size. The Danish discard rate (discard as percentage of catch) varied between 10% and 35% in the years 2003–2013, while in 2014–2021 estimated Danish discards were between 0.2 and 6 tonnes, resulting in very low Danish discard rates of between 1% and 5%. The low discards the last eight years may indicate low recruitment to the stock. There are no Norwegian discard data, and Norwegian discards are assumed to be zero (stock annex, Section A.3). At least for the creel fishery, with high survival of discarded *Nephrops*, this is a valid assumption.

Length composition

The average size of *Nephrops* in Danish landings (≥ 40 mm = MLS) showed a general increasing trend for both males and females in the period 2005–2012 (Figure 11.9.6). This increase coincided with a sharp decrease in landings and may imply a lower exploitation pressure. However, the mean size of both males and females in the Danish landings decreased sharply from 2012 to 2013. In 2014, the mean size of landed males jumped back to the high 2012–level, increased further until 2018, and then dropped to the 2012-level in 2019 and 2020. The average size of landed females, on the other hand, remained at the low 2013-level until 2019, but showed a very high value in 2020. The mean size of discards (< 40 mm) has fluctuated without trend since 2002. There was no sampling of discards in 2020, and no sampling of landings in 2021. The Danish fishery has shown a gradual contraction into the southern part of the functional unit, an area with possibly smaller *Nephrops*, however, sampling has in most years taken place in the whole functional unit (Figure 11.9.1). It should be noted that Danish sampling has been low in 2017 and 2019-2021, and these data should be interpreted with care.

Mean size of the Danish catches from the years 2007, 2010, 2012, 2014, 2016, 2017, and especially 2018, 2019 and 2020, were larger compared with former years (Figure 11.9.7). The high 2018 mean size was due to the high mean size of the males, while the high 2020 mean size was due to the high mean size of the females as well as the lack of length sampling of discards. In general, there are few individuals below the MLS of 40 mm due to the legislated 120 mm minimum mesh size. The figure was not updated in 2022 due to lack of sampling of landings in 2021.

In 2022, length samples from Danish and Norwegian trawl catches obtained from Norwegian Coast Guard inspections were analysed. Data are available back to 2002, except 2005. Most length measurements are in total length (TL) which were converted to CL and pooled with the CL-samples in order to use all available data for estimating annual mean size and length frequency distribution (stock annex, Section B.1). Mean size of both landings (catch fraction ≥ 40 mm) and discards (catch fraction < 40 mm) fluctuated without trend from 2002 to 2021 (Figure 11.9.6). Mean sizes of discards were in general lower than the corresponding values from the Danish data. The length frequency distributions show low catches of *Nephrops* below MLS, similar to the Danish data (Figures 11.9.7, 11.9.8).

Natural mortality, maturity at age and other biological parameters

Very little data are available.

Data on sex ratio exist from a citizen science survey (recreational creel fishers) in 2012-2014 in the coastal part of FU 32 (Zimmermann et al. 2022). The proportion of females in all catches was 27%, with the highest proportions (37%) in the third quarter. The proportion of berried females was 9% (of all females) across all fishing trips and showed a seasonal pattern towards an increased proportion in the fourth quarter (20% of all females).

Effort, LPUE and scientific survey data

Effort figures for the period 1989–2021 are available from Danish logbooks (Table 11.9.2, Figure 11.9.6). In 2013, the Danish effort index was changed to kW days (formerly fishing days) (stock annex, Section B.4), as kW days account for temporal differences in vessel size. Days at sea and fishing days are presented in addition to kW days (Table 11.9.2). The Danish effort increased from 2004 to 2006, but showed a strong decline in 2007 and continued decreasing, to 313 kW days in 2018, the lowest observed effort in the time series. The effort more than doubled from 2018 to 2019, but increased some in both 2020 and 2021 (462 kW days) (Table 11.9.2). It has not been possible to incorporate 'technological creep' in the evaluation of the effort data. However, the use of twin trawls has been widespread for many years.

The Danish LPUE index based on kW days shows a stepwise decreasing trend (Figure 11.9.6). However, due to changes in the management regime, changes in the LPUE index do not necessarily imply stock size changes. In the beginning of the 1990s, vessel size increased in the Danish fleet fishing in FU 32. This increase, and more directed fisheries for *Nephrops* in areas with previously low exploitation levels are probably partly responsible for the observed increase in the Danish LPUE in those years (Table 11.9.2, Figure 11.9.6). The Norwegian mesh size legislation was changed in 2004 (stock annex, Section A.2) with the introduction of a larger minimum mesh size of 120 mm. This change in legislation occurred some years too late to explain the decrease in LPUE (catch rate) from 1999 to 2001 with a subsequent stabilizing at a lower level relative to the late 1990s. The lower LPUE may, on the other hand, reflect a stock decrease as Danish landings in 1999 increased to > 1000 tonnes and remained at this level until 2006. In 2007, individual vessel quotas were introduced in the Danish fishery. This resulted in vessels buying up a lot of fish quotas and shifting their effort to finfish rather than *Nephrops*. To get good catches of *Nephrops* vessels need to target this species by fishing at dusk/dawn when the animals are out of their burrows, as opposed to finfish fisheries where good catches can be obtained around the clock. This change in management coincided with the onset of steadily decreasing Danish *Nephrops* landings as well as a decreasing LPUE. From 2020 to 2021, the Danish LPUE increased by 116%, as landings increased and effort decreased. It is not clear why the effort did not increase as landings increased.

Spatial analyses of Danish logbooks and VMS data in the 2016 benchmark (ICES, 2016) showed that the LPUE decreased over the whole Norwegian Deep from 2005 to 2015, with the largest decline in the north. Only the southernmost part of the functional unit had reasonably good catch rates in 2013–2015. Environmental changes resulting in lower *Nephrops* densities in the whole functional unit cannot be ruled out. The likely low recruitment to the stock in 2014–2021 may imply continuing low catch rates.

The 2013 benchmark (ICES, 2013) analysed Norwegian logbooks from bottom and shrimp trawls. Data prior to 2011 are considered unsuitable for LPUE analyses (stock annex, Section B.4). The 2016 benchmark (ICES, 2016) analysed data from Norwegian electronic logbooks (Electronic Reporting System (ERS)), compulsory since 2011 for all vessels ≥ 15 m. The data situation did not improve, however, basically because of few large Norwegian vessels landing *Nephrops* from this area. The creel fishery is carried out by small vessels, not obliged to fill out logbooks. A Norwegian reference fleet of creel fishers established in 2019 and compulsory ERS reporting for vessels 11-15 m from July 1st 2022, and for vessels 10-10.99 m from March 1st 2023, will enable the establishment of new CPUE time series for both the trawl and the creel fisheries.

Zimmermann et al. (2022) estimated stock indices by gear for *Nephrops* in FU 32 from 2005 to 2020 from Norwegian landings data per fishing trip (sales notes of all boats in each year with more than one trip and annual landings of > 100 kg). The trawl index declined from 2005 to 2018, but showed a marked increase in 2019 and 2020, while the creel index increased from 2005 to 2012, but has since shown a decreasing trend.

The annual Norwegian shrimp bottom trawl survey covers all of Skagerrak and the Norwegian Deep (stock annex, Section B.3). *Nephrops* is distributed in areas deeper than 100 m in FU 32 (Figure 11.9.9). (Areas shallower than 100 m are not covered by the survey). Catches of *Nephrops* in the bottom trawl are small and variable within and between years. The 2016 benchmark (ICES, 2016) analysed the *Nephrops* data from the shrimp survey with the aim of establishing a fishery independent stock size index (stock annex, Section B.3).

Data analysis

The advice given in 2022 is based on the previous advice from 2020 plus a 20% uncertainty cap for a gradual increase in catches, which follows the precautionary approach for the stock and is well founded given the results of the assessment. As the state of the stock in relation to reference points is unknown, the precautionary buffer of 20% was applied to the advice for the first time in 2020. The 2022-advice translates to an estimated harvest rate of 1.69%, which is below the most conservative lower bound for MSY in other FUs (7.5%).

Exploratory analysis of catch data

The Danish LPUE has shown a decreasing trend since 2007, but increased markedly from 2020 to 2021 (Figure 11.9.6). The Norwegian landings-per-boat-trip indices show opposite trends for the coastal (creel) and offshore (trawl) fisheries. The increase in 2019-2020 in the trawl index is in accordance with the increase in the Danish LPUE index in 2021.

There was no length-based analysis carried out.

Exploratory analysis of survey data

The biomass index from the Norwegian shrimp bottom trawl survey showed high values in 2006 and 2007, but declined to a lower level in 2008. Thereafter it fluctuated without trend around this lower level until 2019. The last three years have seen a further downward trend, with the index reaching its minimum value in 2022 (Table 11.9.3, Figure 11.9.10). The survey index is based on few observations (Figure 11.9.9). However, in lack of an UWTV survey, the 2016 benchmark concluded that the index should be presented and updated as part of the assessment of the FU 32 stock.

Final assessment

No assessment model exists for *Nephrops* in FU 32. The state of the stock was judged on the basis of basic fishery data and the biomass index from the Norwegian shrimp survey. The indices show similar decreasing trends since 2007, but disagree regarding stock status in recent years. It should be noted that the survey index covers the whole Norwegian Deep for depths > 100 m, while the Danish LPUE covers the western and southern part of the Norwegian Deep.

11.9.6 Historic stock trends

The increase in mean size in landings from 2006 to 2012 in females and from 2005 to 2018 in males could reflect the lower exploitation pressure since 2007. The introduction of a new Danish effort index (kW days) in 2013 resulted in a stepwise declining trend in the LPUE index, from the mid–1990s until present. The survey biomass index has declined since 2015.

11.9.7 Recruitment estimates

There are no recruitment estimates for this stock. Fluctuations in catches of small *Nephrops* are used as a proxy for recruitment. Danish discards of small *Nephrops* were very low in 2014–2021, indicating low recruitment these years.

11.9.8 Forecasts

The ICES framework for category 4 *Nephrops* stocks was applied (ICES, 2012). In the absence of a full analytical assessment, ICES base its advice for *Nephrops* on the most recent advice. Maximum sustainable yield (MSY) harvest rates estimated for other functional units vary between 7.5% and 16%. ICES use the lower boundary as an upper limit for advice for data-limited *Nephrops* stocks. Providing the harvest rate is less than 7.5%, the default basis for advice is the average landings of the last ten years (2012–2021), subject to the application of the uncertainty cap to restrict annual advice change to less than 20%. The ten-year average corresponds to 196 tonnes of advised catch which implies a 49% reduction from the 2020 advice. Therefore, the chosen advice option was the 2020 advice – 20% corresponding to catches of 304 tonnes, assuming recent discard rates. The current advice option results in a harvest rate of 1.13%. This is well below the range of maximum sustainable yield (MSY) harvest rates in the North Sea (between 7.5% and 16%), which is considered conservative. The precautionary buffer was applied in 2020 and its application has, therefore, not been considered again.

Following the precautionary approach, catches in each of the years 2023 and 2024 should be no more than 304 tonnes. Assuming discard rates do not change from the recent average, this implies landings of no more than 303 tonnes.

Basis for the catch scenarios.

Variable	Value	Notes
Density in TV assessment	0.1 *Nephrops*	Minimum value from FU 7; density in numbers per m^{-2}
Mean weight in projected landings	75.17	Average of 2016, 2018 and 2019; poor sampling in 2017, 2020 and 2021: grammes
Mean weight in projected discards	42.79	Average of 2016, 2018 and 2019; poor sampling in 2017, 2020 and 2021; grammes
Projected discard rate (total)	0.8	Average of 2016, 2018 and 2019 (percentage by numbers); poor sampling in 2017, 2020 and 2021; percentage by number of the total catch
Discard survival rate	25	Percentage by numbers of the discard
Surface area estimate	3613	Benchmark estimate WKNEP (2016); km^2

Sensitivity analysis of harvest rates for a range of potential densities. All weights in tonnes.

Discarding not allowed, but based on recent sampling assumed to take place

Basis	Total catch	Projected surviving discards	Projected dead discards	Projected landings	Dead removals	Range of potential densities (*Nephrops* m⁻²)								
						0.05	0.1*	0.2	0.3	0.4	0.5	0.6	0.7	0.8
						Harvest rate in %								
Average landings (2012–2021)	196	0	1	195	196	1.45	0.73	0.36	0.24	0.182	0.145	0.121	0.104	0.091
Recent average landings (2019-2021)	196	0	1	195	196	1.45	0.73	0.36	0.24	0.182	0.145	0.121	0.104	0.091
0.5 × Average landings (2012–2021)	97	0	0	97	97	0.72	0.36	0.181	0.120	0.090	0.072	0.060	0.052	0.045
2020 advice -20% cap	304	0	1	303	304	2.3	1.13	0.57	0.38	0.28	0.23	0.188	0.161	0.141
2020 advice	381	1	1	379	380	2.8	1.41	0.71	0.47	0.35	0.28	0.24	0.20	0.176
2020 advice +20% cap	457	1	1	455	456	3.4	1.69	0.85	0.57	0.42	0.34	0.28	0.24	0.21
Maximum landings	1195	1	4	1190	1194	8.9	4.4	2.2	1.48	1.11	0.89	0.74	0.63	0.55
FMSY	2029	2	7	2020	2027	15.1	7.5	3.8	2.5	1.88	1.51	1.25	1.08	0.94

*** A density of 0.1 *Nephrops* m⁻² is among the lowest observed densities in the North Sea in FU 7 (Fladen Ground).**

11.9.9 Biological reference points

No reference points are defined for this stock.

11.9.10 Quality of assessment

The data available for this stock remain limited.

A large part of the Norwegian *Nephrops* landings come from the coastal creel fishery. A reference fleet of creel fishers was established in 2019 and will provide information on this fishery, as well as biological information about the coastal part of the stock.

The advice is based on calculation of potential catch options and harvest rates, given the estimated surface area of *Nephrops* habitat and assumed densities of the functional unit. The area of the *Nephrops* grounds in FU 32 is based on the distribution of the current Danish trawl fishery; this estimate does not include the *Nephrops* habitat along the Norwegian coast where the creel fishery takes place nor *Nephrops* ground in northern parts of the functional unit.

11.9.11 Status of stock

The perceptions of this stock (FU 32) are based on Danish landings and effort data, mean sizes (CL) in landings and discards, and a biomass index from the Norwegian shrimp bottom trawl survey. This year, a recently published study on the Norwegian *Nephrops* fishery presenting landings-per-boat-trip indices for both the trawl and the creel fisheries (Zimmermann et al. 2022) was also considered. The Danish LPUE index shows a stepwise declining trend from the mid–1990s until present, however with a substantial increase in 2021. It is difficult to determine whether the decrease in LPUE is due to changes in management and the fishery, or whether the decrease to some extent also reflects stock changes. Recent Danish landings are small, but fished in a restricted area. The low LPUE in 2013–2020 might imply stock size changes in the southern part of FU 32, but could also be caused by vessels now targeting finfish rather than *Nephrops*. The increased index in 2021 is difficult to explain, but is in accordance with trends in the trawl-based landings index in Zimmermann et al. (2022). The survey index is presently at a low level compared with the years 2006–2007, indicating a lower stock size. Trends in mean size in landings and discards and overall size distribution in catches have for many years indicated that the *Nephrops* stock in FU 32 is not over-exploited. The low catches of small *Nephrops* during the last eight years indicate low recruitment to the stock.

The WG concludes that the available data give a non-conclusive perception of stock status. The average annual landings over the last ten years are 195 tonnes (2012–2021), and the short-term average landings are also 195 tonnes (2019–2021).

11.9.12 Issues for future benchmarks

Data

Sampling of trawl catches by the Norwegian Coast Guard should be improved by sampling discards and landings components separately to enable discards estimations. The sampled *Nephrops* should also be sexed.

An UWTV survey should be carried out in FU 32 to explore and map distribution and density.

More biological knowledge on the coastal part of the stock, and the creel fishery is needed. Catch data from reference fishers since 2020 will help to fill the knowledge gap. Electronic logbooks made mandatory for larger segments of the Norwegian fleet since mid-2022 will provide data for a new Norwegian CPUE time series from the trawl fishery.

Assessment

Assessment methods for data poor species should be explored for this *Nephrops* stock.

11.9.13 Ecosystem and fisheries productivity

Stock indices indicate that the density of *Nephrops* may be lower in recent years, but there is no information on actual density in the functional unit, neither present nor past. The 2016 benchmark (ICES, 2016) concluded that catch rates (LPUE) declined especially in northern parts of the functional unit from 2005 to 2015. Catch advice has always been based on a density of 0.1 m^{-2} (the lowest observed density in the neighbouring FU 7 (Fladen Ground)). It is unknown why density seems to be lower in recent years. Discards have been low the last eight years, indicating low recruitment to the stock, which may be part of the explanation. The area of *Nephrops* grounds in the harvest rates table was changed in the 2016 benchmark, from an estimate of the area of the whole functional unit to an estimate of the area of the distribution of the present Danish trawl fishery.

11.9.14 Management considerations

ICES provide catch advice for *Nephrops* in FU 32. Discarding of *Nephrops* is illegal in FU 32 as of January 1st 2022. As discarding is assumed to continue, advice in 2022 was given for a scenario assuming continued discards. Following the procedure outlined in the stock annex (Section H) a table of harvest rates (see table in Section 11.9.8) was calculated. The biomass estimates imply low harvest rates in FU 32, even in former years with high landings (1000–1200 tonnes).

References

ICES. 2013. Report of the Benchmark Workshop on *Nephrops* Stocks (WKNEPH). 25 February-1 March 2013 Lysekil, Sweden. ICES CM 2013/ACOM: 45. 183 pp.

ICES. 2016. Report of the Benchmark Workshop on *Nephrops* Stocks (WKNEP), 24–28 October 2016, Cadiz, Spain. ICES CM 2016/ACOM:38. 223 pp.

Zimmermann, F., Kleiven, A. R., Ottesen, M. V. and Søvik, G. 2022. Inclusion of recreational fishing in data-limited stocks: a case study on Norway lobster (*Nephrops norvegicus*) in Norway. Canadian Journal of Fisheries and Aquatic Sciences. https://cdnsciencepub.com/doi/full/10.1139/cjfas-2021-0152.

11.10 Off Horns Reef (FU 33)

11.10.1 Ecosystem aspects.

See stock annex (Section A).

11.10.2 Management

Total Allowable Catch (TAC) management is at the ICES Subarea level.

11.10.3 Advice in 2020

Advice for *Nephrops* in FU 33 is biennial and was last updated in 2020. This advice applied for 2021 and 2022 (single-stock exploitation boundaries). The stock is not subject to the reopening procedure.

"ICES advises that when the precautionary approach (PA) is applied, landings in each of the years 2021 and 2022 should not exceed 956 tonnes. ICES cannot quantify the corresponding total catches.

To ensure that the stock in Functional Unit (FU) 33 is exploited sustainably, management should be implemented at the functional unit level."

ICES did not remark on the state of the stock in 2020, as an abbreviated advice was issued due to the COVID-19 disruption.

11.10.4 Assessment

Data available

Catch

The landings from FU 33 were marginal for many years. However, from 1997 to 2004, Danish landings increased considerably, from 274 to 1097 tonnes. Denmark dominated the fishery during this period. Between 2004 and 2015, Danish landings gradually decreased, and in 2015 were 371 tonnes. In 2016 and 2017, the Danish landings increased considerably from previous years, however, in 2018 they were at the lowest level since the beginning of the 1990s. From 2019 to 2021, landings have shown an increasing trend, with Danish landings in 2021 being 349 tonnes. The other countries reporting landings from this FU are Belgium, Netherlands, Germany and the UK. Dutch landings show an increasing trend from the start of the time series until 2007 when landings were almost 500 tonnes. Since 2007, Dutch landings show a decreasing trend and in 2015 were the lowest landings recorded over the last decade (187 tonnes). However, since 2016 Dutch landings increased considerably with record high landings of 599 tonnes in 2019. In 2021, Dutch landings were still high with 541 tonnes landed from FU 33. Belgium and German landings having increased throughout the period and in 2019 were the highest landings recorded for this FU, 462 and 329 tonnes, respectively. However, in more recent years landings from both countries have decreased considerably, with landings of 287 and 193 tonnes in 2021 for Belgium and Germany, respectively. UK landings were highest in 2009 (170 tonnes) and have since decreased dramatically, reporting 0.5 tonnes from this FU in 2021. Regarding total landings from this FU, in 2016 total landings were the highest on record (1636 tonnes). However, in 2018 total landings decreased substantially, primarily due to the large reduction in Danish landings. Total landings in 2019 have returned to levels of the previous years with the second highest total landings on record, 1612 tonnes. In 2021, total landings from Off Horns Reef were 1371 tonnes (Table 11.10.1 and Figure 11.10.1).

Discards from FU 33 are poorly documented and scarce. Discard information from Denmark were recorded in InterCatch since 2015. These data typically consist of few trips per year and are considered too scarce to be used for providing catch advice. No length data were available from Denmark from 2017–2021. In 2015, Dutch discards were recorded in InterCatch, however, length information was missing. Between 2016 and 2021, Dutch discards included length information. Due to a National minimum landing size, a large majority of the Dutch discards are above the MCS of 25 mm set for the North Sea and, thus, not considered representative for the other countries.

Length compositions

Length (CL) distributions of the Danish catches 2001–2005 and 2009–2016 are shown in Figure 11.10.2. Notice, that except for 2005 and 2011 they are rather similar. No discards were observed in the Danish at-sea observer data in 2016, hence the large increase in mean length. Figure 11.10.1 shows the development of the mean size of *Nephrops* in catches. The drop in the mean CL in the catches in 2005 and 2011 reflects an increase in numbers at around 30 mm CL and could indicate a large recruitment in these years, see also Figure 11.10.1.

In the period 2001–2005, and in 2009–2015 the Danish at-sea-sampling programme has provided data for discard estimates. However, the samples do not cover all quarters. In 2021, length distributions were only available from Dutch catches.

Natural mortality, maturity at age and other biological parameters

No data available

Catch and effort data

Figure 11.10.1 shows the development in Danish effort and LPUE. Notice that the 10-fold increase in fishing effort from 1996 to 2004 seems to correspond to the increase in landings during the same period and the LPUE was relatively stable. After 2004, the Danish effort decreased markedly, and since 2009 has remained stable at around 300 000 kW days. In 2021, Danish effort was around 555 000 kW days, although lower than the effort in 2017 (~615 000 kW days). Dutch effort data are available for 2005–2021 and shows an increasing trend over the time period. However, Dutch effort decreased from around 1 300 000 kW days in 2013 to 1 000 000 kW days in 2014 and 2015. Between 2016 and 2019, Dutch effort returned to the same levels as observed in 2013. In 2020 and 2021, Dutch effort was approximately 1 550 000 kW days, the highest recorded since the beginning of the time series, and maybe attributed to the redefinition of métiers in the Netherlands.

From the beginning of the time-series until 2016, the Danish LPUE showed an increasing trend, and in 2016, was the highest in the time series at around 1.7 kg/kW day. This increase in LPUE observed from 2011–2016 could reflect an increase in gear efficiency (technological creep) or in fishers' ability to exploit the stock. However, in 2017 and 2018 the Danish LPUE decreased considerably, to 0.8 kg/kW day and 0.2 kg/kW day, respectively. Between 2019 and 2021, the Danish LPUE increased and stabilised around 0.6 kg/kW day. These low Danish LPUE values observed in recent years may be explained by the low number of Danish vessels exploiting this FU. This may also explain some of the variability in LPUE observed. LPUE from the Netherlands increased from 0.3 kg/kW day in 2005 to around 0.7 kg/kW day in 2007, and has since fluctuated between 0.2 and 0.5 kg/kW day, being 0.3 kg/kW day in 2021.

Research vessel data

An underwater TV (UWTV) survey for this FU has been conducted since 2017, with no survey occurring in 2020 or 2022. Figure 11.10.3 shows the distribution of stations in the UWTV surveys, with the size of the symbol reflecting the *Nephrops* burrow density. The number of stations sampled per year has been relatively high, with 59, 85 and 60 stations in 2017, 2018 and 2019, respectively. In 2021 the number of stations was only 28, due to reduction of planned stations and logistic issues during the survey. The most recent survey gives an estimated density of 0.22 burrows per m^2 that is three times higher than the two previous surveys estimates (2018 and 2019). The range of 95% confidence interval around the density estimate for 2021 reflects the lower sample size, but its lower bound is still around 0.2 burrows per m^2, thus supporting the conclusion that the increase in abundance for FU 33 is most likely true. The results of the UWTV surveys are shown in Figure 11.10.4 and Table 11.10.2.

11.10.5 Historic stock trends

The available data do not provide any clear signals on stock development:

The TV survey estimate of abundance for *Nephrops* in Off Horn's Reef suggests that the population declined from the first survey in 2017 to 2018 and remained at a lower level on the following surveyed year. However, in 2021 the TV survey estimates of abundance for *Nephrops* in Off Horn's Reef suggests an increase in stock abundance, with the estimate of lower bound of the 95% confidence interval being two times larger than the abundance estimates from 2019.

In general, over the entire time-series landings have shown an increasing trend. Since 2001, landings have fluctuated without trend from around 800 to 1600 tonnes. Landings in 2019, were the second highest on record, although in more recent years seem to have stabilized around 1400 tonnes being 1371 tonnes in 2021.

In 2016, the size distribution in the catches is similar to those in 2001–2004, 2009–2010 and 2012–2013. The smaller individuals in the 2005 and 2011 catches could reflect a high recruitment in these years. Data for 2020 showed the lowest mean size in catch recorded, which could be an explanation for the higher density values observed in the UWTV survey in the area for 2021. Data for 2021, showed the third highest mean size of catches, potentially indicating lower recruitment for this functional unit. The decrease in mean size could indicate either high recruitment or a decline in the stock, reflected by fewer large individuals. However, there are no recruitment estimates for this FU.

Biological reference points

There are no reference points defined for this stock.

Perceptions of the stock are based on Danish and Dutch LPUE data and trends in size composition in Danish catches. As stated above, comparing the size distribution in the 2005 and 2011 catches with those in other years could indicate high recruitment in 2005 and 2011. Likewise, 2020 showed the lowest mean size in catch in the current time series, indicating again that a strong recruitment event could have occurred in the area.

11.10.6 Forecasts

The ICES framework for category 4 Norway lobster stocks was applied (ICES, 2012). In the absence of a full analytical assessment, ICES base its advice for Norway lobster on the most recent advice. Maximum sustainable yield (MSY) harvest rates estimated for other FUs vary between 7.5% and 16%. ICES use the lower boundary as an upper limit for advice for data-limited Norway lobster stocks.

Providing the harvest rate is less than 7.5%, the default basis for advice is the average landings of the last ten years (2012–2021), subject to the application of the uncertainty cap to restrict annual advice change to less than 20%. The ten year average corresponds to 1223 tonnes of advised catch which implies a 28% increase from the 2020 advice. Therefore, the chosen advice option was the 2020 advice + 20% corresponding to landings of 918 tonnes, assuming a 25% discard rate. This advice option results in a harvest rate of 3.0%. This is well below the range of maximum sustainable yield (MSY) harvest rates in the North Sea (between 7.5% and 16%), which is considered conservative. The precautionary buffer was last applied in 2019 and its application has, therefore, been considered again. The stock status relative to candidate reference points is unknown; therefore, the precautionary buffer was applied in the advice.

Following the precautionary approach, catches in each of the years 2023 and 2024 should be no more than 918 tonnes.

Basis for the catch scenarios.

Variable	Value	Notes
Mean observed density	0.22 *Nephrops* m^{-2}	Density in UWTV 2021. The UWTV survey was not conducted in 2022.
Mean weight in projected landings	40.57 g	Estimated in 2015.
Mean weight in projected discards	17.2 g	Assumed mean discard weight for the calculation of the harvest rate only. Mean weight in Danish discards in 2015.
Projected discard rate (total)	25%	Assumed maximum discard rate for the calculation of the harvest rate only.
Discard survival rate	0%	ICES (2019).
Surface area estimate	5737 km^2	Estimate from the underwater TV (UWTV) survey. WGNEPS (ICES, 2017).

Sensitivity analysis of harvest rates for a range of potential densities (assuming discard rate of 25%). Shaded cells indicate harvest ratios above the MSY proxy harvest rate for this stock of 7.5%. All weights are in tonnes.

Basis	Total catch	Projected landings	Projected discards	Range of potential densities (*Nephrops* m^{-2})									
				0.05	0.1	0.2	0.22*	0.3	0.4	0.5	0.6	0.7	0.8
				Harvest rate in %									
0.5 x Average landings (2012–2021)	698	612	86	7	3.5	1.75	1.59	1.17	0.88	0.7	0.58	0.5	0.44
Advice for 2020 & 2021 −20% cap	873	765	108	8.8	4.4	2.2	1.99	1.46	1.1	0.88	0.73	0.63	0.55
(Average landings (2012–2021) +20% cap) - 20% PA buffer	**1047**	**918**	**130**	**10.5**	**5.3**	**2.6**	**2.4**	**1.75**	**1.31**	**1.05**	**0.88**	**0.75**	**0.66**
Advice for 2020 & 2021	1091	956	135	11	5.5	2.7	2.5	1.83	1.37	1.1	0.91	0.78	0.68
Advice for 2020 & 2021 +20%	1309	1147	162	13.1	6.6	3.3	3	2.2	1.64	1.31	1.1	0.94	0.82
Average landings (2012–2021)	1396	1223	173	14	7	3.5		3.2	2.3	1.75	1.4	1.17	1
Maximum	1867	1636	231	18.7	9.4	4.7	4.3	3.1	2.3	1.87	1.56	1.34	1.17
MSY proxy harvest rate	3287	2880	407	33	16.5	8.3	7.5	5.5	4.1	3.3	2.7	2.4	2.1

11.10.7 Quality of the assessment

Catch sampling needs to be improved. Discard data exist but are not considered representative and are not used to formulate advice. It is currently not possible to update mean weight estimates for landings because current sampling levels are too low. Samples are needed from the main fleets fishing in this FU.

The advice is based on a calculation of potential landing options and harvest rates, given the known surface area of Norway lobster habitat and observed densities of the functional unit.

11.10.8 Management considerations for FU 33

The North Sea TAC is not thought to be restrictive for the fleets exploiting this stock. Considering the recent trend in LPUE and the technological creep of the gear, the exploitation of this stock should be monitored closely.

11.10.9 Status of the stock

Previously, the state of this stock has been unknown, where an assumed low density (based on the lowest observed density in FU 7 (Fladen Ground) has been used to estimate harvest rates. In 2017, Denmark began conducting an UWTV survey of this functional unit. The observed density in 2017 (0.13 *Nephrops* m^{-2}) conformed well to those previous adopted from FU 7 (0.1 *Nephrops* m^{-2}). In 2018 and 2019, the observed densities were lower than what was observed in 2017 at 0.073 *Nephrops* m^{-2}. Harvest rates are considered low for this stock.

The mean individual weight in landings and discards in 2015 are 40.57 and 17.19 g respectively and the survival rate of discards is 0%. Discards are known to take place for the entire fishery, however only length measured discard data exist for the Dutch fishery. These data are not believed to be representative for the entire fishery as considerable high-grading is known to take place. Therefore, these data have not been used to calculate the values in the catch options table. Based on the available landings and discards it was not possible to update these estimates and therefore the 2015 values have been used.

References

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11.11 Devil's Hole (FU 34)

The Devil's Hole was designated as a functional unit in 2010, after recommendation from SGNEPS because of increasing landings in the area. The latest advice for this functional unit was provided in 2020 using the ICES data limited approach for *Nephrops*.

11.11.1 Ecosystem aspects

The area consists of a number of narrow trenches (up to 2 km wide) running in a north-south direction, with an average length of 20–30 km. These trenches fall across six ICES statistical rectangles: 41–43F0 and 41–43F1, which are used to define this functional unit. The British Geological Survey (BGS) sediment map (showing sediments suitable for *Nephrops*) of the area is shown in Figure 11.11.5 and suggests that there is one large, and several smaller areas of muddy sand (10–50% silt and clay).

11.11.2 The Fishery in 2020 and 2021

The fishery in this area is prosecuted largely by Scottish vessels operating out of ports in the northeast of Scotland, but occasionally making landings into northeast England. The fleet consists of large *Nephrops* trawlers which have the capability of operating in such offshore areas. Around five vessels operate out of Peterhead with another 12 from Fraserburgh regularly visiting the areas. These vessels also fish the Fladen on a regular basis and visit the other more inshore functional units in times of poor weather or poor *Nephrops* catch rates in the offshore areas.

Advice in 2020

Advice provided in 2020 was biennial for 2021 and 2022.

"ICES advises that when the precautionary approach is applied, catches in each of the years 2021 and 2022 should not exceed 566 tonnes, assuming recent discard rates.

In order to ensure the stock in this functional unit (FU) is exploited sustainably, management should be implemented at the functional unit level."

11.11.3 Management

Total Allowable Catch (TAC) management is at the ICES Subarea level.

11.11.4 Assessment

Data are presented which in future may form the basis for an assessment. A benchmark was carried out for this functional unit in 2013 (WKNEPH, 2013) which advised to continue with the data limited approach at present with the aim of moving to a full underwater TV (UWTV) assessment (Category 1) in the near future.

Data available

Commercial catch and effort data

Overall landings from this fishery for 1986–2021 are presented in Table 11.11.1 and Figure 11.11.1. Landings gradually increased from 378 tonnes in 2005 to approximately 1300 tonnes in 2009 followed by a decline in the following years to 121 tonnes in 2013. In recent years landings increased again and in 2021, 875 tonnes were recorded (a 10% decrease in relation to 2021).

In previous years, concerns were expressed over the reliability of the effort figures provided for Scottish *Nephrops* trawlers; effort figures were unrealistically low in some areas. Investigation of the issue revealed a problem in the MSS Marine Laboratory database, where only the effort expended in the first statistical rectangle visited by a vessel during a trip was being output. This did not affect landings. An extraction of effort data by the Marine Scotland data unit in Edinburgh covering the four main trawl gears landing *Nephrops* into Scotland produced higher figures which capture all the effort.

Trends in Scottish effort and LPUE are shown in Figure 11.11.2 and Table 11.11.2. Combined effort for trawlers has declined over the time period showing generally a downwards trend and reaching its lowest point in 2013. The decrease may partly be explained as a result of reductions in available effort imposed by the effort management regime and partly because this ground is more remote than a number of other *Nephrops* grounds and costs of steaming to and from the ground are likely to be high. Effort decreased from the start of the time series until 2011 after which it has shown a fluctuating trend. LPUE increased until 2009, decreasing in the early 2010s to around 400 kg/day and in 2019 a marked increase was recorded in line with the landings rise, and it remains at a relatively high value (~800 kg/day) in 2021.

Length compositions

Levels of both market and discard sampling are low and data are only available from the Scottish fleet. Most observer sampling in FU 34 took place in the period 2008–2011. In the last ten years, occasional sampling events in observer trips targeting FU 7 reveal low levels of discarding in the fishery. No market samples were taken in 2012–2013 and in the following years only a few fishing trips were sampled. Mean sizes in the catch and landings from 2006 are shown in Table 11.11.3. Sampling has not been conducted in all quarters, so there is potential bias in these results.

InterCatch

Scottish data for 2021 were successfully uploaded into InterCatch prior the 2022 WG meeting according with the deadline proposed. Both landings and discard sampling have been very limited in recent years and Intercatch has been used mainly to record landings data from countries who submitted data into FU 34 (Scotland and England).

Length Base Indicators (LBI)

The terms of Reference for the 2018 WGNSSK meeting requested the WG to propose appropriate MSY proxies for a number of Category 3 and 4 stocks including (*Nephrops* FU 34) by using methods provided in the ICES Technical Guidelines (ICES, 2017) along with available data and expert judgement. For FU 34, only limited length frequency information is available with few landings and discard samples collected per year. An attempt was made to run the Length Base Indicators (LBI) screening method using data from 2014 to 2017 (Figure 11.11.7). In recent years, the low number of discard trips conducted within FU 34 showed discard rates to be approximately zero, therefore only landings data were used when applying the method.

Life history parameters such as L_{inf} and L_{mat} are required to run the LBI method. These parameters were taken from the stock annex for this FU although they were estimated and borrowed from other *Nephrops* stocks. The parameters used were L_{inf} = 66 mm CL and L_{mat} = 25 mm CL (for both males and females).

The results of the application of the LBI method for females and males are presented in the tables below. These show that indicators related to the conservation of immature individuals (L_c/L_{mat} and $L_{25\%}/L_{mat}$) were generally below reference points while other indicators were mostly above reference points. The LBI method applied to FU 34 was not considered to be conclusive due to the limited data available.

Nephrops in FU 34: Length-based indicators (LBI) for females (above) and males (below). Green indicates that the observed value for the indicator is above the respective reference point, red indicates that the indicator is below the reference point.

Females

	Conservation				Optimising yield	MSY
	Lc/Lmat	L25%/Lmat	Lmax5%/Linf	Pmega	Lmean/Lopt	Lmean/L(F=M)
Ref	>1	>1	>0.8	>0.3	~1(>0.9)	≥1
2014	1.32	1.48	0.69	0	0.89	0.95
2015	0.68	1.32	0.72	0.02	0.82	1.23
2016	1.08	1.16	0.67	0	0.77	0.92
2017	1.16	1.32	0.75	0.04	0.87	1

Males

	Conservation				Optimising yield	MSY
	Lc/Lmat	L25%/Lmat	Lmax5%/Linf	Pmega	Lmean/Lopt	Lmean/L(F=M)
Ref	>1	>1	>0.8	>0.3	~1(>0.9)	≥1
2014	1.56	1.56	0.74	0.03	0.95	0.91
2015	0.76	1.4	0.77	0.04	0.89	1.27
2016	1.24	1.32	0.74	0.03	0.87	0.97
2017	1.24	1.32	0.8	0.06	0.89	0.98

Natural mortality, maturity at age and other biological parameters

No specific data are available for this functional unit, but there may be potential to adapt parameters from other functional units which have apparently similar biological characteristics.

Research vessel data

Marine Scotland Science (MSS) have carried out UWTV surveys of the Devil's Hole area opportunistically over the past 15 years. Since 2009, VMS data (Figure 11.11.6) have been used to define the location of the survey stations. It is not known how station locations were selected on the earlier surveys in this area. It was not possible to survey FU 34 in 2013, 2016 and 2020 but the survey has continued in 2014, 2015, 2017–2019 and 2021. The most recent survey, conducted in the summer of 2021 (10 TV stations completed) gives an estimate of density of 0.28 burrows/m^2, a slight 3% decrease in relation to the previous 2019 estimate. A density distribution map of these surveys is shown in Figure 11.11.3 with the size of the symbol reflecting the *Nephrops* burrow density. Table 11.11.4 and Figure 11.11.4 show the time series of mean burrow densities and 95% confidence intervals. There was no survey carried out in FU 34 in 2022

11.11.5 Historical stock trends

Scottish landings from this area have risen substantially from 2005 to 2009 followed by a general decreasing trend until 2013 and increased again in recent years with 2021 being the fifth highest figure recorded in the time series. Estimates of mean density in the stock show an increasing trend since 2016.

11.11.6 Recruitment estimates

There are no recruitment estimates for this FU.

11.11.7 MSY considerations

There is currently insufficient catch-at-length data to conduct a combined length cohort analysis, and therefore F_{MSY} proxy harvest rates have not been calculated for this functional unit.

11.11.8 Short-term forecasts

The advice guidance and category classification for data-limited stocks (DLS) was addressed at WKLIFE2 (ICES 2012). The methodology for DLS *Nephrops* stocks is further described in the 2013 Benchmark report (ICES 2013). Following the procedure outlined (section 10.1), an estimate of the total *Nephrops* grounds was used to give a likely envelope for the total abundance of *Nephrops* in the FU 34 (see text table below). UWTV survey information on the mean density of *Nephrops* (0.28 *Nephrops*/m^2) from the 2021 UWTV survey, was used together with the mean weight in projected landings (average 2007–2010) and projected discard rate (average 2008–2011). The mean weight in projected discards used the information from FU 7 (average 2019–2021). The same advice as provided in 2020 of 566 tonnes (catch) results in a harvest ratio of 3.9%. Providing the harvest rate is less than 7.5%, the default basis for advice is the average landings of the last ten years (2012–2021), subject to the application of the uncertainty cap to restrict annual advice change to less than 20%. The 10-year average (2012-2021) results in a HR of 4.5% which is below the range of maximum sustainable yield (MSY) harvest rates in the North Sea (between 7.5% and 16%). Stock size in relation to reference points is unknown. The precautionary buffer was applied to this stock in the 2020 advice but not in the current advice (for 2023 and 2024). The proposed advice (given in 2022) for 2023 and 2024 is that catches should be no more than 652 tonnes (10-year average), which results in a 15.2% decrease from the previous advice. In line with the advice for other stocks, total catches, projected landings and projected discards expected under the landing obligation policy were added to the table. For data limited stocks the discard survival is assumed to be zero.

Basis for the catch scenarios.

Variable	Value	Notes
Stock density (2023)	0.28	Underwater TV (UWTV) survey in 2021 (UWTV was not completed in 2022); density in numbers m^{-2}
Mean weight in projected landings (2023)	31.76	Average 2007–2010 (benchmark estimate; ICES, 2013); grammes
Mean weight in projected discards (2023)	12.75	Average 2019–2021 (from FU 7); grammes
Projected total discard rate (2023)	12.9	Average 2008–2011 (benchmark estimate; ICES, 2013); percentage by number of the total catch.
Discard survival rate (2023)	0	Discard survival is assumed to be zero
Surface area estimate	1753	Benchmark estimate (ICES, 2013); km2

Sensitivity analysis of harvest rates for a range of potential densities for projected landings only (assuming discard rate of 12.9%). Shaded cells indicate harvest ratios above the MSY proxy harvest rate for this stock of 7.5%. All weights are in tonnes.

Basis	Total Catch	Projected landings	Projected discards	Range of potential densities (*Nephrops* m^{-2})								% advice change**
				0.05	0.1	0.15	0.2	0.28 *	0.4	0.6	0.8	
				Harvest rate in %								
Average landings (2012–2021) (Precautionary approach)	**652**	**615**	**37**	25	12.7	8.4	6.3	**4.5**	3.2	2.1	1.58	**-15.2**
Advice for 2021 and 2022 −20% cap	453	428	25	17.6	8.8	5.9	4.4	3.1	2.2	1.47	1.10	-20
Advice for 2021 and 2022	566	534	32	22	11.0	7.3	5.5	3.9	2.8	1.84	1.38	-0
Average landings (2012–2021)	652	615	37	25	12.7	8.4	6.3	4.5	3.2	2.1	1.58	-15.2
Advice for 2020 and 2022 +20% cap	679	641	38	26	13.2	8.8	6.6	4.7	3.3	2.2	1.65	20
Recent average landings (2019–2021)	1067	1007	60	42	20.8	13.8	10.4	7.4	5.2	3.5	2.6	88
MSY proxy harvest rate (HR)	1079	1018	61	42	21	14	10.5	7.5	5.2	3.5	2.6	91
Maximum landings	1383	1305	78	54	27	18	13.5	9.6	6.7	4.5	3.4	144

*Most recent abundance estimate (2021 UWTV survey). Harvest rates are calculated for dead removals and applied to total catch.

** Advice basis values for 2023 and 2024 relative to the advice value for 2021 and 2022 (catch advice of 566 tonnes).

11.11.9 Quality of the assessment

The time-series of underwater TV (UWTV) survey data is incomplete. Surveys were conducted in 2003 and 2005 and during the periods 2009–2012, 2014–2015, 2017–2019 and 2021.

Catch options (when provided) are based on a calculation of potential landing options and harvest rates, given the known surface area of Norway lobster habitat and observed densities of the functional unit. The surface area is based on an estimate of area derived from Scottish vessel monitoring system (VMS) data from Scottish Norway lobster vessels from 2006 to 2009. The area of ground shown in geological charts is significantly larger than this and landings have been made from these areas. Therefore, the area should be regarded as a minimum estimate and the harvest rate could well be lower than implied by the analysis.

In recent years, only limited sampling data of catches have been available for this stock. Therefore, mean weights in discards are borrowed from the adjacent FU 7 and are used in addition to historical data.

11.11.10 Status of the stock

The current state of the stock is unknown.

11.11.11 Management considerations

The WG, ACOM and STECF have repeatedly advised that management should be at a smaller scale than the ICES Division level. Management at the Functional Unit level could provide the controls to ensure that catch opportunities and effort were compatible and in line with the scale of the resource. In 2016–2017, catches increased substantially to levels well above ICES advice in 2016 and 2017, highlighting the issue that current management arrangements are not sufficient to contain the fishery within the sustainable limits determined by ICES.

There is a by-catch of other species in the Devil's Hole area. It is important that efforts are made to ensure that unwanted by-catch is kept to a minimum in this fishery.

This stock is under the landings obligation although there is a survivability exemption in place for *Nephrops* in the UK waters of the North Sea (ICES division 2.a and Subarea 4) with certain gears, according to the Marine Management Organization (MMO, 2021).

References:

ICES. 2012. Report of The Workshop to Finalize the ICES Data-limited Stock (DLS) Methodologies Documentation in an Operational Form for the 2013 Advice Season and to make Recommendations on Target Categories for Data-limited Stocks (WKLIFE II), 20–22 November 2012, Copenhagen, Den-mark. ICES CM 2012/ACOM:79. 46 pp.

ICES. 2013. Report of the Benchmark Workshop on Nephrops Stocks (WKNEPH), 25 February–1 March 2013, Lysekil, Sweden. ICES CM 2013/ACOM:45. 230 pp.

MMO, 2021. Fishing gear requirements and Landing Obligation exemptions 2022. Applicable to the *Nephrops* Fishery in UK waters of the North Sea. Document No.: V1. Date of Issue: December 2021. *Nephrops* in Subarea 4, outside the functional units (27.4outFU)

11.12 *Nephrops* in Subarea 4, outside the functional units (27.4outFU)

The fishery

The *Nephrops* fishery in Subarea 4 outside of the functional units is dominated by the Netherlands, Germany, Scotland, and Belgium, followed by England, Denmark and Sweden (Figure 11.12.1, Table 11.12.1). *Nephrops* are landed throughout the year although the main fishing season is the summer (mainly Q3), and the predominant gears are bottom otter trawl (OTB) and beam trawls (TBB) with 70–99 mm of mesh size. Landings by creel vessels are typically lower than 1.5%.

The *Nephrops* fishery outside of the functional units has fluctuated over time. Landings were 1166 tonnes in 2011, the first year with data. They then declined, reaching a minimum of 393 tonnes in 2014. This was followed by an increase to 1195 tonnes 2017. Except Scotland and Sweden, all countries decreased their landings in 2018 by 50–60% in comparison to 2017, while Scottish landings increased from 158 to 181 tonnes. Since then, landings have fluctuated within the 2012 – 2016 range.

Discards have been reported by Denmark since 2012 (but only negligible amounts since the first year), and by Netherlands since 2016. Scotland also reported discards in 2016, 2017, and 2019. The highest Dutch discards of 605 tonnes were reported in 2019, followed in magnitude by 551 tonnes in 2016 (Table 11.12.2). In 2020, Dutch reported discards dropped to 115 tonnes, decreasing further to 42 tonnes in 2021.

At WGNSSK 2022, the suggestion was made to analyse the spatial distribution of landings from the outside-FU area in more detailed. All nations participating in the *Nephrops* fishery in Subarea 4 provided annual landings by rectangle for the 2017 – 2021 period. On the basis of these data, the average annual landings by rectangle are shown in Figure 11.12.2. Over the past five years, the landings from the two southernmost rectangles within FU 5 have been low. The landings within the northeast corner of FU 5 seem to be connected to two neighbouring rectangles outside the functional unit, which are routinely fished by Belgium, the Netherlands, and Germany. An argument could therefore be made to reduce the current size of FU 5 by removing the two southernmost and the two easternmost rectangles, and by introducing a new functional unit that incorporates the three routinely fished rectangles in the northeast corner of FU 5 and links up with FU 33 from the south.

Advice in 2020

Subarea 4 outside the functional units is assessed every two years. The last assessment was conducted in 2020, and the outcome was that *"the state of Nephrops outside the functional units is unknown".*

No new information has emerged that would warrant a change to the previous advice:

"ICES advises that when the precautionary approach is applied, landings should be no more than 301 tonnes in each of the years 2021 and 2022. ICES cannot quantify the corresponding total catches."

Management

Management is at the ICES Subarea level as described in Section 10.1.

Assessment

The previous assessments of the Subarea 4 outside of the functional units has been based on the examination of the trends in landings, since they are the only information available in a consistent manner.

Catch scenarios

The ICES framework for Category 5 stocks was applied (ICES, 2012). For stocks without information on abundance or exploitation, ICES considers that a precautionary reduction of catches should be implemented, unless ancillary information clearly indicates that the current level of exploitation is appropriate for the stock. The precautionary buffer was applied for the previous advice in 2020.

Basis for the catch scenarios.

Advised landings for 2021–2022		301 tonnes
Discard rate		Unknown
Precautionary buffer	Not applied	
Landings advice		301 tonnes
% advice change *		0%

*** Advice value for 2023–2024 relative to the advice value for 2021–2022.**

Table 11.2.1. Nominal landings (tonnes, including BMS landings) of *Nephrops* in Subarea 4, 1984–2021, as officially reported to ICES.

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Belgium	638	679	344	437	500	574	610	427	384	418	304	410	185	311	238
Denmark	7	50	323	479	409	508	743	880	581	691	1128	1182	1315	1309	1440
Faeroe Islands	-	-	-	0	0	0	0	0	0	1	3	12	0	1	1
France	-	-	-	7	0	0	0	0	0	0	0	0	0	0	0
Germany	.	.	.	0	0	0	0	2	2	16	24	16	69	64	58
Germany (Fed. Rep.)	5	4	5	1	2	1	2	0	0	0	0	0	0	627	
Netherlands	-	-	-	0	0	0	9	3	134	131	159	254	423	64	6945
Norway	1	1	1	2	17	17	46	117	125	107	171	74	83	1	93
Sweden	-	1	-	0	0	0	0	4	0	1	1	1	0		3
UK (Eng + Wales + NI)	.	.	.	0	0	2938	2332	1955	1451	2983	3613	2530	2462	2206	2094
UK (Eng + Wales)	1477	2052	2002	2173	2397	0	0	0	0	0	0	0	-	-	8980
UK (Scotland)	4158	5369	6190	5304	6527	7065	6871	7501	6898	8250	8850	10018	8981	10466	13602
Total	6286	8156	8865	8403	9852	11103	10613	10889	9575	12598	14253	14497	13518	15049	13602

Table 11.2.1 (continued). Nominal landings (tonnes, including BMS landings) of *Nephrops* in Subarea 4, 1984–2021, as officially reported to ICES.

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Belgium	350	252	283	284	229	213	180	214	205	200	265	115	295	374
Denmark	1963	1747	1935	2154	2128	2244	2339	2024	1408	1078	875	603	828	728
Faeroe Islands	1	0	-	-	-	-	-	-	-	-	-	-		
France	0	0	-	-	-	-	-	-	-	-	-	+		+
Germany	104	79	140	125	50	50	109	288	602	266	410	373	552	385
Netherlands	662	572	851	966	940	918	1019	982	1147	737	882	701	1012	1024
Norway	144	147	115	130	100	93	132	96	99	143	139	123	70	75
Sweden	4	37	26	14	1	1	3	1	5	26	2	1	1	1
UK (Eng + Wales + NI)	2431	2210	2691	1964	2295	2241	3236	4937	3295	1679	3437	-		
UK (Scotland)	10715	9834	9681	11045	10094	12912	10565	16165	17930	17960	18587	-		
UK	-	-	-	-	-	-		-	-	-	-	18941	14066	11108
Total	16374	14878	15722	16682	15838	18674	17583	24707	24691	22089	24597	20857	16824	13695

Table 11.2.1 (continued). Nominal landings (tonnes, including BMS landings) of *Nephrops* in Subarea 4, 1984–2021, as officially reported to ICES.

	2013	2014	2015	2016	2017	2018	2019	2020	2021
Belgium	303	494	349	880	1109	635	752	675	732
Denmark	387	624	515	755	594	100	343	307	687
Faeroe Islands	0	0	0	0	0	0	0	0	0
France	0	0	0	0	0	0	70	17	0
Germany	425	418	435	862	923	557	804	258	395
Ireland	0	1	0	0	0	0	1	0	0
Netherlands	910	1154	1113	1464	1418	803	1390	931	1275
Norway	63	63	81	98	94	103	103	97	81
Sweden	0		0	1	0	0	0	3	7
Isle of Man	-	-	-	-	-	-	-	-	5
UK	10685	13905	9457	13511	16317	13243	22176	11397	15540
Total	10713	13965	9318	13397	16049	13164	21808	13687	18723

* **Landings data for 2020 and 2021 are preliminary.**

Table 11.2.2. Summary of *Nephrops* landings from the ICES area, by Functional Unit, 1981–2021.

Year	FU 5	FU 6	FU 7	FU 8	FU 9	FU 10	FU 32	FU 33	FU 34	Other *	Total
1981		1073	372	1007	1416	35				76	3980
1982		2524	421	1195	1119	19				157	5437
1983		2078	693	1724	941	16				101	5551
1984		1479	646	2134	1169	111				88	5628
1985		2027	1147	1968	2081	22				139	7386
1986		2015	1543	2263	2143	67			23	204	8236
1987		2191	1695	1675	1992	45			5	195	7791
1988		2495	1575	2529	1959	76			2	364	8995
1989		3098	2299	1888	2576	84			28	233	10176
1990		2498	2540	1931	2037	218			26	222	9442
1991	862	2063	4223	1405	1520	197			85	560	10827
1992	612	1473	3363	1756	1591	188			106	401	9385
1993	721	3030	3492	2368	1809	376	339	160	44	434	12730
1994	503	3683	4568	1850	1537	494	755	137	129	703	14233
1995	869	2569	6419	1762	1279	279	489	164	132	844	14715
1996	679	2483	5210	1687	1451	345	952	77	129	808	13699
1997	1149	2189	6170	2193	1447	317	760	276	100	662	15163
1998	1111	2177	5136	2144	1032	256	836	350	88	694	13735
1999	1244	2391	6518	2207	1009	278	1119	724	202	988	16479
2000	1121	2178	5570	1785	1539	274	1084	597	184	900	15050
2001	1443	2574	5542	1527	1401	177	1190	791	271	1268	15915
2002	1231	1954	7245	1340	1132	403	1170	861	343	1383	16705
2003	1144	2245	6294	1127	1080	336	1089	929	675	1390	15633
2004	1070	2153	8730	1657	1333	228	922	1268	488	1224	18587
2005	1099	3094	10684	1989	1605	165	1089	1050	378	1120	21897
2006	974	4903	10791	2458	1805	133	11033	1288	448	1249	24627
2007	1294	2966	11911	2651	1843	153	755	1467	717	1637	24678
2008	963	1220	12239	2450	1515	172	675	1444	937	1673	22352
2009	728	2713	13327	2663	1067	87	477	1163	1305	2367	24593
2010	958	1443	12968	1950	1063	39	407	806	865	709**	20846
2011	1053	2072	7559	1889	1391	68	395	1191	432	1167^	17217
2012	1240	2460	4415	2129	866	13	310	1084	597	590	13704
2013	1050	2982	2951	1503	623	16	191	946	120	409	10791
2014	1416	2503	4147	2384	1253	15	205	1146	320	392	13765
2015	1517	1371	1784	1897	816	15	192	1003	440	610	9657

Year	FU 5	FU 6	FU 7	FU 8	FU 9	FU 10	FU 32	FU 33	FU 34	Other *	Total
2016	2535	1854	2399	1937	1146	23	178	1636	780	966	13454
2017	2109	1993	5155	2554	1143	9	147	1472	548	1195	16325
2018	1004	1881	4420	2698	1397	4	137	776	318	625	13260
2019	1172	4364	8931	2585	1356	21	191	1612	1167	724	22381
2020	540	1912	5543	1787	963	11	179	1186	980	531	13632
2021	1067	2022	9559	1835	1221	14	216	1371	875	636	18816

*** Includes Division 3.a.**
**** 695 t in Subarea 4 and 14 t in Division 3.a**
^ Subarea 4 only

Table 11.3.1. *Nephrops* in FU 5: Nominal Landings (tonnes) of *Nephrops*, 1991–2021, as reported to the WG.

	Belgium	Denmark	Netherlands	Germany	UK	Total*	Discards**
1991	682	176			4	862	
1992	571	22			19	612	
1993	694	20			7	721	
1994	494	0			9	503	
1995	641	77	148		3	869	
1996	266	41	317		55	679	
1997	486	67	540		56	1149	
1998	372	88	584	39	28	1111	
1999	436	53	538	59	158	1244	
2000	366	83	402	52	218	1121	
2001	353	145	553	114	278	1443	
2002	281	94	617	88	151	1231	
2003	265	36	661	24	158	1144	
2004	171	39	646	16	198	1070	
2005	109	87	654	51	198	1099	
2006	77	24	444	99	330	974	
2007	75	3	464	201	551	1294	
2008	49	29	268	108	509	963	
2009	52	3	288	98	287	728	
2010	48	5	354	140	411	958	
2011	60	18	480	145	350	1053	
2012	129	0	497	121	493	1240	
2013	142	1	447	168	292	1050	
2014	131	41	645	139	460	1416	
2015	146	0	681	184	506	1517	1352
2016	233	0	801	442	1059	2535	708
2017	416	0	745	374	574	2109	786
2018	234	1	429	204	136	1004	537
2019	194	0	551	284	143	1172	155

	Belgium	Denmark	Netherlands	Germany	UK	Total*	Discards**
2020	191	0	284	52	13	540	230
2021	314	37	603	101	12	1067	242

*** Totals for 1991–94 exclusive of landings by the Netherlands**
**** Reported Dutch discards, not raised**

Table 11.4.1. *Nephrops* in FU 6: Nominal Landings (tonnes) of *Nephrops*, 1981–2021, as reported to the WG.

Year	UK England & N. Ireland	UK Scotland	UK total	Other countries*	Total
1981	1006	67	1073	0	1073
1982	2443	81	2524	0	2524
1983	2073	5	2078	0	2078
1984	1471	8	1479	0	1479
1985	2009	18	2027	0	2027
1986	1987	28	2015	0	2015
1987	2158	33	2191	0	2191
1988	2390	105	2495	0	2495
1989	2930	168	3098	0	3098
1990	2306	192	2498	0	2498
1991	1884	179	2063	0	2063
1992	1403	60	1463	10	1473
1993	2941	89	3030	0	3030
1994	3530	153	3683	0	3683
1995	2478	90	2568	1	2569
1996	2386	96	2482	1	2483
1997	2109	80	2189	0	2189
1998	2029	147	2176	1	2177
1999	2197	194	2391	0	2391
2000	1947	231	2178	0	2178
2001	2319	255	2574	0	2574
2002	1739	215	1954	0	1954
2003	2031	214	2245	0	2245
2004	1952	201	2153	0	2153
2005	2936	158	3094	0	3094
2006	4430	434	4864	39	4903
2007	2525	437	2962	4	2966
2008	976	244	1220	0	1220
2009	2299	414	2713	0	2713
2010	1258	185	1443	0	1443
2011	1806	251	2057	15	2072
2012	2177	257	2434	26	2460
2013	2666	305	2971	11	2982

Year	UK England & N. Ireland	UK Scotland	UK total	Other countries*	Total
2014	2104	345	2449	54	2503
2015	1187	174	1361	10	1371
2016	1726	125	1851	3	1854
2017	1685	290	1975	18	1993
2018	1557	304	1861	20	1881
2019	3456	853	4309	55	4364
2020	1644	234	1878	34	1912
2021	1800	218	2018	4	2022

*** Other countries includes NL, BE, DK, and SE**

Table 11.4.2. *Nephrops* in FU 6: Mean carapace lengths (mm) in catches and landings by sex.

Year	Catches		Landings	
	Males	Females	Males	Females
1985	30.1	28.5	35.4	33.8
1986	31.7	30.2	35.3	33.7
1987	28.6	27	35.3	33.3
1988	28.7	27.3	35	33.9
1989	29	28.2	32.4	31.9
1990	27.1	27.4	31.8	31.3
1991	28.9	27.1	33.5	33.1
1992	30.8	29	33	31.9
1993	32.1	28.7	33.4	30.1
1994	30.5	27.7	33.8	30.5
1995	28.4	27.4	33.8	31.6
1996	29.8	28.2	34.5	32.1
1997	29.9	29.6	33.5	32.1
1998	30	28.9	34.9	33.7
1999	29.6	27.5	35.1	33.6
2000	27.2	26.8	31.1	31.3
2001	26.2	26.3	30.6	31.3
2002	28.0	26.9	30.9	30.0
2003	29.0	27.1	31.7	30.6
2004	29.2	27.0	32.3	30.6
2005	29.7	29.4	32.1	32.2
2006	29.0	30.3	31.4	32.4
2007	31.3	30.7	33.3	32.6
2008	31.5	31.1	33.5	33.3
2009	30.0	31.0	32.1	33.3
2010	31.2	31.4	32.8	33.2
2011	32.0	31.6	33.7	33.6

Year	Catches		Landings	
	Males	Females	Males	Females
2012	30.8	32.0	33.2	34.5
2013	29.6	32.4	32.0	35.4
2014	31.8	35.4	32.9	36.6
2015	31.5	31.7	33.9	34.9
2016	31.2	31.3	33.3	34.3
2017	32.4	32.1	34.1	34.7
2018	32.2	32.4	33.6	34.6
2019	32.1	32.8	33.4	34.6
2020	30.3	30.1	31.9	32.5
2021	30.8	28.3	33.0	31.2

Table 11.4.3. *Nephrops* in FU 6: Landings and effort by UK vessels targeting *Nephrops*

Year	Landings (tonnes)	Effort (kWd)	LPUE (kg/kWd)	Number of trips	Landings per trip (kg)	Days at sea	Landings per day at sea (kg)
2006	3046	3232136	0.942	7647	398	12577	242
2007	2208	2933270	0.753	6082	363	10893	203
2008	1207	1772977	0.681	4636	260	7313	165
2009	2267	2827506	0.802	6596	344	9685	234
2010	1438	1948707	0.738	4821	298	7017	205
2011	1816	1941503	0.935	5756	316	7776	234
2012	1997	2136594	0.935	6038	331	8410	237
2013	2315	2432936	0.952	6259	370	8787	263
2014	2032	2324575	0.874	5702	356	8022	253
2015	1139	1691667	0.673	4347	262	5925	192
2016	1519	1754167	0.866	5622	270	7555	201
2017	1178	1393107	0.845	4744	248	6032	195
2018	911	1398222	0.652	4258	214	5302	172
2019	1834	2410208	0.761	5860	313	7542	243
2020	873	1359463	0.642	3930	222	4957	176
2021	1157	1629491	0.710	4548	254	6640	174

Table 11.4.4. *Nephrops* in FU 6: Results of the UWTV survey.

Year	Stations	Season	Mean density (burrows/m²)	Absolute abundance (millions)	95% confidence interval (millions)	Method
1997	87	Autumn	0.46	1500	125	Box
1998	91	Autumn	0.33	1090	89	Box
1999	-	Autumn		No survey		Box
2000	-	Autumn		No survey		Box
2001	180	Autumn	0.56	1685	67	Box
2002	37	Autumn	0.33	1048	112	Box
2003	73	Autumn	0.33	1085	90	Box
2004	76	Autumn	0.43	1377	101	Box
2005	105	Autumn	0.49	1657	148	Box
2006	105	Autumn*	0.37	1244	114	Box
2007	105	Autumn*	0.28	858	23	Geostatistics
2008	95	Autumn*	0.31	987	39	Geostatistics
2009	76	Autumn*	0.22	682	38	Geostatistics
2010	95	Autumn*	0.25	785	21	Geostatistics
2011	97	Autumn*	0.28	878	17	Geostatistics
2012	97	Autumn*	0.24	758	13	Geostatistics
2013	110	Summer	0.23	706	18	Geostatistics
2014	110	Summer	0.24	755	18	Geostatistics
2015	110	Summer	0.18	565	13	Geostatistics
2016	110	Summer	0.22	697	19	Geostatistics
2017	110	Summer	0.29	902	21	Geostatistics
2018	109	Summer	0.31	950	23	Geostatistics
2019	86	Summer	0.37	1163	26	Geostatistics
2020	110	Summer	0.35	1102	24	Geostatistics
2021	110	Summer	0.31	982	22	Geostatistics
2022	109	Summer	0.28	878	20	Geostatistics

Table 11.4.5. *Nephrops* in FU 6: Individual mean weights in landings and discards, and observed harvest rate.

Year	UWTV abundance	Landings	Discards	Dead discards	Mean weight in landings (g)	Mean weight in discards (g)	Individuals landed	Individuals discarded	Individuals removed	Discard rate	Dead discard rate	Observed harvest rate
	millions	tonnes	tonnes	tonnes			millions	millions	millions	% by number	% by number	% by number
2001	1685	2574	2393	2034	20.60	9.62	125	249	336	66.6	56.6	20.0
2002	1048	1954	795	676	20.01	9.50	98	84	169	46.1	39.2	16.1
2003	1085	2245	716	608	21.89	9.56	103	75	166	42.2	35.9	15.3
2004	1377	2153	615	523	23.14	9.22	93	67	150	41.8	35.5	10.9
2005	1657	3094	715	608	23.58	10.32	131	69	190	34.6	29.4	11.5
2006	1244	4903	1051	893	22.53	10.58	218	99	302	31.3	26.6	24.3
2007	858	2966	432	367	24.95	10.89	119	40	153	25.0	21.3	17.8
2008	987	1220	166	141	26.63	10.97	46	15	59	24.9	21.1	5.9
2009	682	2713	461	392	24.45	10.54	111	44	148	28.3	24.1	21.7
2010	785	1443	201	171	25.18	11.74	57	17	72	23.0	19.5	9.2
2011	878	2072	246	209	27.05	11.02	77	22	96	22.6	19.2	10.9
2012	758	2460	345	293	27.34	10.16	90	34	119	27.4	23.3	15.7
2013	706	2982	450	383	27.60	9.79	108	46	147	29.9	25.4	20.8
2014	755	2503	199	169	29.93	13.59	84	15	96	14.9	12.7	12.7
2015	565	1371	190	162	29.28	10.01	47	19	63	28.8	24.5	11.1
2016	697	1854	272	231	28.03	10.24	66	27	89	28.7	24.4	12.7
2017	902	1993	200	170	29.38	10.29	68	19	84	22.3	18.9	9.4
2018	950	1881	195	166	28.14	11.22	67	17	82	20.6	17.5	8.6
2019	1163	4364	453	385	28.21	11.74	155	39	187	20.0	17.0	16.1
2020*	1102	1912	310	264	23.50	10.63	81	29	106	26.4	22.4	9.6
2021	982	2022	419	356	24.88	10.10	81	41	117	33.8	28.7	11.9
2022	878											

*** Discard rates and mean weights in landings and discards are adjusted according to the procedure described in Section 11.4.9.**

Table 11.5.1. *Nephrops*, Fladen (FU 7), Nominal Landings (tonnes) of *Nephrops*, 1981–2021, as reported to the WG

Year	UK Scotland				Denmark	Other countries **	Total
	Nephrops trawl	Other trawl	Creel	Sub-total			
1981	304	68	0	372	0	0	372
1982	381	40	0	421	0	0	421
1983	588	105	0	693	0	0	693
1984	552	94	0	646	0	0	646
1985	1020	120	0	1140	7	0	1147
1986	1401	92	0	1493	50	0	1543
1987	1023	349	0	1372	323	0	1695
1988	1309	185	0	1494	81	0	1575
1989	1724	410	0	2134	165	0	2299
1990	1703	598	0	2301	236	3	2540
1991	3021	772	0	3793	424	6	4223
1992	1809	1164	0	2973	359	31	3363
1993	2031	1234	0	3265	224	3	3492
1994	1816	2356	0	4172	390	6	4568
1995	3568	2389	19	5976	439	4	6419
1996	2338	2578	7	4923	286	1	5210
1997	2712	3221	0	5933	235	2	6170
1998	2290	2673	0	4963	173	0	5136
1999	2860	3546	0	6406	96	16	6518
2000	2916	2546	0	5462	103	5	5570
2001	3540	1936	0	5476	64	2	5542
2002	4511	2546	0	7057	173	15	7245
2003	4175	2033	0	6208	82	4	6294
2004	7274	1319	1	8594	136	0	8730
2005	8849	1508	5	10362	321	1	10684
2006	9470	1026	1	10497	283	11	10791
2007	11055	734	0	11789	119	3	11911
2008	11432	666	0	12098	133	8	12239
2009	12688	499	0	13187	130	10	13327
2010	12544	288	0	12832	124	12	12968
2011	7367	128	0	7495	64	<0.5	7559
2012	4257	81	0	4338	75	2	4415
2013	2275	663	0	2938	5	8	2951
2014	3928	206	0	4134	10	3	4147
2015	1465	307	0	1772	8	4	1784
2016	2021	374	0	2395	2	2	2399
2017	2862	2290	0	5152	1	2	5155
2018	2282	2133	0	4415	1	4	4420
2019	6702	2203	0	8905	7	19	8931
2020	3532	1991	0	5523	18	2	5543
2021*	7191	2286	0	9477	80	2	9559

* provisional

**Other countries includes Belgium, Norway, Netherlands, Sweden and UK England

Table 11.5.2. *Nephrops*, Fladen (FU 7): Landings, effort (days fishing) and LPUE (kg/day) for UK bottom trawlers landing in Scotland and fishing *Nephrops* with codend mesh sizes of 70 mm or above, 2000–2021.

Year	Landings (tonnes)	Effort (days)	LPUE (kg/day)
2000	5462	35367	154.4
2001	5476	28558	191.8
2002	7057	28586	246.9
2003	6208	21960	282.7
2004	8593	21562	398.5
2005	10357	23555	439.7
2006	10496	22836	459.6
2007	11789	21603	545.7
2008	12098	22856	529.3
2009	13187	21153	623.4
2010	12832	20968	612.0
2011	7495	15273	490.7
2012	4338	11994	361.7
2013	2938	11933	246.2
2014	4134	12629	327.3
2015	1772	10562	167.8
2016	2395	12297	194.8
2017	5152	15205	338.8
2018	4415	14431	305.9
2019	8905	15244	584.2
2020	5523	13543	407.8
2021*	9477	16351	579.6

*** Provisional**

Table 11.5.3. *Nephrops*, Fladen (FU 7): Logbook recorded effort (kW days) and LPUE (kg/kW day) for bottom trawlers catching *Nephrops* with cod end mesh sizes of 70 mm or above, and estimated total effort by Danish trawlers, 1991–2021.

Year	Logbook data	
	Effort	LPUE
1991	2522342	0.168
1992	1965624	0.183
1993	663625	0.338
1994	1044387	0.373
1995	716551	0.613
1996	538889	0.531
1997	283424	0.829
1998	210432	0.822
1999	153844	0.624
2000	266899	0.386
2001	142374	0.450
2002	217053	0.797
2003	105864	0.775
2004	212114	0.641
2005	430272	0.746
2006	363866	0.778
2007	160590	0.741
2008	121981	1.090
2009	114319	1.137
2010	129625	0.957
2011	67864	0.943
2012	129148	0.581
2013	130833	0.038
2014	168866	0.059
2015	70415	0.114
2016	117517	0.013
2017	135650	0.011
2018	121761	0.011
2019	172904	0.038
2020	126608	0.139
2021	252096	0.319

Table 11.5.4. *Nephrops*, Fladen (FU 7): Mean sizes (CL mm) above and below 35 mm of male and female *Nephrops* in Scottish catches and landings, 1993–2021.

Year	Catches		Landings			
	< 35 mm CL		< 35 mm CL		> 35 mm CL	
	Males	Females	Males	Females	Males	Females
1993	na	na	30.4	29.6	38.7	38.2
1994	na	na	30.0	28.9	39.2	37.8
1995	na	na	30.6	29.8	39.9	38.1
1996	na	na	30.4	29.1	40.6	38.8
1997	na	na	30.2	29.1	40.9	38.8
1998	na	na	30.8	29.4	40.7	38.3
1999	na	na	30.9	29.6	40.5	38.5
2000	30.7	30.1	31.2	30.5	41.3	38.7
2001	30.1	29.4	30.7	29.7	39.6	38.0
2002	30.6	30.0	31.3	30.7	39.5	38.3
2003	30.9	29.8	31.2	30.1	40.0	38.1
2004	30.8	29.9	31.1	30.2	40.1	38.7
2005	30.9	30.0	31.2	30.1	40.1	38.2
2006	30.3	29.7	30.8	30.0	40.7	38.2
2007	29.8	29.2	30.4	29.5	40.8	38.8
2008	29.7	28.6	29.8	28.7	41.8	39.1
2009	30.7	29.5	31.2	29.9	39.7	38.7
2010	30.4	29.0	30.5	29.0	39.8	38.4
2011	31.7	29.6	31.7	29.6	41.2	38.6
2012	31.9	30.6	31.9	30.6	41.8	38.5
2013	31.4	30.2	31.4	30.2	42.2	39.0
2014	30.4	30.1	30.8	30.2	411.5	39.2
2015	32.3	31.2	32.3	31.2	41.5	40.0
2016	32.0	31.0	32.0	31.0	41.2	40.6
2017	29.5	29.1	29.7	29.4	41.4	39.7
2018	31.3	29.7	31.3	29.7	39.7	40.0
2019	30.8	29.1	30.9	29.2	38.8	39.4
2020	31.6	30.5	31.8	30.7	40.1	39.6
2021	31.5	30.8	31.7	30.9	40.4	38.4

na = not available

Table 11.5.5. *Nephrops*, FUs 7–9 and 34 (Fladen, Firth of Forth, Moray Firth and Devil's Hole: Mean weight (g) in the landings.

Year	Fladen	Firth of Forth	Moray Firth	Devil's Hole	Noup
1990	31.59	20.29	20.05	Na	Na
1991	26.50	20.03	18.53	Na	Na
1992	29.61	20.96	23.49	Na	Na
1993	25.38	24.30	23.42	Na	Na
1994	23.72	19.51	22.25	Na	Na
1995	27.51	19.55	20.59	Na	Na
1996	29.82	20.81	21.40	Na	Na
1997	32.08	18.87	20.43	Na	23.94
1998	31.37	18.23	20.47	Na	20.58
1999	30.55	20.05	21.79	Na	21.23
2000	36.35	21.83	25.44	Na	30.81
2001	25.10	21.22	24.18	Na	25.30
2002	27.93	19.62	27.68	Na	27.95
2003	30.15	22.31	23.32	Na	20.05
2004	30.98	22.45	27.57	Na	28.98
2005	29.05	22.33	23.84	Na	24.13
2006	29.25	21.43	22.34	22.93	25.97
2007	26.63	20.97	23.04	26.27	25.58
2008	28.18	17.23	25.29	30.08	33.18
2009	28.20	19.41	23.46	39.62	49.38
2010	26.38	19.76	26.94	31.08	51.93
2011	36.17	19.75	21.63	42.05	45.73
2012	36.91	21.66	23.16	Na	34.48
2013	34.90	19.30	24.95	Na	43.56
2014	43.11	24.30	28.94	50.09	68.31
2015	36.70	21.84	29.10	48.75	Na
2016	39.43	23.62	26.83	33.51	35.61
2017	25.37	23.07	26.34	42.94	27.67
2018	30.58	24.29	28.86	40.91	Na
2019	28.31	21.81	25.13	35.83	33.01
2020	35.26	28.75	26.63	36.20	Na
2021	35.68	23.78	29.41	34.32	35.56
Mean (2019–2021)	33.08	24.78	27.06	31.76*	-

*** Mean weight for Devil's Hole based on 2007–2010 range (WKNEPH, 2013)**

Na = not available

Table 11.5.6. *Nephrops*, Fladen (FU 7): Results of the 1992–2022 TV surveys

Year	Stations	Abundance	Mean density	95% confidence interval
		Millions	burrows/m2	millions
1992	69	3661	0.13	376
1993	74	4450	0.16	569
1994	59	6170	0.22	814
1995	61	4987	0.18	896
1996		No survey		
1997	56	2767	0.10	510
1998	60	3838	0.13	717
1999	62	4146	0.15	649
2000	68	3628	0.13	491
2001	50	4981	0.17	970
2002	54	6087	0.21	757
2003	55	5547	0.20	1076
2004	52	5725	0.20	1030
2005	72	4325	0.16	662
2006	69	4862	0.17	619
2007	82	7017	0.25	730
2008	74	7360	0.26	1019
2009	59	5457	0.19	772
2010	67	5224	0.19	710
2011	73	3382	0.12	435
2012	70	2748	0.10	392
2013	71	2902	0.10	336
2014	70	2990	0.11	412
2015	71	2569	0.09	320
2016	78	4449	0.16	662
2017	71	7036	0.25	968
2018	71	5656	0.20	689
2019	70	6129	0.22	802
2020	61	4589	0.16	688
2021	70	6336	0.23	697
2022	70	5550	0.20	700

Table 11.5.7. *Nephrops*, Fladen Ground (FU 7): Summary of TV results for most recent 3 years (2020–2022) showing strata surveyed, numbers of stations in each strata, mean density and observed variance, overall abundance and variance raised to stratum area. Proportion indicates relative amounts of overall raised variance attributable to each stratum.

Stratum (ranges of % silt clay)	Area (km²)	Number of Stations	Mean burrow density (no./m²)	Observed variance	Abundance (millions)	Stratum variance	Proportion of total variance
2020 TV survey							
>80	3248	10	0.196	0.002	637.6	2255	0.019
55<80	4967	11	0.224	0.008	1113.7	17548	0.148
40<55	4304	11	0.16	0.012	689.7	19867	0.168
<40	15634	29	0.138	0.009	2148.4	78539	0.664
Total	28153	61			4589.4	118209	1
2021 TV survey							
>80	3248	9	0.299	0.007	973	8540	0.07
55<80	4967	13	0.301	0.010	1497	20118	0.165
40<55	4304	13	0.274	0.010	1180	15191	0.125
<40	15634	35	0.172	0.011	2687	77714	0.639
Total	28153	70			6336	121563	1
2022 TV survey							
>80	3248	9	0.381	0.009	1238	10325	0.084
55<80	4967	14	0.273	0.015	1359	26779	0.219
40<55	4304	11	0.249	0.014	1072	23008	0.188
<40	15634	36	0.120	0.009	1882	62253	0.509
Total	28153	70			5550	122366	1

Table 11.5.8. *Nephrops*, Fladen (FU 7): Adjusted TV survey abundance, landings, total discard rate (proportion by number), dead discard rate and estimated harvest ratio 1992–2022.

Year	Adjusted abundance (millions)	95% CI	Harvest ratio	Landings numbers	Discards numbers	Removals numbers	Landings (tonnes)	Discards (tonnes)	Dead Discards (tonnes)	Discard rate	Mean weight in landings	Mean weight in discards	Dead discard rate
1992	3661	376	3.1	114	NA	NA	3363	NA	0	NA	29.61	NA	NA
1993	4450	569	3.1	138	NA	NA	3492	NA	0	NA	25.38	NA	NA
1994	6170	814	3.1	193	NA	NA	4568	NA	0	NA	23.72	NA	NA
1995	4987	896	4.7	233	NA	NA	6419	NA	0	NA	27.51	NA	NA
1996	NA	NA	NA	175	NA	NA	5210	NA	0	NA	29.82	NA	NA
1997	2767	510	7.0	192	NA	NA	6170	NA	0	NA	32.08	NA	NA
1998	3838	717	4.3	164	NA	NA	5136	NA	0	NA	31.37	NA	NA
1999	4146	649	5.1	213	NA	NA	6518	NA	0	NA	30.55	NA	NA
2000	3628	491	4.7	153	21	169	5570	340	255	12.0	36.35	16.24	9.3
2001	4981	970	5.1	221	43	253	5542	687	515	16.3	25.1	15.94	12.8
2002	6087	757	4.9	259	55	301	7245	820	615	17.4	27.93	14.97	13.7
2003	5547	1076	4.1	209	24	226	6294	349	262	10.1	30.15	14.83	7.8
2004	5725	1030	5.4	282	34	307	8730	506	379	10.6	30.98	15.06	8.2
2005	4325	662	9.3	368	46	403	10684	823	617	11.2	29.05	17.74	8.6
2006	4862	619	8.4	369	54	409	10791	798	599	12.7	29.25	14.87	9.8
2007	7017	730	7.0	447	55	488	11911	747	560	10.9	26.63	13.67	8.4
2008	7360	1019	6.1	434	18	448	12239	257	192	3.9	28.18	14.54	3.0
2009	5457	772	9.4	473	51	511	13327	707	530	9.7	28.20	13.85	7.5
2010	5224	711	9.9	492	34	517	12968	560	420	6.5	26.38	16.44	4.9
2011	3382	435	6.2	209	0	209	7559	0	0	0	36.17	NA	0
2012	2748	392	4.7	128	0	128	4415	0	0	0	36.91	NA	0
2013	2902	335	3.1	89	0	89	2951	0	0	0.024	34.90	NA	0.0181
2014	2990	412	3.5	102	3	104	4147	37	28	2.5	43.11	13.9	1.92

Year	Adjusted abundance (millions)	95% CI	Harvest ratio	Landings numbers	Discards numbers	Removals numbers	Landings (tonnes)	Discards (tonnes)	Dead Discards (tonnes)	Discard rate	Mean weight in landings	Mean weight in discards	Dead discard rate
2015	2569	320	1.97	51	0	51	1784	0	0	0	36.7	NA	0
2016	4449	662	1.43	63	0	63	2399	0	0	0.022	39.43	NA	0.0167
2017	7036	968	3.1	212	10	219	5155	115	86	4.4	25.37	11.66	3.4
2018	5656	689	2.8	155	5	159	4420	68	51	2.9	30.58	14.42	2.2
2019	6129	802	5.6	338	8	344	8931	100	75	2.2	28.31	13.32	1.64
2020	4589	688	3.7	166	2	168	5543	28	21	1.4	35.26	11.74	1.06
2021	6336	697	4.7	293	5	296	9559	66	50	1.69	35.68	13.19	1.28
2022	5550	700	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table 11.6.1 *Nephrops*. Firth of Forth (FU 8), Nominal Landings (tonnes) of *Nephrops*, 1981–2021, as reported to the WG.

Year	UK Scotland					UK	Total **
	Nephrops trawl	Other trawl	Creel	BMS	Sub-total	(E, W & NI)	
1981	947	60	0	0	1007	0	1007
1982	1138	57	0	0	1195	0	1195
1983	1681	43	0	0	1724	0	1724
1984	2078	56	0	0	2134	0	2134
1985	1907	61	0	0	1968	0	1968
1986	2204	59	0	0	2263	0	2263
1987	1583	90	2	0	1675	0	1675
1988	2455	74	0	0	2529	0	2529
1989	1834	53	0	0	1887	1	1888
1990	1900	30	0	0	1930	1	1931
1991	1362	43	0	0	1405	0	1405
1992	1715	41	0	0	1756	0	1756
1993	2349	17	0	0	2366	2	2368
1994	1827	17	0	0	1844	6	1850
1995	1707	53	0	0	1760	2	1762
1996	1621	66	0	0	1687	0	1687
1997	2136	55	0	0	2191	2	2193
1998	2105	37	0	0	2142	2	2144
1999	2193	10	1	0	2204	3	2207
2000	1775	9	0	0	1784	1	1785
2001	1484	34	0	0	1518	9	1527
2002	1302	31	1	0	1334	6	1340
2003	1116	8	0	0	1124	3	1127
2004	1650	4	0	0	1654	3	1657
2005	1974	0	4	0	1978	11	1989
2006	2438	3	12	0	2453	5	2458
2007	2627	10	7	0	2644	7	2651
2008	2435	2	8	0	2445	5	2450
2009	2620	8	26	0	2654	9	2663
2010	1923	5	13	0	1941	9	1950
2011	1789	6	89	0	1884	5	1889
2012	1944	17	126	0	2087	42	2129
2013	1409	24	58	0	1491	12	1503
2014	2344	4	14	0	2362	22	2384
2015	1784	2	43	0	1829	68	1897

Year	UK Scotland					UK	Total **
	Nephrops trawl	Other trawl	Creel	BMS	Sub-total	(E, W & NI)	
2016	1786	1	116	2	1903	32	1935
2017	2472	11	10	0	2493	61	2554
2018	2646	7	4	0	2657	41	2698
2019	2531	10	5	0	2546	39	2585
2020*	1768	3	0	0	1771	16	1787
2021*	1697	112	2	15	1811	9	1820

*** provisional na = not available**

**** There are no landings by other countries from this FU**

Table 11.6.2 *Nephrops*, Firth of Forth (FU 8): Landings, effort (days fishing) and LPUE (kg/day) for UK bottom trawlers landing in Scotland and fishing *Nephrops* with codend mesh sizes of 70 mm or above, 2000–2021.

Year	Landings (tonnes)	Effort (days)	LPUE (kg/day)
2000	1784	10508	169.8
2001	1518	11513	131.9
2002	1333	10394	128.2
2003	1124	8279	135.8
2004	1654	9505	174.0
2005	1974	7704	256.2
2006	2441	6174	395.4
2007	2637	6409	411.5
2008	2437	6440	378.4
2009	2628	5852	449.1
2010	1928	5054	381.5
2011	1795	4614	389.0
2012	1961	5058	387.7
2013	1433	4029	355.7
2014	2348	6812	344.7
2015	1786	6024	296.5
2016	1787	5224	342.1
2017	2483	5261	472.0
2018	2653	4886	543.0
2019	2541	5116	496.7
2020	1771	4159	425.8
2021*	1809	3494	517.7

*** provisional na = not available**

Table 11.6.3 *Nephrops*, Firth of Forth (FU 8): Mean sizes (CL mm) above and below 35 mm of male and female *Nephrops* in Scottish catches and landings, 1981–2021.

Year	Catches		Landings			
	<35 mm CL		<35 mm CL		>35 mm CL	
	Males	Females	Males	Females	Males	Females
1981	na	na	31.5	31.0	39.7	38.7
1982	na	na	30.4	30.1	40.0	39.1
1983	na	na	31.1	30.8	40.2	38.7
1984	na	na	30.3	29.7	39.4	38.4
1985	na	na	30.6	29.9	39.4	38.2
1986	na	na	29.7	29.2	39.1	38.5
1987	na	na	29.9	29.6	39.1	38.2
1988	na	na	28.5	28.5	39.1	39.0
1989	na	na	29.2	28.9	38.7	38.9
1990	28.9	27.8	29.8	28.6	38.3	38.8
1991	28.7	27.5	29.8	28.7	38.3	38.7
1992	29.5	27.9	30.2	28.7	38.1	38.7
1993	28.7	28.0	30.3	29.5	39.0	38.6
1994	25.7	25.1	29.1	28.5	38.8	37.8
1995	27.9	27.1	29.4	28.9	38.7	37.9
1996	28.0	27.4	29.8	28.8	38.6	38.6
1997	27.2	27.0	29.2	28.7	38.8	38.2
1998	27.7	26.4	29.0	27.9	38.5	38.4
1999	27.2	26.5	29.6	28.8	38.0	37.9
2000	28.5	27.2	30.6	29.8	38.2	38.3
2001	28.1	27.0	30.6	29.2	38.0	37.9
2002	27.1	26.3	29.8	29.3	38.3	37.9
2003	27.2	25.4	30.2	29.1	38.1	38.0
2004	28.6	27.8	30.7	30.0	38.4	37.6
2005	27.6	26.9	30.3	30.0	38.7	38.2
2006	27.3	27.0	29.8	29.9	38.7	37.8
2007	29.2	28.3	29.8	28.6	39.1	38.6
2008	27.7	27.2	28.1	26.9	39.4	37.9
2009	27.5	26.2	29.7	28.5	38.3	38.0
2010	28.3	26.9	29.8	28.4	38.6	38.2
2011	28.6	27.5	30.0	28.3	38.8	38.2
2012	28.4	28.0	30.4	29.3	39.0	38.1
2013	28.3	27.4	29.6	28.8	38.8	37.9
2014	29.6	29.1	31.1	30.3	38.6	38.1
2015	27.9	28.3	29.5	29.3	39.6	38.5

Year	Catches		Landings			
	<35 mm CL		<35 mm CL		>35 mm CL	
	Males	Females	Males	Females	Males	Females
2016	29.3	28.6	30.5	29.7	39.4	38.5
2017	29.6	28.1	30.9	29.3	38.5	38.9
2018	29.2	28.6	30.1	29.5	39.1	39.1
2019	28.1	27.0	29.7	28.1	39.2	38.5
2020	30.5	29.7	31.4	30.3	39.5	39.4
2021	29.9	28.4	30.9	29.2	39.0	38.4

na = not available

Table 11.6.4. *Nephrops*, Firth of Forth (FU 8): Results of the 1993–2021 TV surveys.

Year	Stations	Mean Density	Abundance	95% conf interval
		Burrows/m²	millions	millions
1993	37	0.61	555	142
1994	30	0.49	448	78
1995		no survey		
1996	27	0.41	375	88
1997		no survey		
1998	32	0.32	292	81
1999	49	0.51	463	78
2000	53	0.48	443	70
2001	46	0.46	419	79
2002	41	0.56	508	119
2003	36	0.84	767	138
2004	37	0.69	630	141
2005	54	0.78	710	143
2006	43	0.91	827	125
2007	49	0.76	692	132
2008	38	0.97	881	297
2009	45	0.80	732	142
2010	39	0.75	682	147
2011	45	0.58	533	87
2012	66	0.57	522	64
2013	51	0.73	668	125
2014	51	0.47	428	80
2015	51	0.73	664	127
2016	50	0.87	797	146
2017	52	0.73	670	133

Year	Stations	Mean Density	Abundance	95% conf interval
		Burrows/m²	millions	millions
2018	50	1.12	1025	190
2019	50	0.95	865	135
2020	34	1.22	1119	180
2021	41	0.92	837	107
2022		no survey		

Table 11.6.5. *Nephrops*, Firth of Forth (FU 8): Summary of TV results for most recent 3 years (2019–2021) showing strata surveyed, numbers of stations in each strata, mean density and observed variance, overall abundance and variance raised to stratum area. Proportion indicates relative amounts of overall raised variance attributable to each stratum.

Stratum	Area (km²)	Number of Stations	Mean burrow density (no./m²)	Observed variance	Abundance (millions)	Stratum variance	Proportion of total variance
2019 TV survey							
M & SM	170	8	0.950	0.243	162	886	0.196
MS(west)	139	9	0.593	0.246	82	529	0.117
MS(mid)	211	12	1.264	0.306	266	1130	0.25
MS(east)	395	21	0.898	0.266	355	1982	0.438
Total	915	50			865	4527	1
2020 TV survey							
M & SM	170	6	1.438	0.795	245.1	3852	0.475
MS(west)	139	5	1.407	0.339	195.4	1309	0.162
MS(mid)	211	8	1.41	0.358	296.9	1986	0.245
MS(east)	395	15	0.967	0.092	381.9	954	0.118
Total	915	34			1119.3	8102	1
2021 TV survey							
M & SM	170	6	1.017	0.097	173	470	0.165
MS(west)	139	5	0.654	0.173	91	666	0.234
MS(mid)	211	12	0.865	0.175	182	644	0.227
MS(east)	395	18	0.989	0.123	391	1062	0.374
Total	915	41			837	2843	1

Table 11.6.1 *Nephrops*. Firth of Forth (FU 8), Nominal Landings (tonnes) of *Nephrops*, 1981–2021, as reported to the WG.

Year	UK Scotland					UK	Total **
	Nephrops trawl	Other trawl	Creel	BMS	Sub-total	(E, W & NI)	
1981	947	60	0	0	1007	0	1007
1982	1138	57	0	0	1195	0	1195
1983	1681	43	0	0	1724	0	1724
1984	2078	56	0	0	2134	0	2134
1985	1907	61	0	0	1968	0	1968
1986	2204	59	0	0	2263	0	2263

Year	UK Scotland					UK	Total **
	Nephrops trawl	Other trawl	Creel	BMS	Sub-total	(E, W & NI)	
1987	1583	90	2	0	1675	0	1675
1988	2455	74	0	0	2529	0	2529
1989	1834	53	0	0	1887	1	1888
1990	1900	30	0	0	1930	1	1931
1991	1362	43	0	0	1405	0	1405
1992	1715	41	0	0	1756	0	1756
1993	2349	17	0	0	2366	2	2368
1994	1827	17	0	0	1844	6	1850
1995	1707	53	0	0	1760	2	1762
1996	1621	66	0	0	1687	0	1687
1997	2136	55	0	0	2191	2	2193
1998	2105	37	0	0	2142	2	2144
1999	2193	10	1	0	2204	3	2207
2000	1775	9	0	0	1784	1	1785
2001	1484	34	0	0	1518	9	1527
2002	1302	31	1	0	1334	6	1340
2003	1116	8	0	0	1124	3	1127
2004	1650	4	0	0	1654	3	1657
2005	1974	0	4	0	1978	11	1989
2006	2438	3	12	0	2453	5	2458
2007	2627	10	7	0	2644	7	2651
2008	2435	2	8	0	2445	5	2450
2009	2620	8	26	0	2654	9	2663
2010	1923	5	13	0	1941	9	1950
2011	1789	6	89	0	1884	5	1889
2012	1944	17	126	0	2087	42	2129
2013	1409	24	58	0	1491	12	1503
2014	2344	4	14	0	2362	22	2384
2015	1784	2	43	0	1829	68	1897
2016	1786	1	116	2	1903	32	1935
2017	2472	11	10	0	2493	61	2554
2018	2646	7	4	0	2657	41	2698
2019	2531	10	5	0	2546	39	2585
2020*	1768	3	0	0	1771	16	1787
2021*	1697	112	2	15	1811	9	1820

*** provisional na = not available**

**** There are no landings by other countries from this FU**

Table 11.6.2 *Nephrops*, Firth of Forth (FU 8): Landings, effort (days fishing) and LPUE (kg/day) for UK bottom trawlers landing in Scotland and fishing *Nephrops* with codend mesh sizes of 70 mm or above, 2000–2021.

Year	Landings (tonnes)	Effort (days)	LPUE (kg/day)
2000	1784	10508	169.8
2001	1518	11513	131.9
2002	1333	10394	128.2
2003	1124	8279	135.8
2004	1654	9505	174.0
2005	1974	7704	256.2
2006	2441	6174	395.4
2007	2637	6409	411.5
2008	2437	6440	378.4
2009	2628	5852	449.1
2010	1928	5054	381.5
2011	1795	4614	389.0
2012	1961	5058	387.7
2013	1433	4029	355.7
2014	2348	6812	344.7
2015	1786	6024	296.5
2016	1787	5224	342.1
2017	2483	5261	472.0
2018	2653	4886	543.0
2019	2541	5116	496.7
2020	1771	4159	425.8
2021*	1809	3494	517.7

*** provisional na = not available**

Table 11.6.3 *Nephrops*, Firth of Forth (FU 8): Mean sizes (CL mm) above and below 35 mm of male and female *Nephrops* in Scottish catches and landings, 1981–2021.

Year	Catches		Landings			
	<35 mm CL		<35 mm CL		>35 mm CL	
	Males	Females	Males	Females	Males	Females
1981	na	na	31.5	31.0	39.7	38.7
1982	na	na	30.4	30.1	40.0	39.1
1983	na	na	31.1	30.8	40.2	38.7
1984	na	na	30.3	29.7	39.4	38.4
1985	na	na	30.6	29.9	39.4	38.2
1986	na	na	29.7	29.2	39.1	38.5
1987	na	na	29.9	29.6	39.1	38.2
1988	na	na	28.5	28.5	39.1	39.0
1989	na	na	29.2	28.9	38.7	38.9
1990	28.9	27.8	29.8	28.6	38.3	38.8
1991	28.7	27.5	29.8	28.7	38.3	38.7
1992	29.5	27.9	30.2	28.7	38.1	38.7
1993	28.7	28.0	30.3	29.5	39.0	38.6
1994	25.7	25.1	29.1	28.5	38.8	37.8
1995	27.9	27.1	29.4	28.9	38.7	37.9
1996	28.0	27.4	29.8	28.8	38.6	38.6
1997	27.2	27.0	29.2	28.7	38.8	38.2
1998	27.7	26.4	29.0	27.9	38.5	38.4
1999	27.2	26.5	29.6	28.8	38.0	37.9
2000	28.5	27.2	30.6	29.8	38.2	38.3
2001	28.1	27.0	30.6	29.2	38.0	37.9
2002	27.1	26.3	29.8	29.3	38.3	37.9
2003	27.2	25.4	30.2	29.1	38.1	38.0
2004	28.6	27.8	30.7	30.0	38.4	37.6
2005	27.6	26.9	30.3	30.0	38.7	38.2
2006	27.3	27.0	29.8	29.9	38.7	37.8
2007	29.2	28.3	29.8	28.6	39.1	38.6
2008	27.7	27.2	28.1	26.9	39.4	37.9
2009	27.5	26.2	29.7	28.5	38.3	38.0
2010	28.3	26.9	29.8	28.4	38.6	38.2
2011	28.6	27.5	30.0	28.3	38.8	38.2
2012	28.4	28.0	30.4	29.3	39.0	38.1
2013	28.3	27.4	29.6	28.8	38.8	37.9
2014	29.6	29.1	31.1	30.3	38.6	38.1
2015	27.9	28.3	29.5	29.3	39.6	38.5

Year	Catches		Landings			
	<35 mm CL		<35 mm CL		>35 mm CL	
	Males	Females	Males	Females	Males	Females
2016	29.3	28.6	30.5	29.7	39.4	38.5
2017	29.6	28.1	30.9	29.3	38.5	38.9
2018	29.2	28.6	30.1	29.5	39.1	39.1
2019	28.1	27.0	29.7	28.1	39.2	38.5
2020	30.5	29.7	31.4	30.3	39.5	39.4
2021	29.9	28.4	30.9	29.2	39.0	38.4

na = not available

Table 11.6.4. *Nephrops*, Firth of Forth (FU 8): Results of the 1993–2021 TV surveys.

Year	Stations	Mean Density	Abundance	95% conf interval
		Burrows/m²	millions	millions
1993	37	0.61	555	142
1994	30	0.49	448	78
1995		no survey		
1996	27	0.41	375	88
1997		no survey		
1998	32	0.32	292	81
1999	49	0.51	463	78
2000	53	0.48	443	70
2001	46	0.46	419	79
2002	41	0.56	508	119
2003	36	0.84	767	138
2004	37	0.69	630	141
2005	54	0.78	710	143
2006	43	0.91	827	125
2007	49	0.76	692	132
2008	38	0.97	881	297
2009	45	0.80	732	142
2010	39	0.75	682	147
2011	45	0.58	533	87
2012	66	0.57	522	64
2013	51	0.73	668	125
2014	51	0.47	428	80
2015	51	0.73	664	127
2016	50	0.87	797	146
2017	52	0.73	670	133

Year	Stations	Mean Density	Abundance	95% conf interval
		Burrows/m²	millions	millions
2018	50	1.12	1025	190
2019	50	0.95	865	135
2020	34	1.22	1119	180
2021	41	0.92	837	107
2022		no survey		

Table 11.6.5. *Nephrops*, Firth of Forth (FU 8): Summary of TV results for most recent 3 years (2019–2021) showing strata surveyed, numbers of stations in each strata, mean density and observed variance, overall abundance and variance raised to stratum area. Proportion indicates relative amounts of overall raised variance attributable to each stratum.

Stratum	Area (km²)	Number of Stations	Mean burrow density (no./m²)	Observed variance	Abundance (millions)	Stratum variance	Proportion of total variance
2019 TV survey							
M & SM	170	8	0.950	0.243	162	886	0.196
MS(west)	139	9	0.593	0.246	82	529	0.117
MS(mid)	211	12	1.264	0.306	266	1130	0.25
MS(east)	395	21	0.898	0.266	355	1982	0.438
Total	915	50			865	4527	1
2020 TV survey							
M & SM	170	6	1.438	0.795	245.1	3852	0.475
MS(west)	139	5	1.407	0.339	195.4	1309	0.162
MS(mid)	211	8	1.41	0.358	296.9	1986	0.245
MS(east)	395	15	0.967	0.092	381.9	954	0.118
Total	915	34			1119.3	8102	1
2021 TV survey							
M & SM	170	6	1.017	0.097	173	470	0.165
MS(west)	139	5	0.654	0.173	91	666	0.234
MS(mid)	211	12	0.865	0.175	182	644	0.227
MS(east)	395	18	0.989	0.123	391	1062	0.374
Total	915	41			837	2843	1

Table 11.6.6. *Nephrops*, Firth of Forth (FU 8): Adjusted TV survey abundance, landings, total discard rate (proportion by number), dead discard rate and estimated harvest ratio 1993–2021.

Year	Adjusted abundance (millions)	95% CI	Harvest ratio	Landings numbers	Discards numbers	Removals numbers	Landings (tonnes)	Discards (tonnes)	Dead Discards (tonnes)	Discard rate	Mean weight in landings	Mean weight in discards	Dead discard rate
1993	555	142	24	97	49	134	2368	567	426	33	24.3	11.64	27
1994	448	78	51	95	180	230	1850	1584	1188	66	19.51	8.79	59
1995	NA	NA	NA	90	59	134	1762	620	465	40	19.55	10.54	33
1996	375	88	37	81	78	140	1687	930	697	49	20.81	11.85	42
1997	NA	NA	NA	116	56	158	2193	494	371	33	18.87	8.79	27
1998	292	81	56	118	60	163	2144	578	434	34	18.23	9.6	28
1999	463	78	40	110	97	183	2207	938	704	47	20.05	9.63	40
2000	443	70	34	82	90	150	1785	1032	774	52	21.83	11.42	45
2001	419	79	25	72	45	106	1527	436	327	39	21.22	9.59	32
2002	508	119	21	68	52	107	1340	421	316	43	19.62	8.16	36
2003	767	138	12.4	51	59	95	1127	546	410	54	22.31	9.25	47
2004	630	140	16.4	74	40	103	1657	406	304	35	22.45	10.25	29
2005	710	143	19.4	89	65	138	1989	602	452	42	22.33	9.28	35
2006	827	126	27	115	142	221	2458	1510	1133	55	21.43	10.67	48
2007	692	132	23	126	43	159	2651	614	461	25	20.97	14.34	20
2008	881	297	21	142	58	186	2450	796	597	29	17.23	13.65	24
2009	732	142	26	137	71	190	2663	573	430	34	19.41	8.09	28
2010	682	147	19.2	99	43	131	1950	407	305	30	19.76	9.55	24
2011	533	87	22	100	24	118	1889	231	173	19.5	19.75	9.56	15.3
2012	522	64	25	100	38	129	2129	379	284	27	21.66	10.10	22
2013	668	126	15.6	81	31	104	1503	301	226	27	19.30	9.82	22
2014	428	80	29	102	30	124	2384	353	265	23	24.30	11.66	18.3

Year	Adjusted abundance (millions)	95% CI	Harvest ratio	Landings numbers	Discards numbers	Removals numbers	Landings (tonnes)	Discards (tonnes)	Dead Discards (tonnes)	Discard rate	Mean weight in landings	Mean weight in discards	Dead discard rate
2015	664	127	16.8	90	29	112	1897	311	234	24	21.84	10.74	19.5
2016	797	146	12.3	85	17	98	1935	167	123	16.4	23.62	9.86	12.8
2017	670	133	19.7	111	28	132	2554	280	210	20	23.07	10.07	15.8
2018	1025	190	12.9	114	24	132	2698	275	206	17.4	24.29	11.42	13.6
2019	865	135	18.3	127	42	158	2585	411	308	25	21.81	9.76	19.9
2020	1119	180	6.1	64	5	68	1787	53	40	6.9	28.75	10.83	5.5
2021	837	107	10.8	82	12	90	1820	128	85	12.8	23.78	9.69	9.7
2022	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table 11.7.1. *Nephrops*, Moray Firth (FU 9), Nominal Landings (tonnes) of *Nephrops*, 1981–2021, as reported to the WG.

Year	UK Scotland				UK *	Total **
	Nephrops trawl	Other trawl	Creel	Sub-total	England	
1981	1299	117	0	1416	0	1416
1982	1033	86	0	1119	0	1119
1983	850	91	0	941	0	941
1984	960	209	0	1169	0	1169
1985	1908	173	0	2081	0	2081
1986	1932	211	0	2143	0	2143
1987	1724	268	0	1992	0	1992
1988	1637	322	0	1959	0	1959
1989	2102	474	0	2576	0	2576
1990	1698	339	0	2037	0	2037
1991	1285	235	0	1520	0	1520
1992	1285	306	0	1591	0	1591
1993	1505	304	0	1809	0	1809
1994	1179	358	0	1537	0	1537
1995	967	312	0	1279	0	1279
1996	1084	364	1	1449	2	1451
1997	1103	343	0	1446	1	1447
1998	739	289	4	1032	0	1032
1999	813	194	2	1009	0	1009
2000	1341	196	2	1539	0	1539
2001	1186	213	2	1401	0	1401
2002	883	247	2	1132	0	1132
2003	873	196	11	1080	0	1080
2004	1222	103	8	1333	0	1333
2005	1526	64	12	1602	3	1605
2006	1751	42	11	1804	1	1805
2007	1818	17	6	1841	2	1843
2008	1444	68	3	1515	0	1515
2009	1033	31	2	1066	1	1067
2010	1026	28	9	1063	0	1063
2011	1358	23	9	1390	1	1391
2012	834	24	8	866	0	866
2013	497	116	7	620	3	623
2014	1183	56	2	1241	12	1253
2015	774	40	0	814	2	816
2016	1105	37	4	1146	<0.5	1146
2017	943	191	8	1142	1	1143
2018	1203	183	9	1395	2	1397
2019	1150	191	13	1354	2	1356
2020	800	154	7	961	2	963
2021*	1100	117	4	1221	0	1221

*** provisional na = not available**

**** No landings by non UK countries from this FU**

Table 11.7.2. *Nephrops*, Moray Firth (FU 9): landings, effort (days fishing) and LPUE (kg/day) for UK bottom trawlers landing in Scotland and fishing *Nephrops* with codend mesh sizes of 70 mm or above, 2000–2021

Year	Landings (tonnes)	Effort (days)	LPUE (kg/day)
2000	1537	7943	193.5
2001	1399	7219	193.8
2002	1130	7495	150.8
2003	1069	5934	180.1
2004	1325	6200	213.7
2005	1590	4805	330.9
2006	1793	4588	390.8
2007	1835	4758	385.7
2008	1512	4328	349.4
2009	1064	3546	300.1
2010	1054	3589	293.7
2011	1381	3880	355.9
2012	858	3079	278.7
2013	613	2954	207.5
2014	1239	4099	302.3
2015	814	3755	216.8
2016	1142	3577	319.3
2017	1134	5044	224.8
2018	1386	4579	302.7
2019	1341	4343	308.8
2020	954	3518	271.2
2021*	1217	3182	382.5

*** provisional na = not available**

Table 11.7.3. *Nephrops*, Moray Firth (FU 9): Mean sizes (CL mm) above and below 35 mm of male and female *Nephrops* in Scottish catches and landings, 1981–2021.

Year	Catches		Landings			
	<35 mm CL		<35 mm CL		=>35 mm CL	
	Males	Females	Males	Females	Males	Females
1981	na	na	30.5	28.2	39.1	37.7
1982	na	na	30.2	29.0	40.0	37.9
1983	na	na	29.9	29.1	40.6	38.3
1984	na	na	29.7	29.3	39.4	38.1
1985	na	na	28.9	28.7	38.7	37.8
1986	na	na	28.7	27.8	39.1	38.4
1987	na	na	29.0	28.3	39.4	38.6
1988	na	na	29.1	28.7	38.9	38.4
1989	na	na	29.8	28.8	40.1	39.4
1990	28.8	28.1	30.3	29.1	38.4	38.7
1991	28.3	27.4	30.1	28.6	38.2	38.2
1992	29.4	28.6	31.0	30.5	38.3	38.0
1993	29.8	29.9	31.3	30.9	38.6	37.7
1994	28.9	30.1	30.8	31.0	39.4	37.5
1995	25.8	25.0	29.9	29.3	39.1	38.0
1996	29.3	28.4	30.6	29.7	38.5	38.0
1997	28.5	27.9	29.5	28.9	38.8	38.2
1998	28.7	28.2	30.1	29.3	38.8	38.2
1999	29.5	28.8	30.4	29.7	38.9	37.6
2000	29.8	29.1	31.5	30.6	39.2	38.3
2001	30.0	29.2	30.9	30.2	39.5	37.9
2002	27.2	27.0	31.2	30.9	41.0	38.7
2003	29.3	29.2	30.3	30.1	39.8	38.0
2004	29.3	28.4	31.3	30.8	39.0	39.2
2005	30.0	28.7	31.0	29.6	39.2	38.5
2006	29.7	28.9	30.6	29.6	39.3	38.6
2007	30.1	28.8	30.3	29.0	39.4	38.6
2008	29.3	27.7	30.2	28.2	39.8	40.2
2009	29.7	28.9	30.7	29.3	39.6	38.5
2010	29.7	29.1	31.1	30.5	40.0	38.9
2011	28.6	28.4	29.4	29.0	39.5	38.4
2012	29.5	29.1	30.5	29.9	39.2	38.5
2013	30.7	29.3	30.9	29.5	39.6	38.4
2014	30.2	29.8	31.6	30.8	40.3	39.0
2015	29.8	29.4	31.5	30.6	40.6	39.1
2016	29.3	28.6	30.7	29.8	40.1	38.5
2017	30.6	29.6	30.7	29.8	40.0	39.7
2018	31.5	30.7	31.6	30.8	39.7	38.8
2019	30.1	29.6	30.3	29.7	40.3	38.5
2020	30.4	29.4	31.0	30.0	40.1	38.3
2021	31.2	31.1	31.4	31.3	40.0	38.1

na = not available

Table 11.7.4. *Nephrops*, Moray Firth (FU 9): Results of the 1993–2022 TV surveys

Year	Stations	Mean density	Abundance	95% confidence interval
		burrows/m²	millions	millions
1993	31	0.16	345	78
1994	29	0.32	702	176
1995			no survey	
1996	27	0.21	465	90
1997	34	0.12	262	55
1998	31	0.15	323	95
1999	52	0.18	400	87
2000	44	0.17	386	98
2001	45	0.16	345	112
2002	31	0.24	521	121
2003	32	0.33	730	314
2004	42	0.29	626	186
2005	42	0.40	869	198
2006	50	0.21	445	124
2007	40	0.24	531	156
2008	45	0.21	481	151
2009	50	0.19	415	140
2010	43	0.18	406	116
2011	37	0.17	372	160
2012	44	0.14	299	90
2013	55	0.21	469	106
2014	52	0.15	331	90
2015	52	0.16	347	84
2016	53	0.18	388	87
2017	55	0.19	412	106
2018	55	0.19	417	126
2019	55	0.17	376	146
2020			no survey	
2021	46	0.30	658	153
2022	45	0.18	396	116

Table 11.7.5. ***Nephrops*****, Moray Firth (FU 9): Summary of TV results for most recent 3 years (2019–2022) showing strata surveyed, numbers of stations in each strata, mean density and observed variance, overall abundance and variance raised to stratum area. Proportion indicates relative amounts of overall raised variance attributable to each stratum.**

Stratum	Area (km²)	Number of Stations	Mean burrow density (no./m²)	Observed variance	Abundance (millions)	Stratum variance	Proportion of total variance
2019 TV survey							
M & SM	169	2	0.39	0.23	66	3279	0.615
MS(west)	682	20	0.12	0.03	84	754	0.141
MS(mid)	698	17	0.18	0.01	123	339	0.064
MS(east)	646	16	0.16	0.04	103	963	0.18
Total	2195	55			376	5335	1
2021 TV survey							
M & SM	169	3	0.42	0.01	71	92	0.016
MS(west)	682	17	0.22	0.07	148	1892	0.322
MS(mid)	698	12	0.31	0.03	214	1151	0.196
MS(east)	646	14	0.35	0.09	225	2738	0.466
Total	2195	46			658	5872	1
2022 TV survey							
M & SM	169	3	0.18	0.04	30	350	0.104
MS(west)	682	15	0.17	0.05	115	1615	0.482
MS(mid)	698	13	0.118	0.004	82.6	165	0.049
MS(east)	646	14	0.26	0.04	169	1221	0.364
Total	2195	46			396	3350	1

Table 11.7.6. *Nephrops*, Moray Firth (FU 9): Adjusted TV survey abundance, landings, discard rate (proportion by number), dead discard rate (proportion by number) and estimated harvest ratio 1993–2022.

Year	Adjusted abundance (millions)	95% CI	Harvest ratio	Landings numbers	Discards numbers	Removals numbers	Landings (tonnes)	Discards (tonnes)	Dead Discards (tonnes)	Discard rate	Mean weight in landings	Mean weight in discards	Dead discard rate
1993	345	78	26	77	19	91	1809	214	161	19.8	23.42	11.26	15.6
1994	702	176	11.4	69	15	80	1537	153	115	17.8	22.25	10.21	14.0
1995	NA	NA	NA	62	72	116	1279	502	376	54	20.59	6.93	47
1996	465	90	21	68	41	98	1451	492	369	37	21.4	12.11	31
1997	262	55	33	71	22	87	1447	230	172	24	20.43	10.42	18.9
1998	323	95	18.1	50	11	58	1032	89	67	17.6	20.47	8.29	13.8
1999	400	87	12.8	46	6	51	1009	55	41	12.0	21.79	8.63	9.3
2000	386	98	20	61	23	78	1539	269	201	27	25.44	11.73	22
2001	345	112	19.3	58	11	66	1401	125	94	16.3	24.18	11.04	12.8
2002	521	121	11.7	41	27	61	1132	220	165	40	27.68	8.18	33
2003	730	314	7.1	46	7	52	1080	70	52	13.7	23.32	9.51	10.6
2004	626	186	10.5	48	23	66	1333	272	204	33	27.57	11.62	27
2005	869	198	8.8	67	12	76	1605	122	92	15.0	23.84	10.31	11.7
2006	445	124	20	81	12	90	1805	117	87	12.8	22.34	9.86	9.9
2007	531	156	16.0	80	7	85	1843	95	72	7.9	23.04	13.95	6.0
2008	481	151	13.7	60	8	66	1515	74	55	11.4	25.29	9.60	8.8
2009	415	140	11.6	45	4	48	1067	33	25	7.6	23.46	8.72	5.8
2010	406	115	11.5	39	10	47	1063	104	78	19.8	26.94	10.63	15.7
2011	372	161	18.9	63	10	70	1391	102	77	13.9	21.63	10.12	10.8
2012	299	90	13.7	37	6	41	866	54	41	13.2	23.16	9.72	10.3
2013	469	106	5.8	26	1	27	623	10	8	3.3	24.95	11.21	2.5
2014	331	90	14.7	43	7	49	1253	87	65	14.6	28.94	11.79	11.3

Year	Adjusted abundance (millions)	95% CI	Harvest ratio	Landings numbers	Discards numbers	Removals numbers	Landings (tonnes)	Discards (tonnes)	Dead Discards (tonnes)	Discard rate	Mean weight in landings	Mean weight in discards	Dead discard rate
2015	347	84	9.1	28	5	32	816	56	42	15.1	29.1	11.35	11.8
2016	388	87	12.7	42	9	49	1146	95	71	18.0	26.83	10.16	14.2
2017	412	106	10.5	42	1	43	1143	12	9	2.6	26.34	10.74	1.99
2018	417	126	11.7	48	0	49	1397	4	3	0.87	28.86	9.58	0.66
2019	376	146	14.8	55	1	56	1356	10	8	1.86	25.13	9.84	1.40
2020	NA	NA	7.4^	36	2	38	963	17	13	5.5	26.63	7.88	4.2
2021	658	153	6.4	41	1	42	1221	7	5	1.64	29.41	10.14	1.23
2022	396	116	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

^ The harvest rate in 2020 was calculated using an interpolated value for abundance (average of 2019 and 2021).

Table 11.8.1. *Nephrops*, Noup (FU 10): Nominal landings (tonnes) of *Nephrops*, 1981–2021, as reported to the WG.

Year	*Nephrops* Trawl	Other trawl	Creel	Sub Total	Other UK	Total
1981	12	23	0	35	0	35
1982	12	7	0	19	0	19
1983	10	6	0	16	0	16
1984	76	35	0	111	0	111
1985	1	21	0	22	0	22
1986	45	22	0	67	0	67
1987	13	32	0	45	0	45
1988	23	53	0	76	0	76
1989	24	60	0	84	0	84
1990	101	117	0	218	0	218
1991	111	86	0	197	0	197
1992	58	130	0	188	0	188
1993	200	176	0	376	0	376
1994	307	187	0	494	0	494
1995	163	116	0	279	0	279
1996	181	164	0	345	0	345
1997	185	131	1	317	0	317
1998	184	72	0	256	0	256
1999	211	67	0	278	0	278
2000	196	78	0	274	0	274
2001	88	89	0	177	0	177
2002	246	157	0	403	0	403
2003	258	78	0	336	0	336
2004	174	54	0	228	0	228
2005	81	84	0	165	0	165
2006	44	89	0	133	0	133
2007	46	107	0	153	0	153
2008	74	98	0	172	0	172
2009	24	63	0	87	0	87
2010	4	35	0	39	0	39
2011	27	41	0	68	0	68
2012	2	11	0	13	0	13
2013	4	12	0	16	0	16
2014	3	11	1	15	0	15
2015	1	14	0	15	0	15
2016	9	14	0	23	0	23

Year	*Nephrops* Trawl	Other trawl	Creel	Sub Total	Other UK	Total
2017	0	9	0	9	0	9
2018	0	4	0	4	0	4
2019	0	21	0	21	0	21
2020	0	11	0	11	0	11
2021*	0	14	0	14	0	14

*** provisional**

Table 11.8.2. *Nephrops*, Noup (FU 10): Landings (tonnes), effort (days fishing) and LPUE (kg/day) for UK bottom trawlers landing in Scotland and fishing *Nephrops* with codend mesh sizes of 70 mm or above, 2000–2021.

Year	Landings (tonnes)	Effort (days)	LPUE (kg/day)
2000	274	1622	168.9
2001	177	1383	128.0
2002	403	2036	197.9
2003	336	1434	234.3
2004	228	899	253.6
2005	165	730	226.0
2006	133	612	217.3
2007	153	591	258.9
2008	172	746	230.6
2009	87	871	99.9
2010	39	813	48.0
2011	68	776	87.6
2012	13	574	22.6
2013	16	454	35.2
2014	14	673	20.8
2015	15	514	29.2
2016	23	520	44.2
2017	9	568	15.8
2018	4	744	5.4
2019	21	642	32.7
2020	11	339	32.4
2021*	14	442	31.7

*** provisional**

Table 11.8.3. *Nephrops*, Noup (FU 10): Mean sizes (CL mm) above and below 35 mm of male and female *Nephrops* in landings, 1997–2021. No females in samples in 2010 and no sampling in 2015, 2018 and 2020.

Year	Landings			
	<35 mm CL		=>35 mm CL	
	Males	Females	Males	Females
1997	29.7	28.3	40.4	38.2
1998	30.4	29.8	38.8	38.6
1999	30.4	30.1	39.2	37.8
2000	31.8	30.1	38.2	39.1
2001	31.4	29.5	38.7	37.9
2002	30.8	29.9	39.7	38.5
2003	29.3	30.4	39.9	38.5
2004	31.4	30.0	40.2	38.8
2005	31.0	29.3	39.3	38.4
2006	30.8	30.2	40.4	38.7
2007	30.7	29.4	40.2	38.7
2008	31.9	30.6	40.3	39.3
2009	33.2	33.2	42.6	42.7
2010	33.3	na	42.6	na
2011	32.8	32.7	43.3	40.1
2012	32.4	31.8	40.7	40.1
2013	34.0	32.4	43.7	39.7
2014	33.3	33.0	46.6	43.2
2015	na	na	na	na
2016	33.2	32.1	38.5	43.9
2017	31.0	31.6	38.0	41.5
2018	na	na	na	na
2019	32.6	32.0	38.6	46.0
2020	na	na	na	na
2021	32.4	31.2	39.7	38.2

na = not available

Table 11.8.4. *Nephrops*, Noup (FU 10): Results of the 1994, 1999, 2006, 2007, 2014 and 2019 TV surveys (absolute conversion factor = 1.35, from Fladen).

Year	Stations	Mean density	Abundance	95% confidence interval
		burrows/m²	millions	millions
1994	10	0.47	185	67
1995		no survey		
1996		no survey		
1997		no survey		
1998		no survey		
1999	10	0.22	89	31
2000		no survey		
2001		no survey		
2002		no survey		
2003		no survey		
2004		no survey		
2005	2	poor visibility, limited survey - see text		
2006	7	0.13	55	35
2007	9	0.11	44	19
2008		no survey		
2009		no survey		
2010		no survey		
2011		no survey		
2012		no survey		
2013		no survey		
2014	12	0.13	51	22
2015		no survey		
2016		no survey		
2017		no survey		
2018		no survey		
2019	11	0.22	90	46
2020		no survey		
2021		no survey		
2022		no survey		

Table 11.9.1. *Nephrops* Norwegian Deep (FU 32): Landings (tonnes) by country, 1993–2021, estimated Danish discards (2003–2021), and TAC (EU) (2004-2022).

Year	Denmark	Danish discards		Norway			Sweden	UK	Netherlands	Total	TAC
		dead	live	Trawl	Creel	Sub-total					
1993	220			102	1	103		16		339	
1994	584			161	0	161		10		755	
1995	418			68	1	69		2		489	
1996	868			73	1	74		10		952	
1997	689			56	8	64		7		760	
1998	743			88	1	89		4		836	
1999	972			119	15	134		13		1119	
2000	871			143	0	143	37	34		1085	
2001	1026			72	13	85	26	53		1190	
2002	1043			42	21	63	13	52		1171	
2003	996	145	48	68	11	79	1	14		1090	
2004	835	200	67	72	8	80	1	6		922	1000
2005	979	194	65	89	13	102	2	6		1089	1000
2006	939	126	42	62	19	81	1	7	5	1033	1300
2007	652	64	21	77	20	97	5	1		755	1300
2008	505			112	30	142	24	4		675	1300
2009	331	29	10	107	31	138	2	6		477	1200
2010	282	36	12	82	41	123	1	1		407	1200
2011	322			29	40	69	1	3		395	1200
2012	234	35	12	25	50	75	1	0		310	1200
2013	128	51	17	18	45	63	0	0		191	1000
2014	143	4	1	15	47	62	0	0		205	1000
2015	110	5	2	8	74	82	0	0		192	1000
2016	80	1	0	7	90	97	0	0	1	178	1000
2017	53	1	0	9	85	94	0	0	0	147	1000
2018	34	0	0	10	93#	103	0	0		137	800
2019	91	1	0	22	78#	100	0	0	0	191	600
2020	81	1	0	25	69#	94	3	1	0	179	600
2021*	129	1	0	26	54#	80	7		0	216	200
2022											200

*** Provisional**

 # Contains some landings from gillnets

Table 11.9.2. *Nephrops* Norwegian Deep (FU 32): Danish effort (kW days, days at sea, fishing days) and LPUE (kg/kW day) for bottom trawlers catching *Nephrops*, 1993–2021.

Year	kW days ('1000)	Days at sea	Fishing days	LPUE
1993	888	1974	1542	248
1994	1439	3572	2824	406
1995	1010	2464	1950	414
1996	1732	4000	3307	501
1997	1982	4189	3466	348
1998	1467	3245	2654	506
1999	2262	4658	3790	430
2000	2662	5068	4161	327
2001	3510	6426	5467	292
2002	3102	5737	4859	336
2003	3500	6294	5416	285
2004	2443	4298	3657	342
2005	2787	5078	4353	351
2006	3023	5274	4516	311
2007	1782	3052	2557	366
2008	1682	2623	2349	300
2009	1496	2334	2304	221
2010	1090	1795	1753	259
2011	1136	1840	1188	283
2012	907	1474	1265	258
2013	862	1449	1227	149
2014	752	1233	1105	190
2015	574	924	793	192
2016	462	728	644	173
2017	410	602	521	129
2018	313	441	387	109
2019	712	996	888	128
2020	628	892	773	129
2021	462	577	604	279

Table 11.9.3. *Nephrops* Norwegian Deep (FU 32): Biomass index from Norwegian bottom trawl survey (shrimp survey) in FU 32 (mean, SD, 25th percentile, median, and 75th percentile), for 2006–2022. Data from the 2016 survey were discarded due to technical problems with the gear that year.

Year	mean	SD	25th percentile	median	75th percentile
2006	1447	760	913	1274	1796
2007	992	335	758	942	1169
2008	297	120	214	275	356
2009	293	106	217	275	348
2010	586	177	464	562	687
2011	406	125	315	390	475
2012	718	310	505	653	865
2013	447	151	337	424	528
2014	390	336	175	296	492
2015	610	281	408	549	756
2016	na	na	na	na	na
2017	426	126	203	264	346
2018	318	104	338	407	498
2019	174	63	246	302	373
2020	139	49	129	163	206
2021	134	57	104	132	167
2022	426	126	94	124	163

Table 11.10.1 *Nephrops* in FU 33: (Off Horns Reef) Landings (tonnes) by country, 1993–2021.

Year	Belgium	Denmark	Germany	Netherl.	UK	Total *
1993	0	159		na	1	160
1994	0	137		na	0	137
1995	3	158		3	1	164
1996	1	74		2	0	77
1997	0	274		2	0	276
1998	4	333	8	12	1	358
1999	22	683	14	12	6	738
2000	13	537	12	39	9	610
2001	52	667	11	61	+	791
2002	21	772	13	51	4	861
2003	15	842	4	67	1	929
2004	37	1097	24	109	1	1268
2005	16	803	31	191	9	1050
2006	97	710	151	314	15	1288
2007	118	610	201	496	42	1467
2008	130	362	160	386	58	1096
2009	121	231	150	491	170	1163
2010	56	180	206	295	69	806
2011	163	396	202	403	28	1191
2012	181	394	132	376	2	1084
2013	156	310	174	304	2	946
2014	229	387	161	360	9	1146
2015	299	371	142	187	4	1003
2016	430	642	201	320	43	1636
2017	423	511	197	336	5	1472
2018	280	48	210	236	2	776
2019	462	220	329	599	2	1612
2020	397	164	128	489	7	1186
2021**	287	349	193	541	0.5	1371

na = not available; + < 0.5 tonnes

*** Totals for 1993–94 exclusive of landings by the Netherlands**

**** Preliminary**

Table 11.10.2. *Nephrops*, Off Horn's Reef (FU 33): Results of the 2017 to 2021 TV surveys (absolute conversion factor = 1.1, from FU 3 & 4).

Year	Stations	Mean density	Abundance	95% confidence interval
		burrows/m²	millions	millions
2017	59	0.13	728	137
2018	85	0.07	427	84
2019	60	0.07	417	117
2021	28	0.22	1279	308

Table 11.11.1. *Nephrops*, Devil's Hole (FU 34): Nominal landings (tonnes) of *Nephrops* 1986–2021 as reported to the WG. Scottish data only from 1986 to 2009.

Year	UK Scotland				UK (E, W & NI)	Denmark	Netherlands	Total
	Nephrops trawl	Other trawl	Creel	Sub-total				
1986	20	3	0	23				23
1987	2	3	0	5				5
1988	1	1	0	2				2
1989	15	13	0	28				28
1990	20	6	0	26				26
1991	64	21	0	85				85
1992	78	28	0	106				106
1993	23	21	0	44				44
1994	79	50	0	129				129
1995	37	95	0	132				132
1996	40	89	0	129				129
1997	30	70	0	100				100
1998	15	73	0	88				88
1999	80	122	0	202				202
2000	89	95	0	184				184
2001	159	112	0	271				271
2002	240	103	0	343				343
2003	518	157	0	675				675
2004	398	90	0	488				488
2005	253	125	0	378				378
2006	359	89	0	448				448
2007	649	68	0	717				717
2008	844	93	0	937				937
2009	1297	8	0	1305				1305
2010	816	22	0	838	25	1	1	865
2011	406	16	0	422	6	4		432
2012	546	4	0	550	37	10		597
2013	65	41	0	106	11	3		120

Year	UK Scotland				UK (E, W & NI)	Denmark	Netherlands	Total
	Nephrops trawl	Other trawl	Creel	Sub-total				
2014	293	14	0	307	13			320
2015	383	18	0	401	39	<0.5		440
2016	738	6	0	744	36			780
2017	398	122	0	520	28			548
2018	218	86	0	304	14			318
2019	1027	103	0	1130	37			1167
2020	855	55	0	910	70			980
2021*	799	40	0	839	36			875

*** Provisional**

Table 11.11.2. *Nephrops*, Devils Hole (FU 34): Landings, effort (days fishing) and LPUE (kg/day) for UK bottom trawlers landing in Scotland and fishing *Nephrops* with cod end mesh sizes of 70 mm or above, 2000–2021.

Year	Landings (tonnes)	Effort (days)	LPUE (kg/day)
2000	184	3391	54.3
2001	271	3142	86.3
2002	343	2022	169.6
2003	675	2614	258.2
2004	488	1551	314.6
2005	378	1545	244.7
2006	448	1440	311.1
2007	717	1824	393.1
2008	937	1673	560.1
2009	1305	1921	679.3
2010	838	1465	572.0
2011	422	1041	405.4
2012	550	1255	438.2
2013	106	438	242.0
2014	307	758	405.0
2015	401	1222	328.2
2016	744	1640	453.7
2017	520	1088	477.9
2018	304	620	490.3
2019	1130	1291	875.3
2020	910	1152	789.9
2021*	839	1004	835.7

*** Provisional**

Table 11.11.3. *Nephrops*, Devil's Hole (FU 34): Mean sizes (CL mm) above and below 35 mm of male and female *Nephrops* in Scottish catches and landings, 2006–2021. Samples not available in 2012 and 2013.

Year	Landings			
	< 35 mm CL		=> 35 mm CL	
	Males	Females	Males	Females
2006	29.7	29.8	39.7	38.1
2007	30.4	28.7	40.5	39.2
2008	31	30.5	40.3	39.6
2009	31.7	31.1	41.3	40.6
2010	32.1	29.7	39.1	38.8
2011	31.7	30.7	43.7	40.4
2012	na	na	na	na
2013	na	na	na	na
2014	33.0	34.0	42.0	41.4
2015	33.0	31.4	41.2	39.9
2016	31.7	30.6	41.0	39.1
2017	32.1	31.1	41.9	41.8
2018	32.3	31.1	43.8	40.7
2019	32.2	31.4	39.8	40.9
2020	32.0	30.6	39.9	41.9
2021	31.7	31.0	40.2	40.8

na = not available

Table 11.11.4. *Nephrops*, Devil's Hole (FU 34): Results of the TV surveys (2003–2021).

Year	Stations	Mean density	95% confidence interval
		burrows/m²	burrows/m²
2003	20	0.09	0.02
2004		no survey	
2005	29	0.09	0.04
2006		no survey	
2007		no survey	
2008		no survey	
2009	12	0.28	0.13
2010	19	0.24	0.08
2011	14	0.16	0.09
2012	15	0.14	0.06
2013		no survey	
2014	13	0.13	0.04
2015	17	0.16	0.06
2016		no survey	
2017	16	0.09	0.04
2018	15	0.21	0.09
2019	20	0.29	0.09
2020		no survey	
2021	10	0.28	0.11
2022		no survey	

Table 11.12.1. *Nephrops* landings (tonnes) from Subarea 27.4 outside FUs.

Year	Belgium	Denmark	Germany	Netherlands	Sweden	UK (England)	UK (Scotland)	Total
2011	411	53	208	137	0	36	322	1167
2012	57	27	132	128	0	44	202	590
2013	31	8	84	152	0	57	78	409
2014	51	31	115	69	0	28	98	392
2015	173	25	105	154	0	36	117	610
2016	217	23	219	290	0	53	164	966
2017	270	35	352	319	0	61	158	1195
2018	121	29	143	118	0	33	181	625
2019	96	25	190	184	0	34	194	724
2020	83	45	77	112	0	55	160	531
2021	109	89	101	127	0	52	158	636

Table 11.12.2. *Nephrops* reported discards (tonnes) from Subarea 27.4 outside FUs.

Year	Belgium	Denmark	Germany	Netherlands	Sweden	UK (England)	UK (Scotland)	Total
2012	-	18.2	-	-	-	-	-	18.2
2013	-	-	-	-	-	-	-	-
2014	-	0.5	-	-	-	-	-	0.5
2015	-	1.4	-	-	-	-	-	1.4
2016	-	0.1	-	550.6	-	-	1.8	552.5
2017	-	0.1	-	62.9	-	-	8.2	71.2
2018	-	0.1	-	176.4	-	-	-	176.5
2019	-	0.3	-	605.0	-	-	0.7	606.1
2020	-	0.3	-	114.9	-	-	-	115.2
2021	-	0.3	-	41.6	-	-	-	41.9

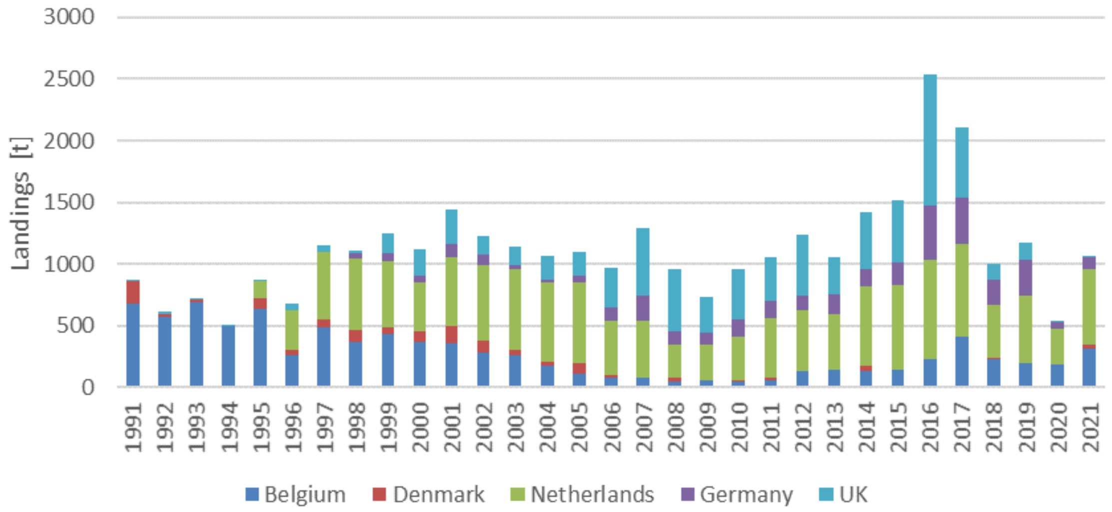


Figure 11.3.1. FU 5 Botney Cut/Silver Pit: Annual landings by country.

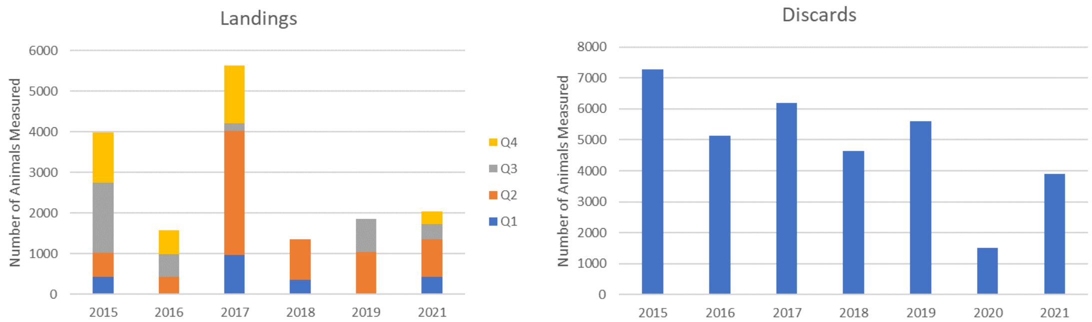


Figure 11.3.2. FU 5 Botney Cut/Silver Pit: Number of length measurements in Dutch landings and discards.

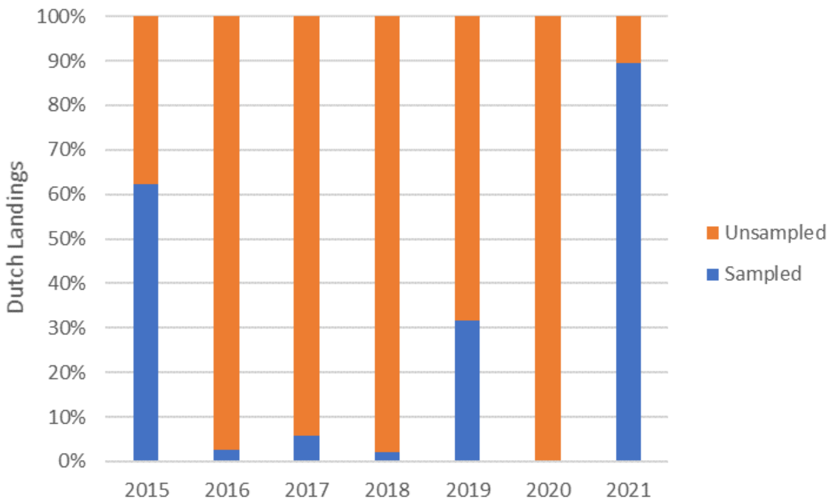


Figure 11.3.3. FU 5 Botney Cut/Silver Pit: Annual UK landings as percent of total international landings (blue), and number of UK *Nephrops* directed trawlers (red).

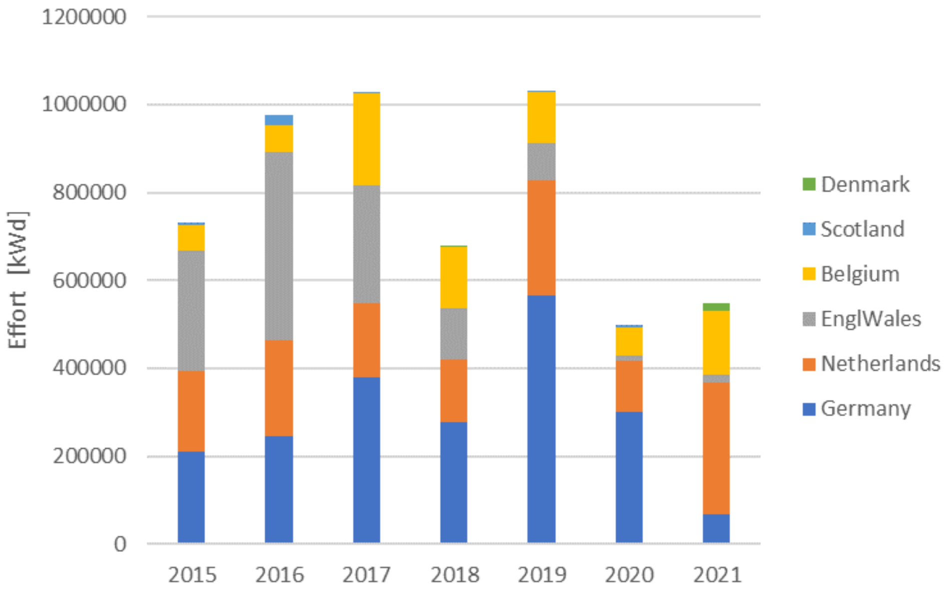


Figure 11.3.4. FU 5 Botney Cut/Silver Pit: Annual targeted effort by country, associated with landings from OTB_CRU_70-99_0_0_all metier.

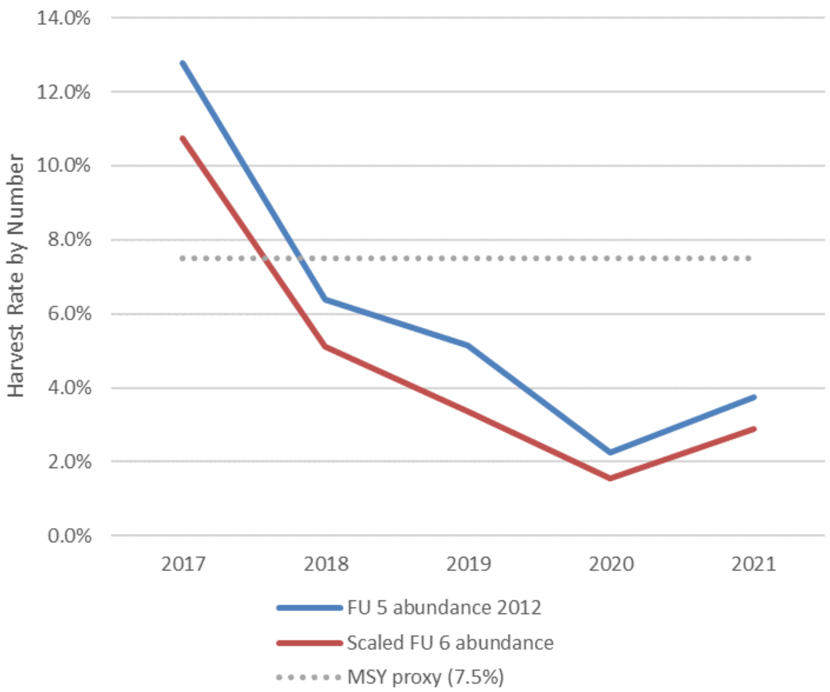


Figure 11.3.5. FU 5 Botney Cut/Silver Pit: Harvest rates based on annual landings and dead discards, together with 2019 & 2021 mean weights in landings and discards, and the 2012 abundance in FU 5 (blue line), or the scaled annual abundance in FU 6 (red line; see Section 11.3.5).

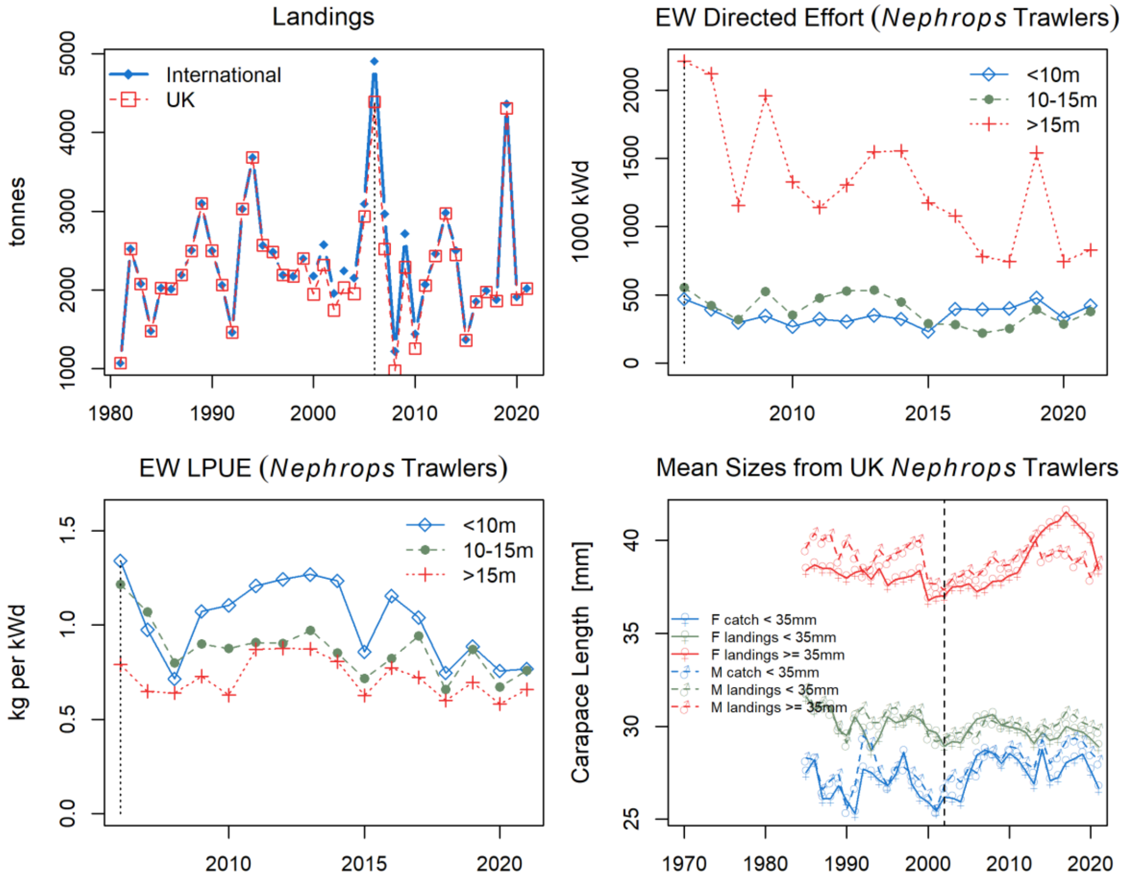


Figure 11.4.1. *Nephrops* in FU 6: Landings, directed effort, directed LPUE and mean sizes of different catch components.

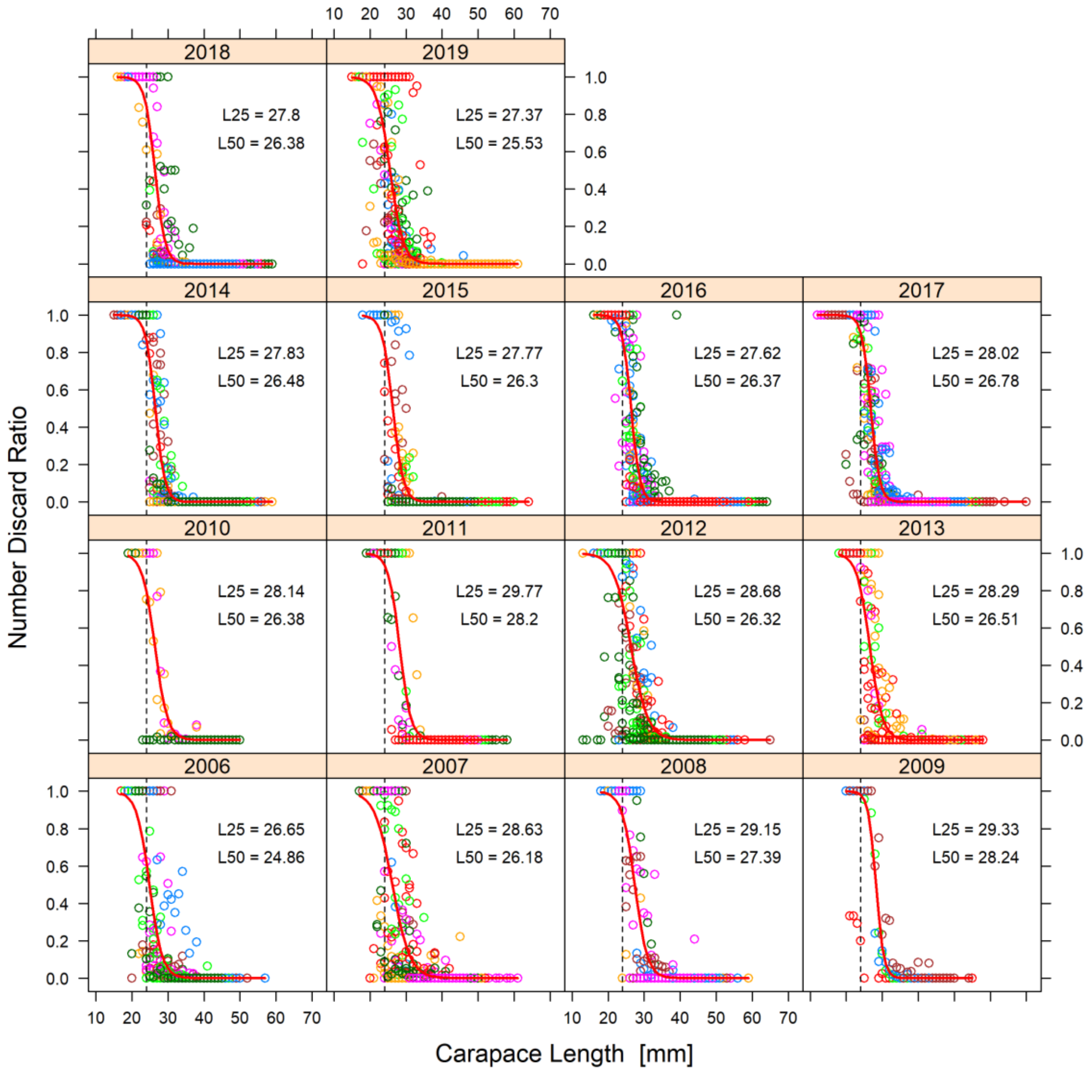


Figure 11.4.2. *Nephrops* in FU 6, annual discard ogives: The different point shapes represent different sampling trips within any year.

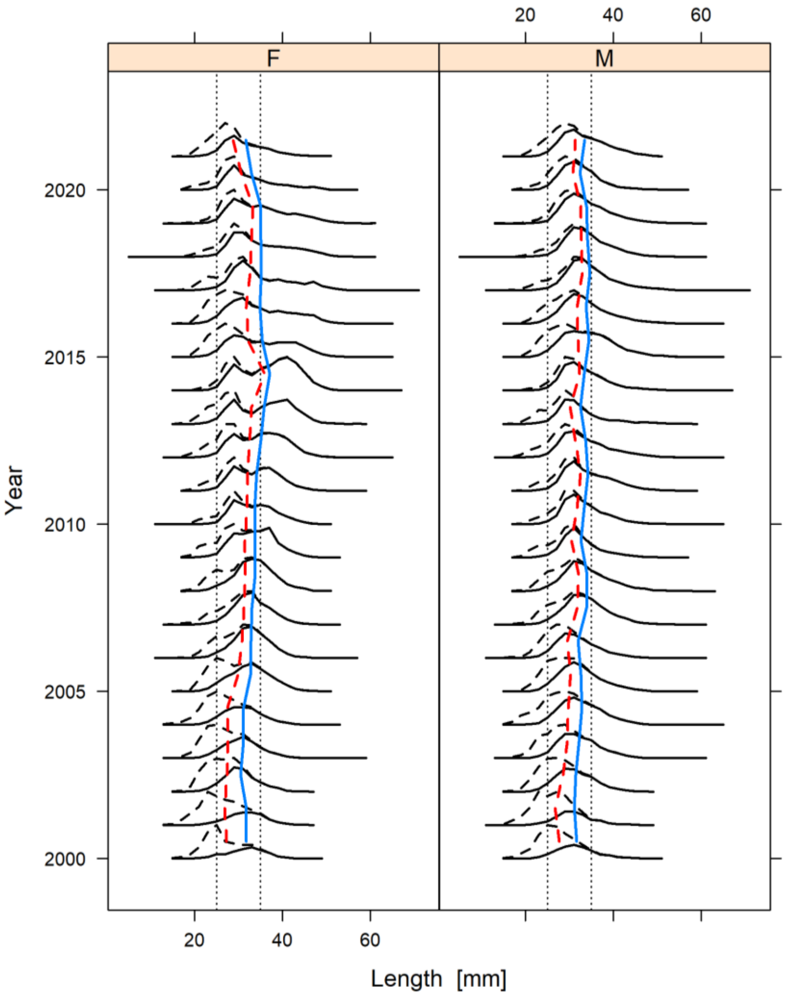


Figure 11.4.3. ***Nephrops*** **in FU 6: Annual length frequencies for landings (solid black lines) and catch (dashed black lines) by sex, together with mean size of the landings (blue lines) and catch (red lines). The minimum conservation reference size (MCRS) of 25 mm carapace length, and 35 mm reference size are indicated by the vertical dotted lines.**

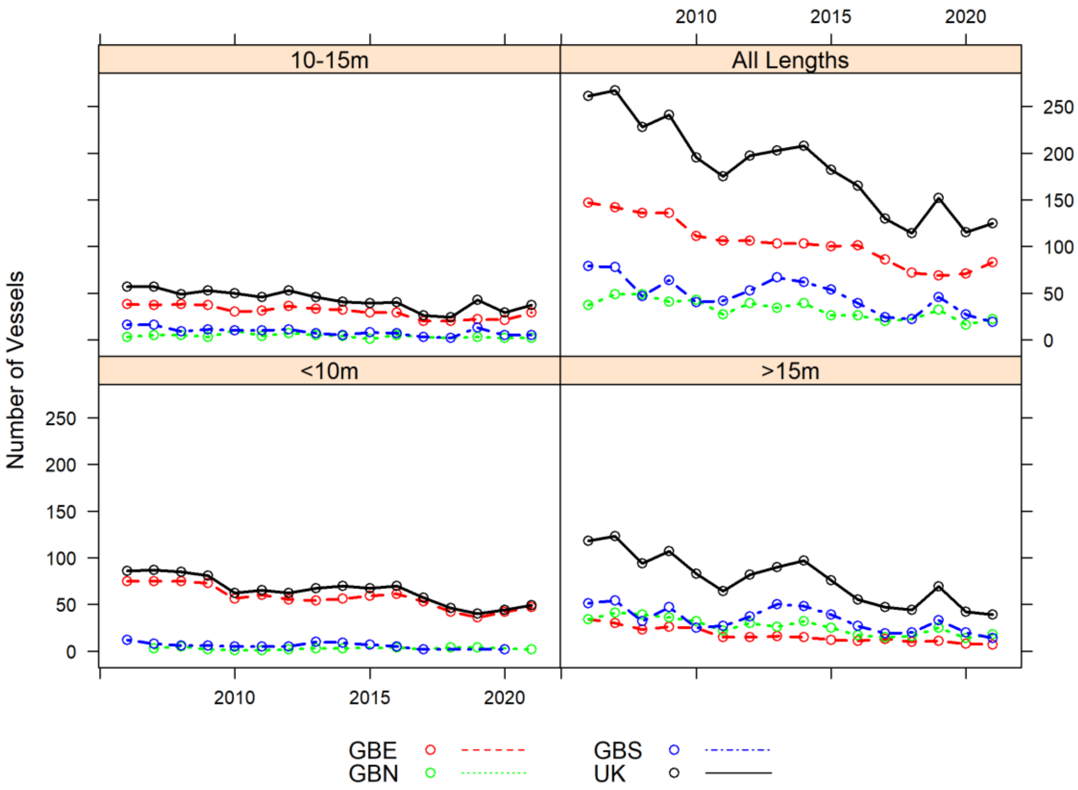


Figure 11.4.4. ***Nephrops*** **in FU 6: Number of participating UK vessels by length class.**

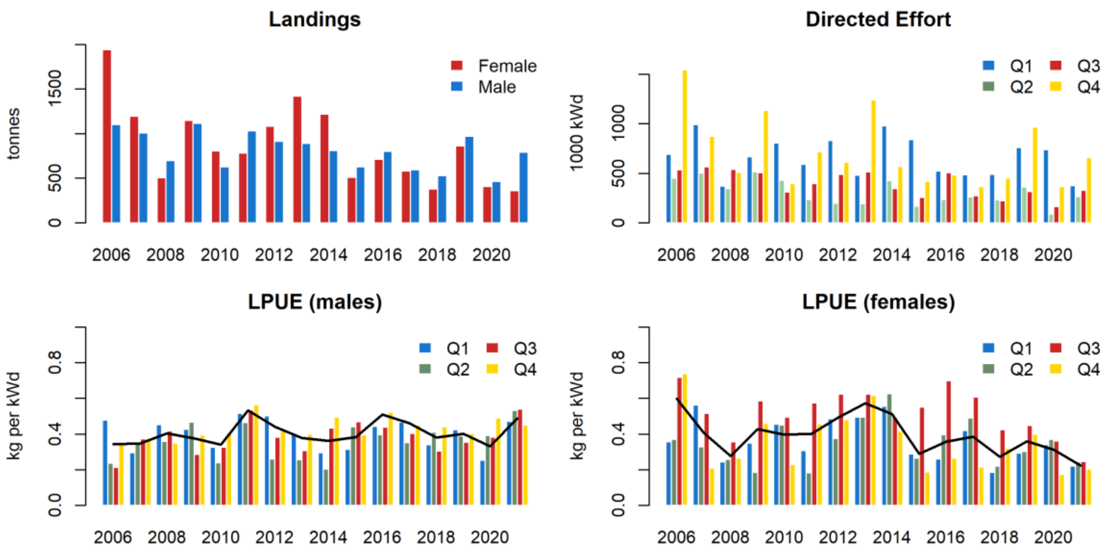


Figure 11.4.5. ***Nephrops*** **in FU 6: Annual landings by sex, directed effort by quarter, and LPUE by sex and quarter.**

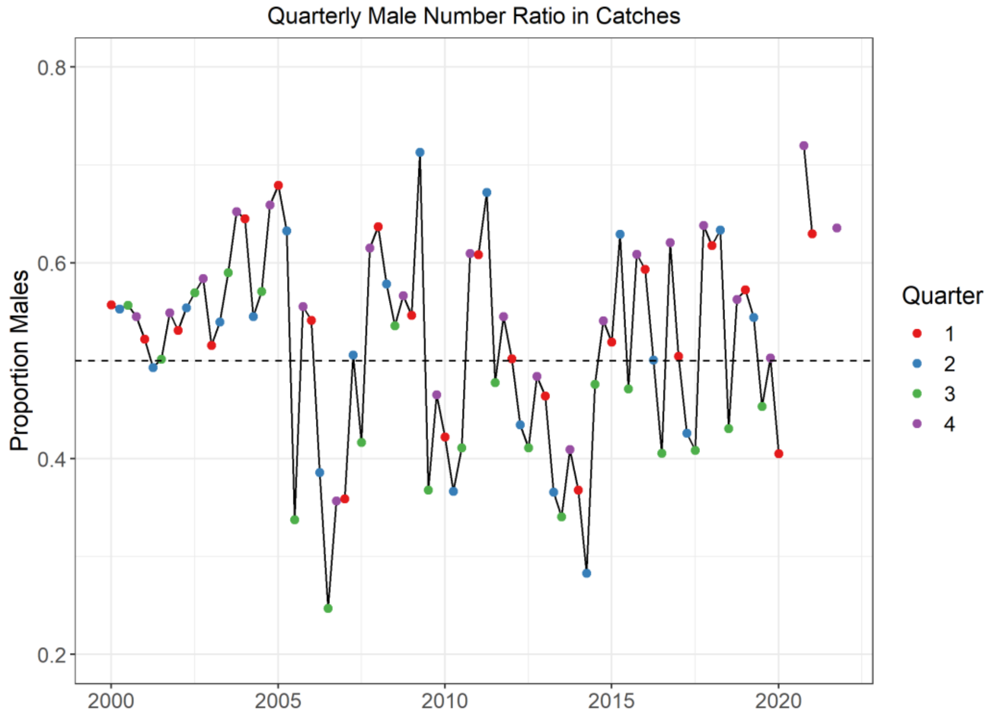


Figure 11.4.6. *Nephrops* in FU 6: Quarterly sex ratio in the catches. Insufficient sampling data are available for quarters 2 to 4 in 2020.

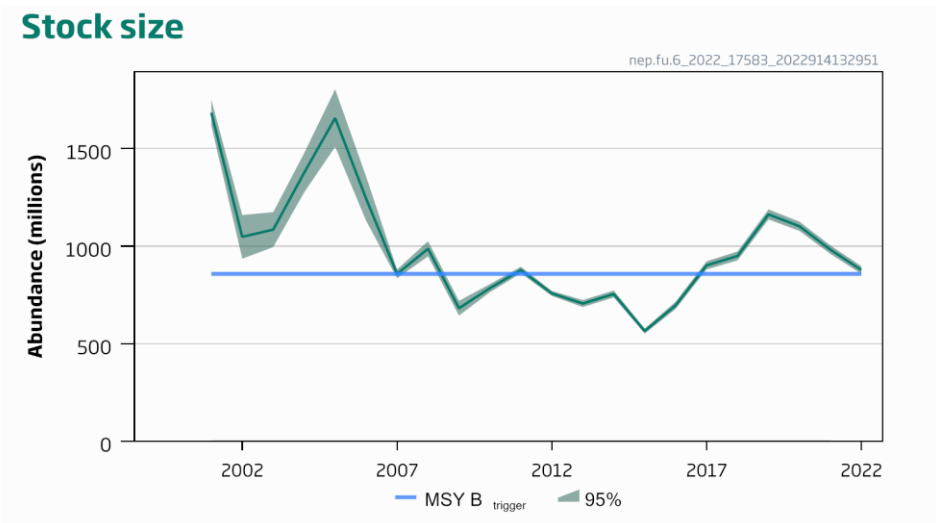


Figure 11.4.7. *Nephrops* in FU 6: Time series of UWTV results. The blue line is the proxy for MSY $B_{trigger}$, defined as the abundance estimate for 2007. The shading around the abundance line indicates the 95% confidence interval (based on random resampling).

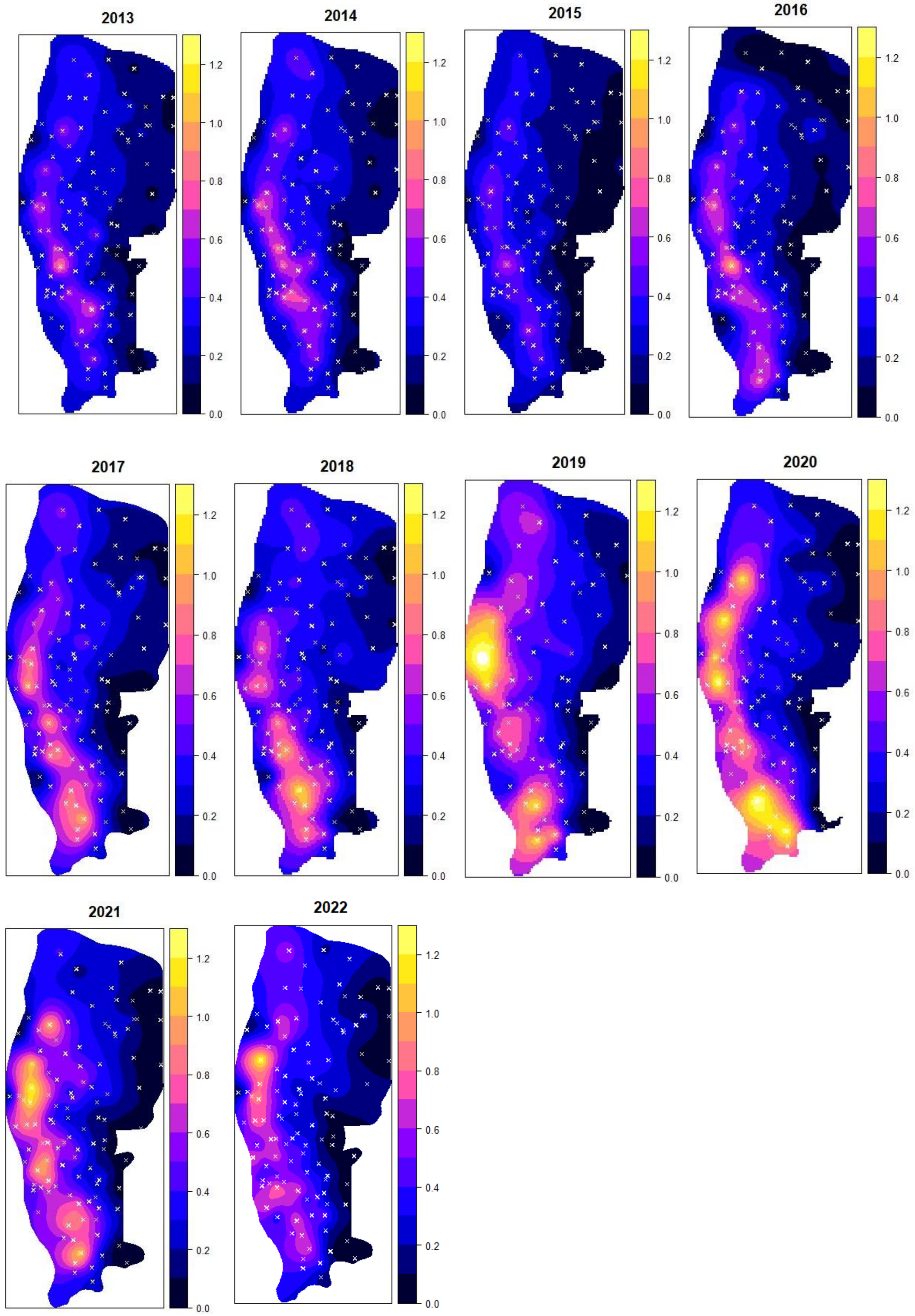


Figure 11.4.8. ***Nephrops*** **in FU 6: Number density (burrows per m²) from the UWTV survey.**

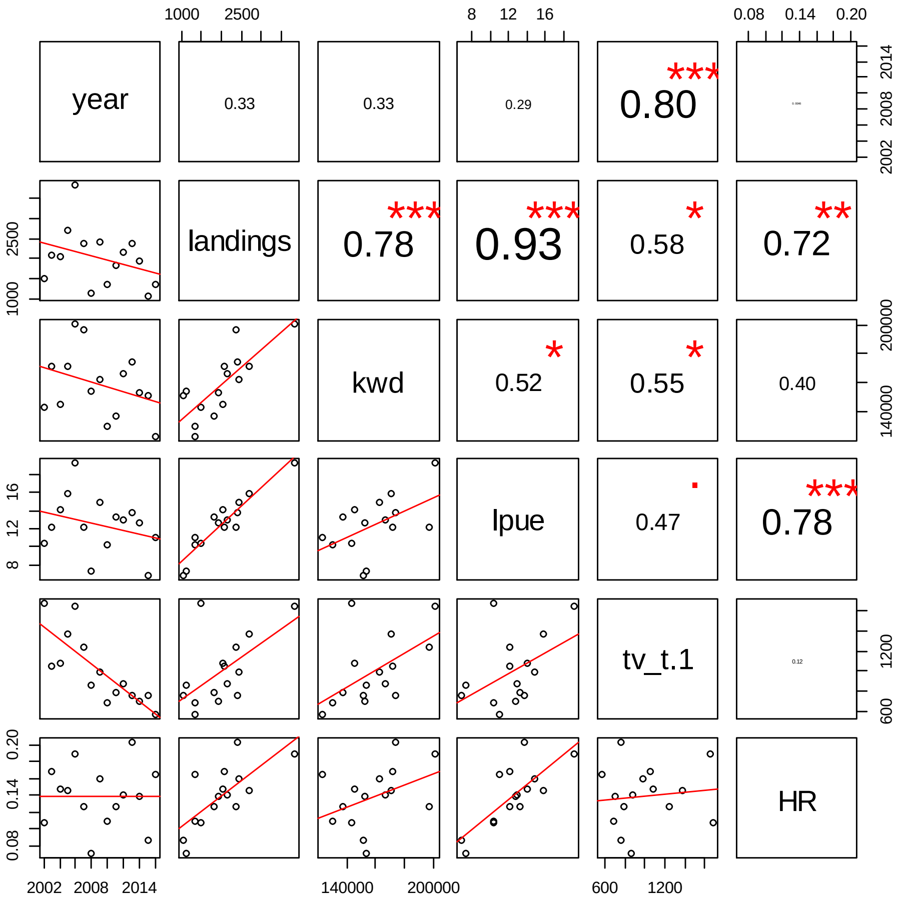


Figure 11.4.9. ***Nephrops*** **in FU 6. Scatterplot matrices of** ***Nephrops*** **metrics, where the UWTV survey lagged by 1 year (i.e., UWTV survey in the year preceding the fishery statistics).**

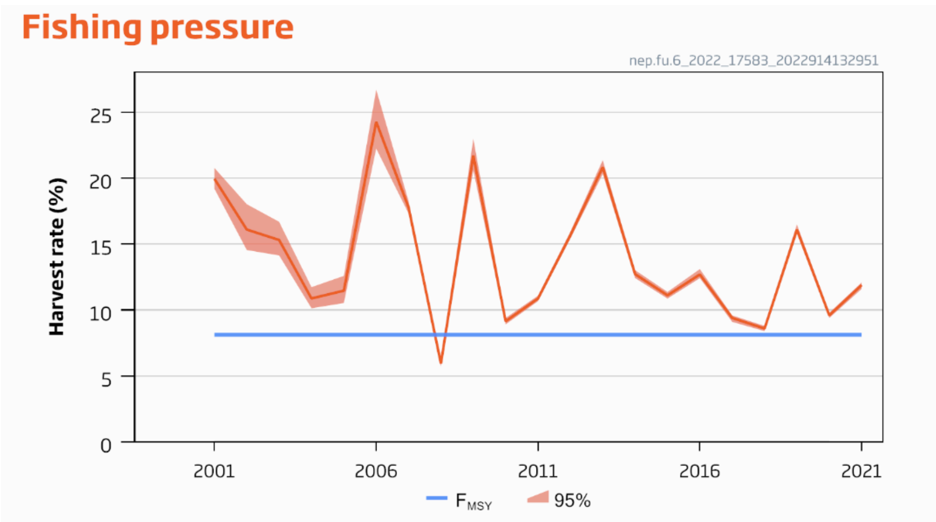


Figure 11.4.10. ***Nephrops*** **in FU 6: Observed harvest rate (total removals divided by abundance estimate).**

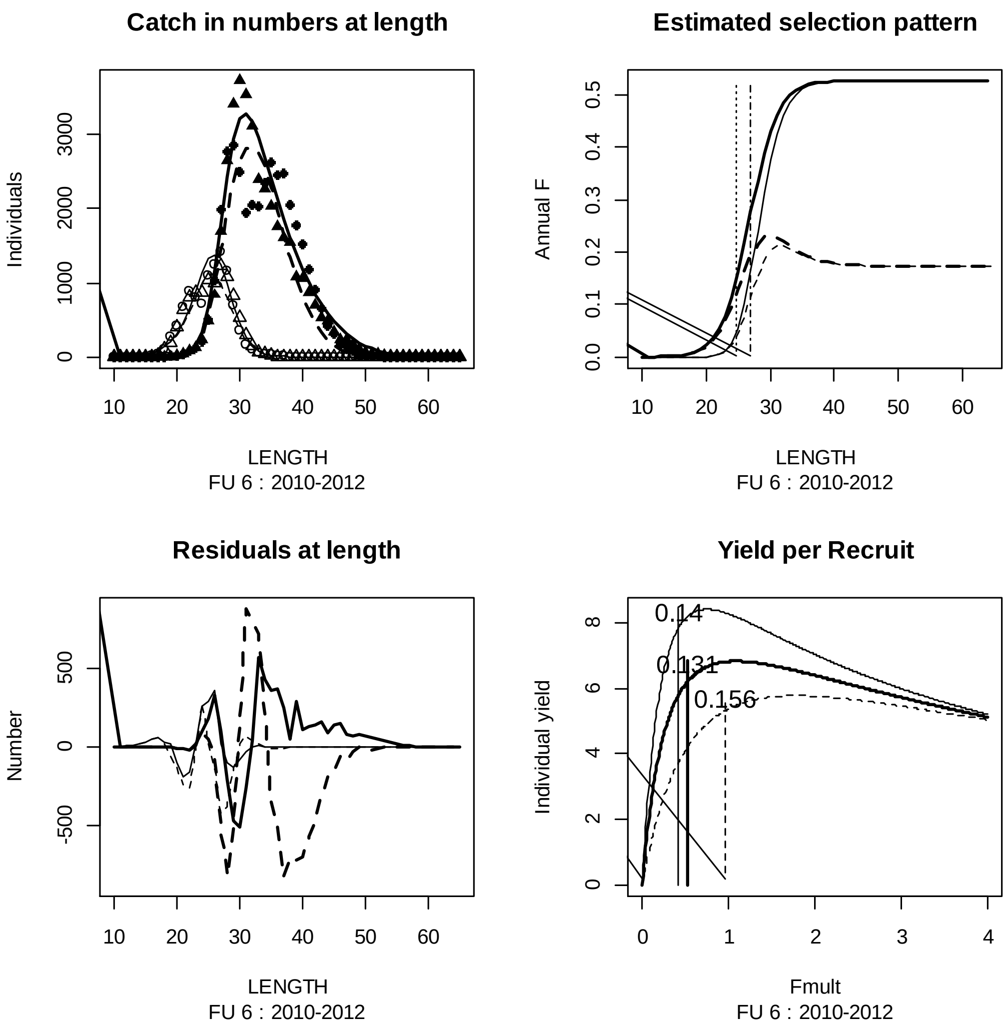


Figure 11.4.11. ***Nephrops*** **in FU 6: Separable Cohort analysis model fit. Solid lines are for males, dashed lines are females, thick lines represent the landings component, the thin lines represent the discarded component. The top left panel gives observed and predicted numbers at length in the discards and landings, top right gives the fishing mortality at length with the vertical lines representing length at 25% selection and 50% selection. Bottom left shows residual numbers (observed-expected) at length. The bottom right gives the Yield Per recruit against fishing mortality, the thick solid line gives the combined value and vertical lines represent $F_{0.1}$ for the three curves.**

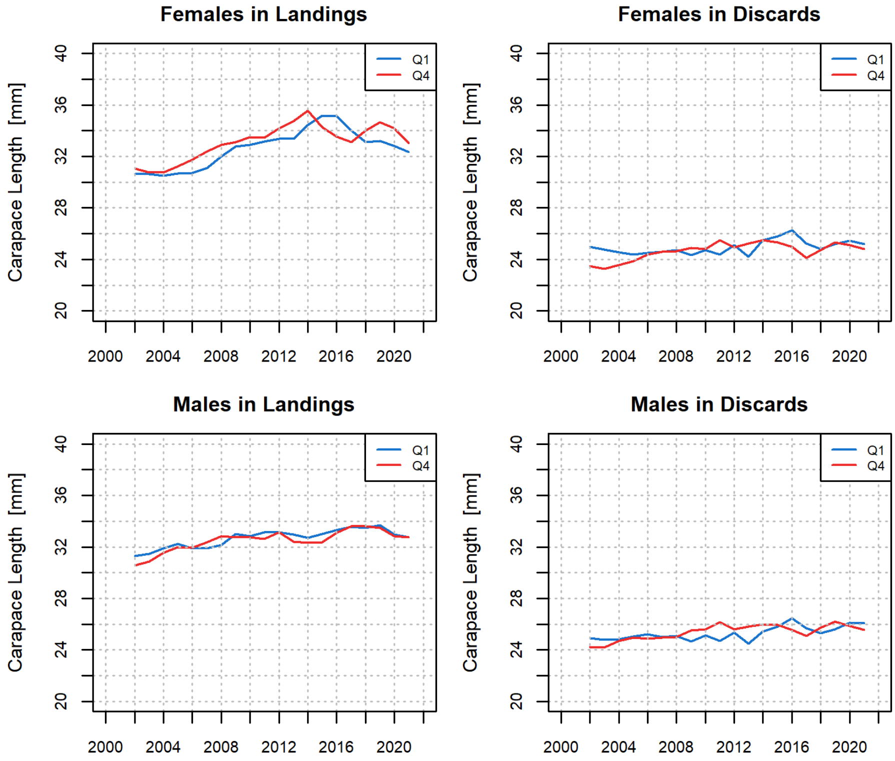


Figure 11.4.11. *Nephrops* in FU 6: Average carapace lengths of females and males in landings and discards in quarters one and four. Values are three-year running means in periods ending in the year for which they are plotted.

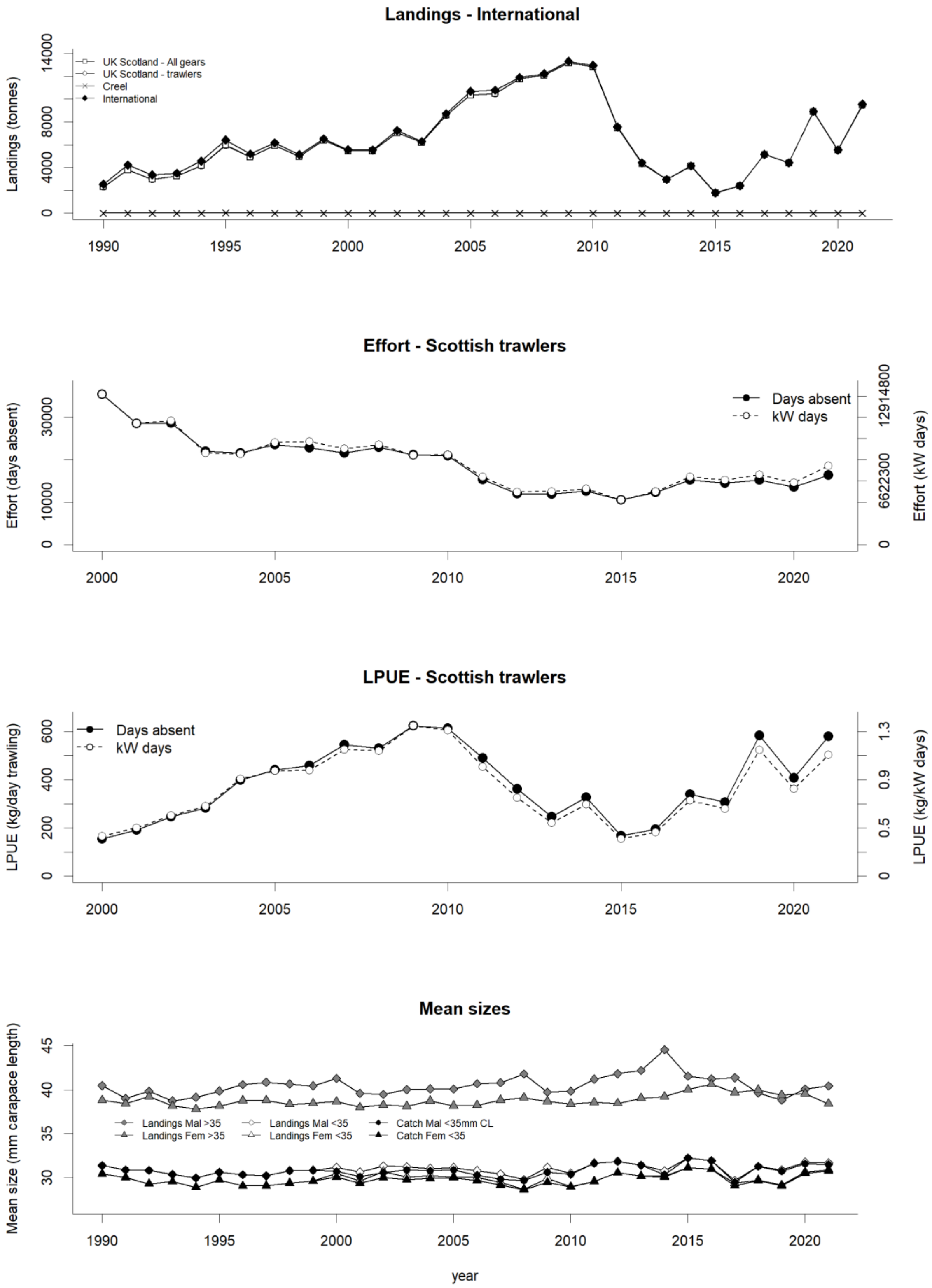


Figure 11.5.1 *Nephrops*, Fladen (FU 7), Long term landings, effort, LPUE and mean sizes. Note that the effort and LPUE from Scottish trawlers cover a shorter period 2000–2021.

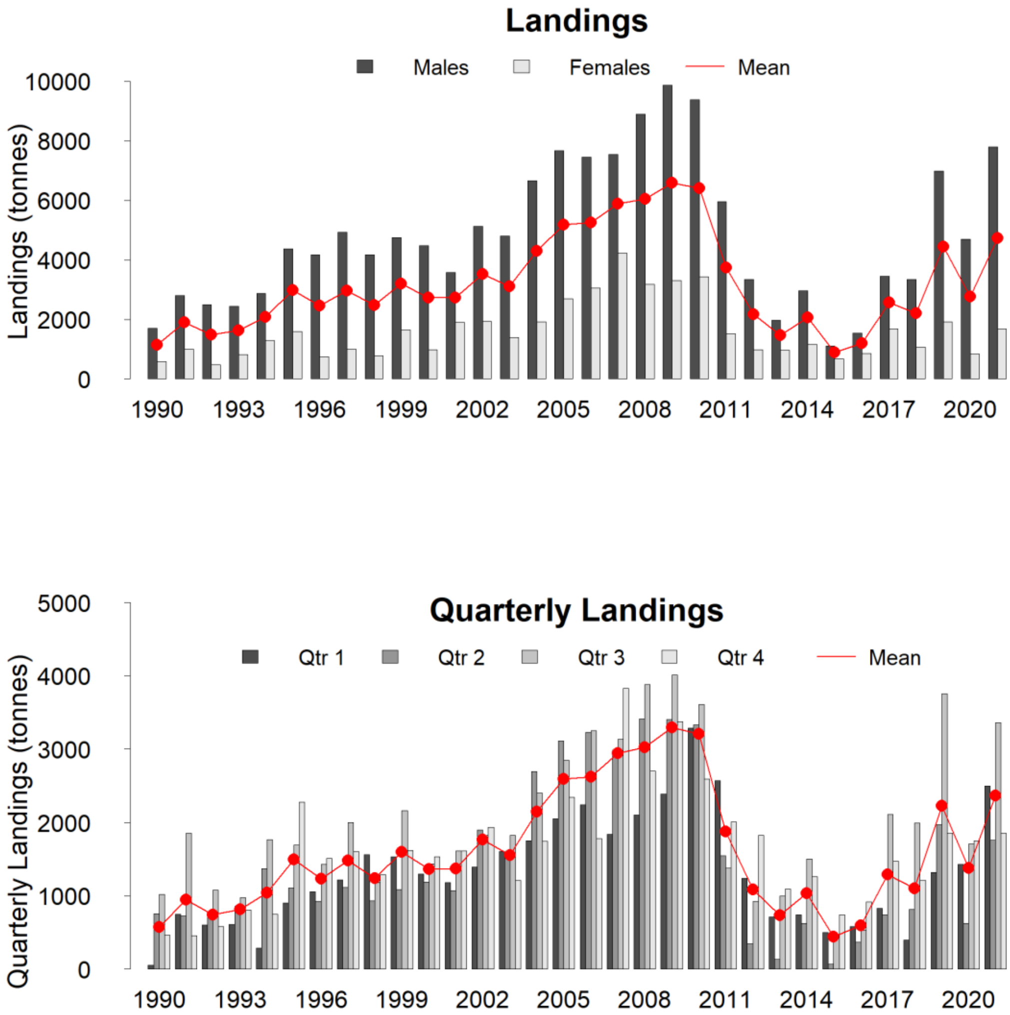


Figure 11.5.2 *Nephrops*, Fladen (FU 7), Landings by quarter and sex from Scottish *Nephrops* trawlers.

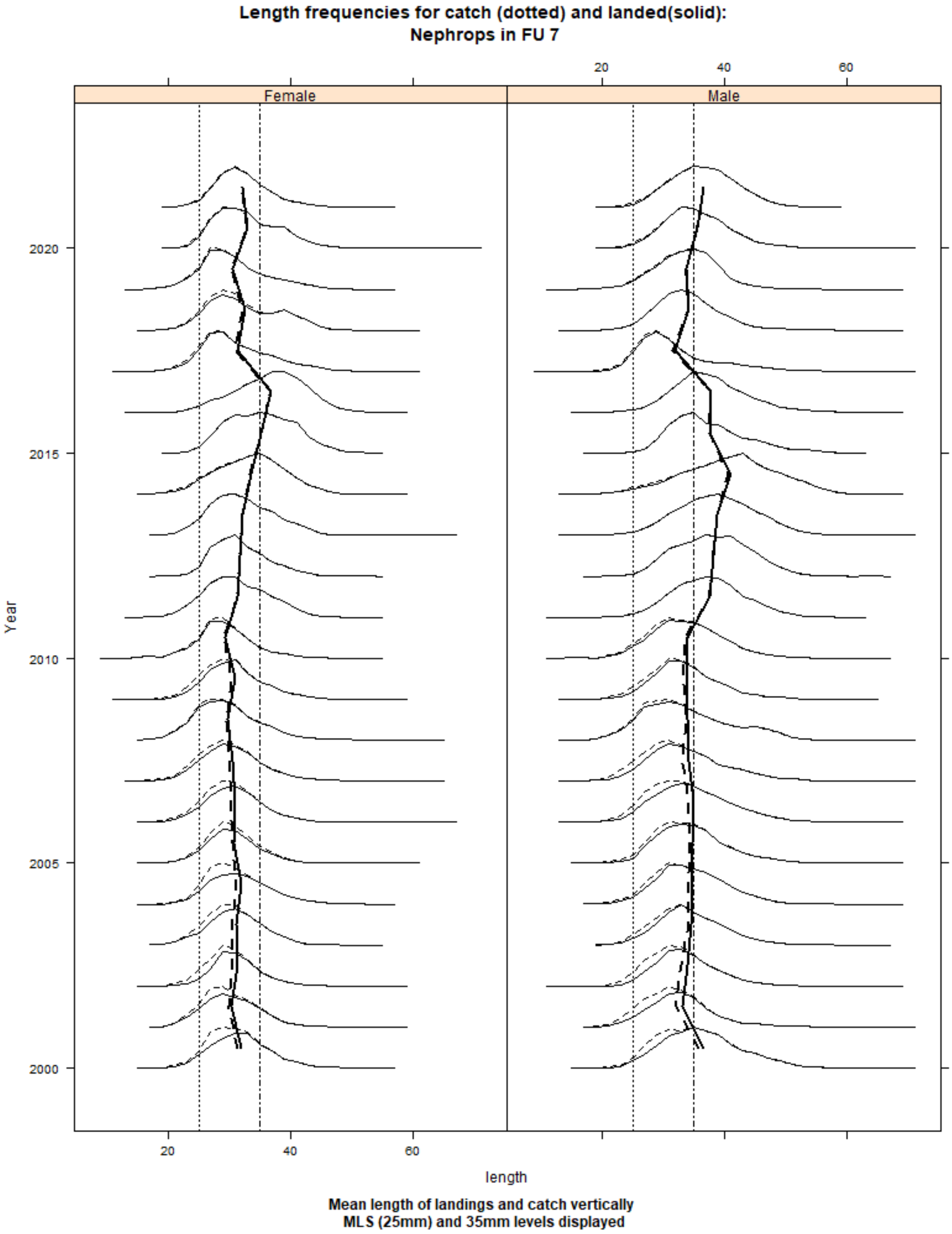
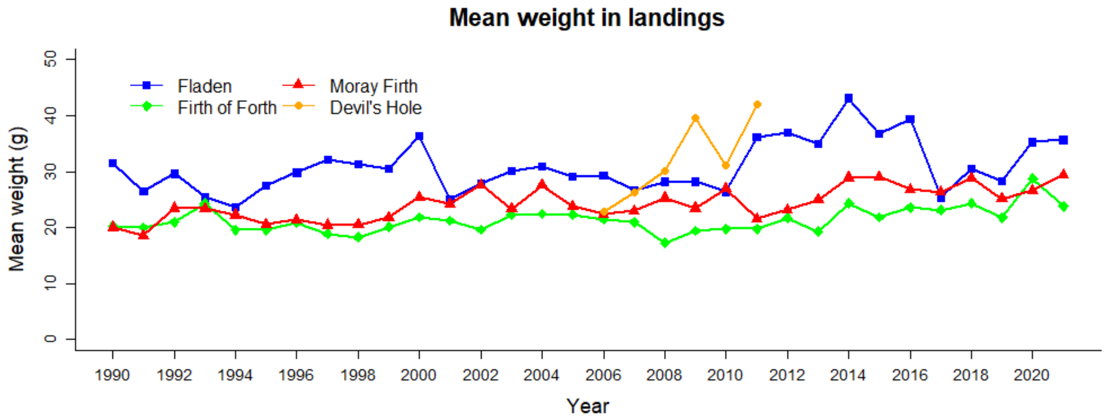


Figure11.5.3 *Nephrops* Fladen Ground (FU 7) Length composition of catch of males (right) and females left from 2000 (bottom) to 2021 (top). Mean sizes of catch and landings are displayed vertically.



11.5.4 *Nephrops,* (FUs 7–9 and 34, Fladen, Firth of Forth, Moray Firth and Devil's Hole). Individual mean weight (g) in the landings from 1990–2021 (Scottish market sampling data). FU 34 data only shown for 2006–2011.

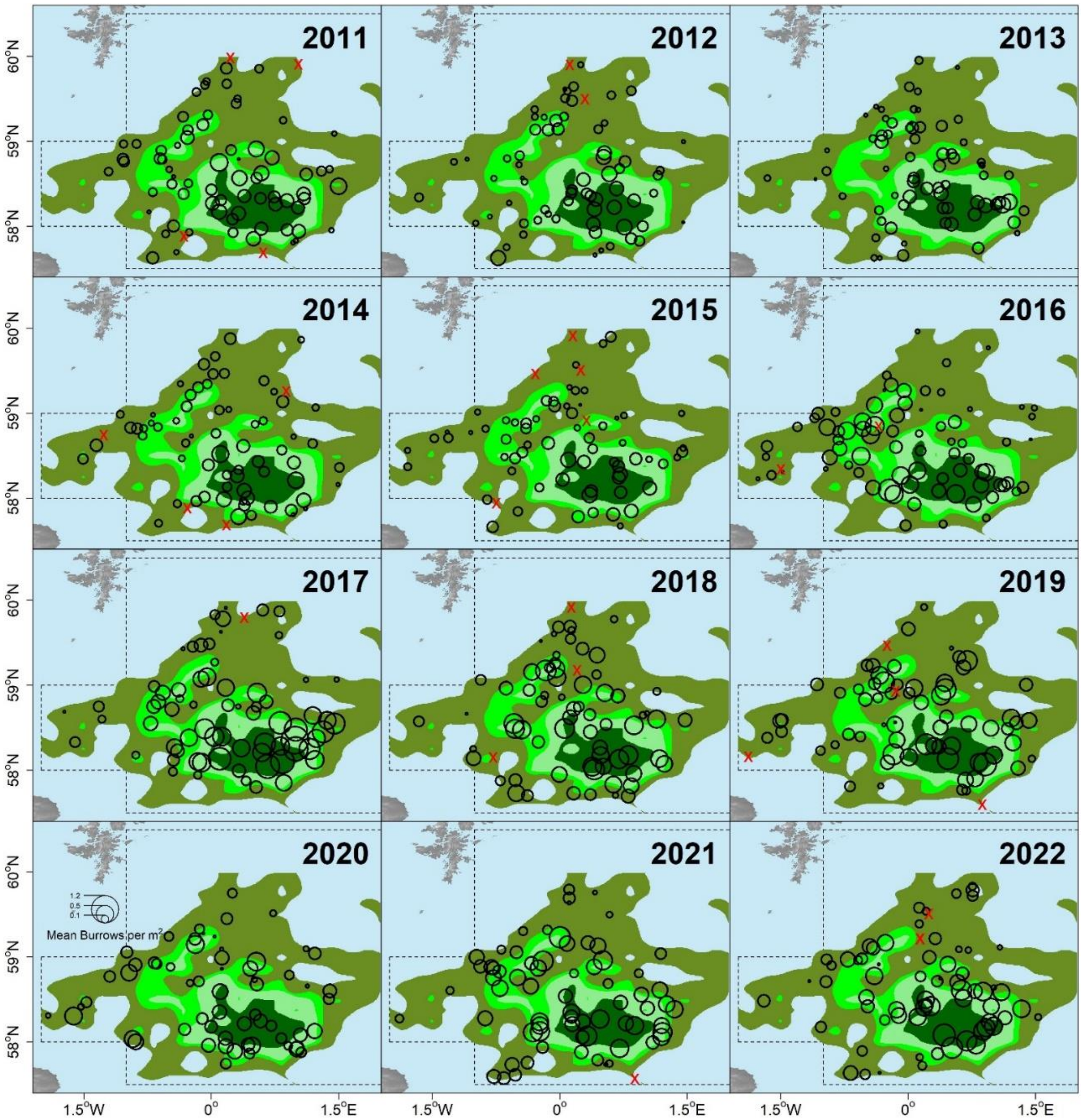


Figure 11.5.5 *Nephrops*, Fladen (FU 7). TV survey distribution and relative density (2011–2022). Green and brown areas represent areas of suitable sediment for *Nephrops*. Density proportional to circle radius. Red crosses represent zero observations.

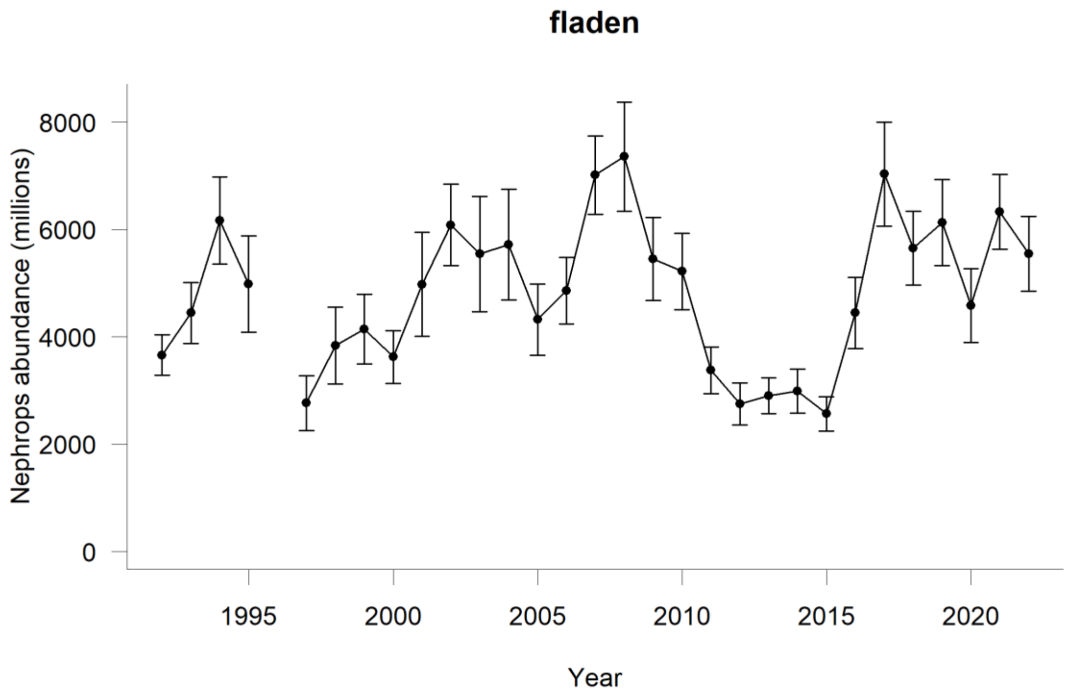


Figure 11.5.6 *Nephrops*, Fladen (FU 7), Time series of TV survey abundance estimates with 95% confidence intervals, 1992–2022.

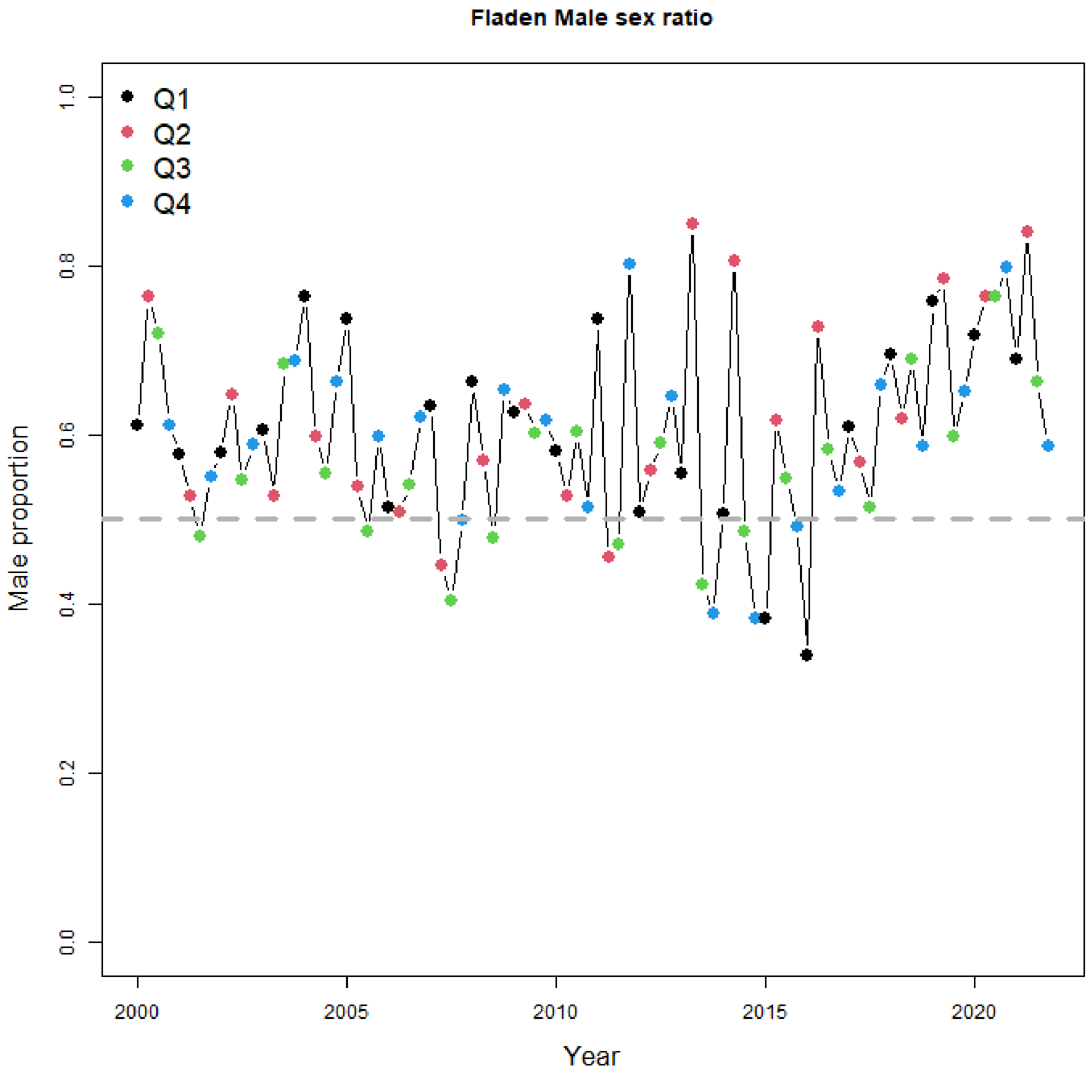


Figure 11.5.7 *Nephrops*, Fladen (FU 7), Quarterly sex ratio (by number) in catches.

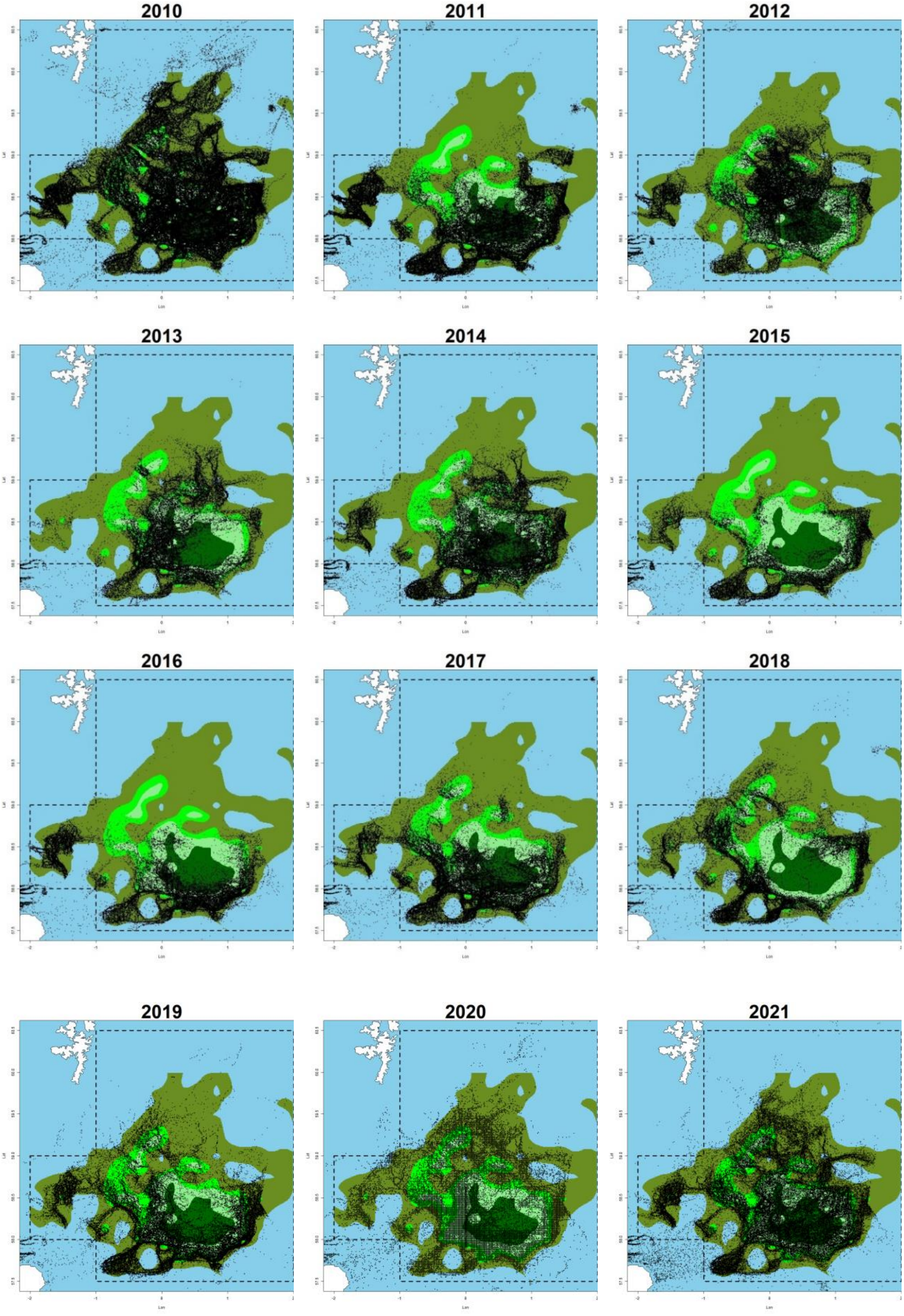


Figure 11.5.8 *Nephrops*, Fladen (FU 7), VMS distribution of vessels in Fladen (2010–2021). Points in figure correspond to fishing pings (speed < 5 kn) associated with trips made by otter trawlers landing more than 25% of *Nephrops* by weight.

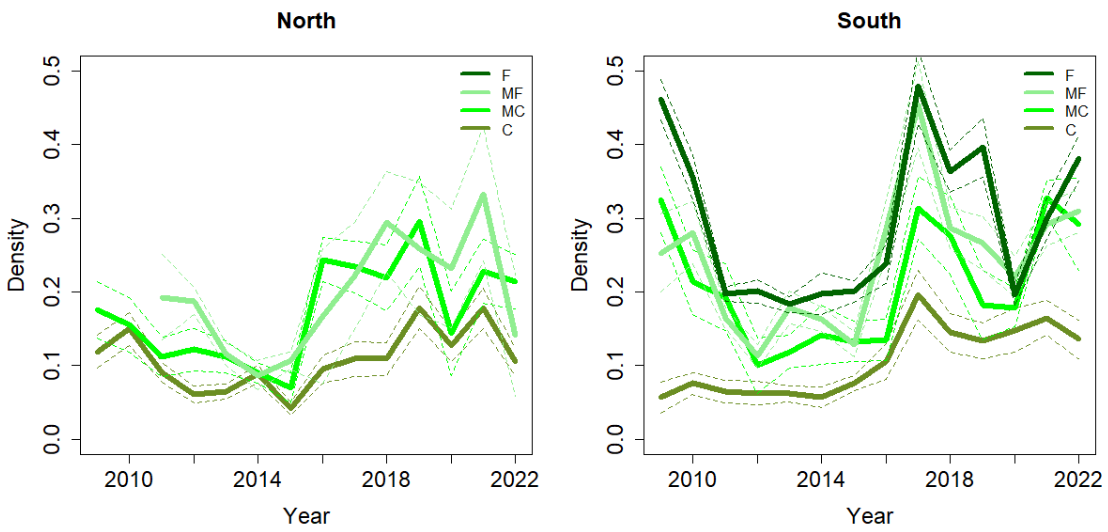


Figure 11.5.9 ***Nephrops*****, Fladen (FU 7), UWTV density by sediment type in the North (left plot) and South (right plot) of Fladen (split at the 58.75 N latitude line). F: fine sediment (silt and clay > 80%); MF: medium fine sediment (55% < silt and clay < 80); MC: medium coarse sediment (40% < silt and clay < 55); C: coarse sediment (silt and clay < 40%).**

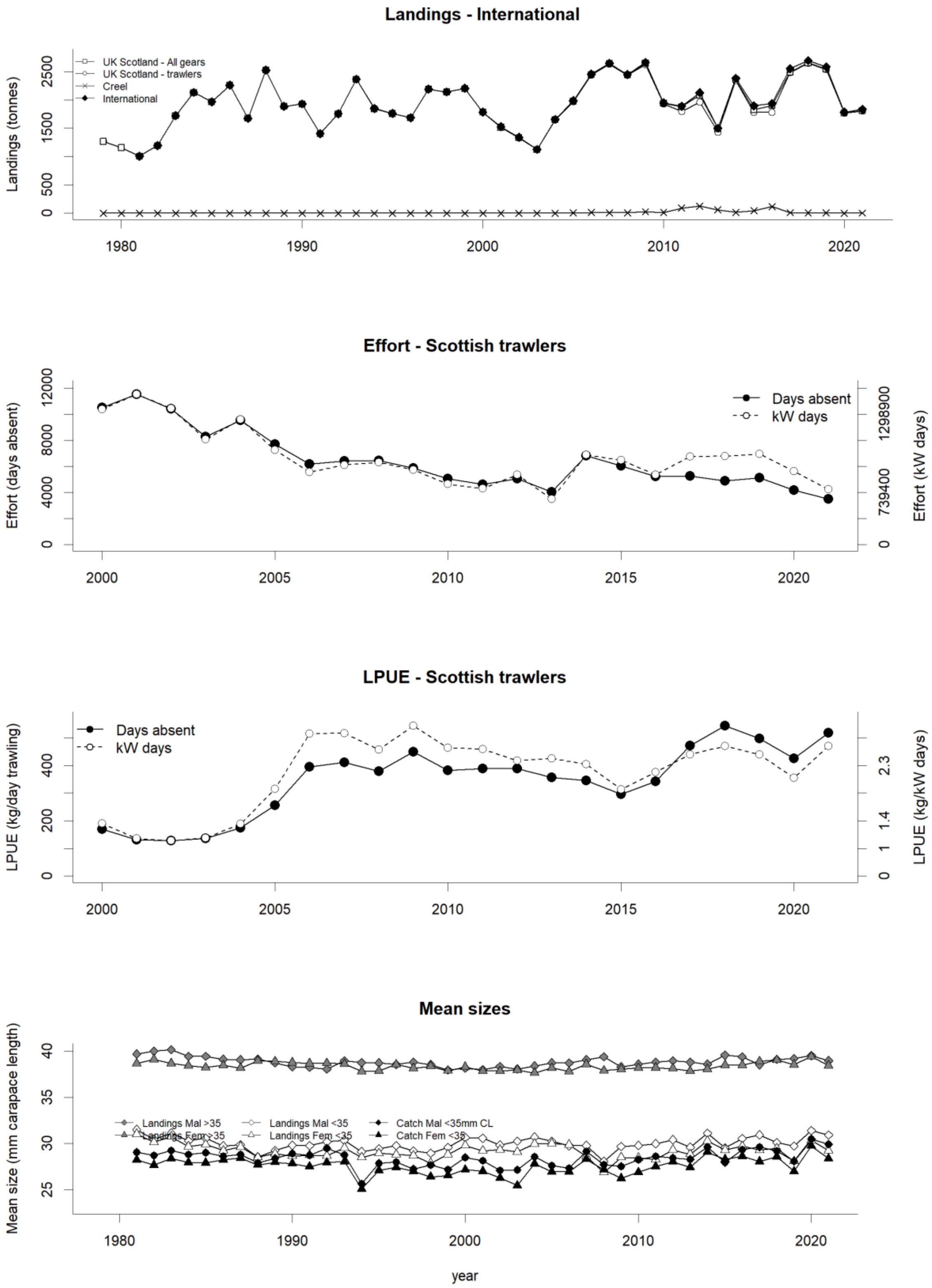
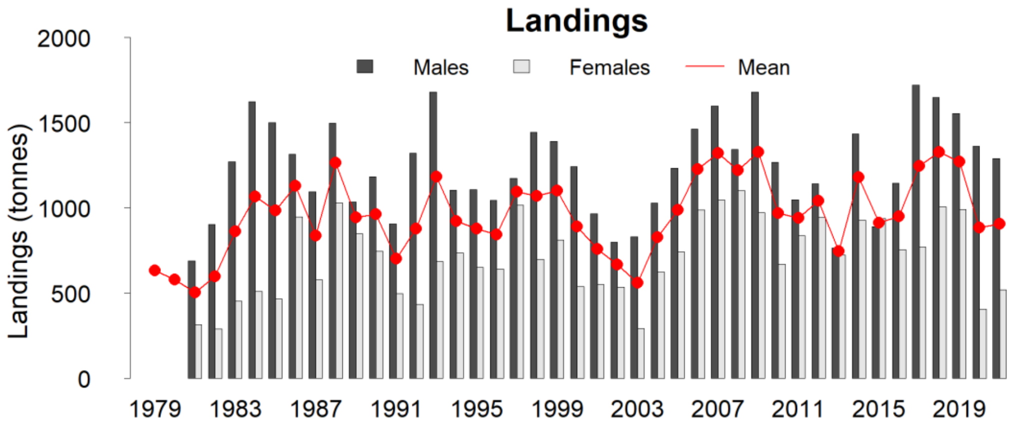


Figure 11.6.1 *Nephrops*, Firth of Forth (FU 8), Long term landings and mean sizes. Note that the effort and LPUE from Scottish trawlers cover a shorter period 2000–2021.



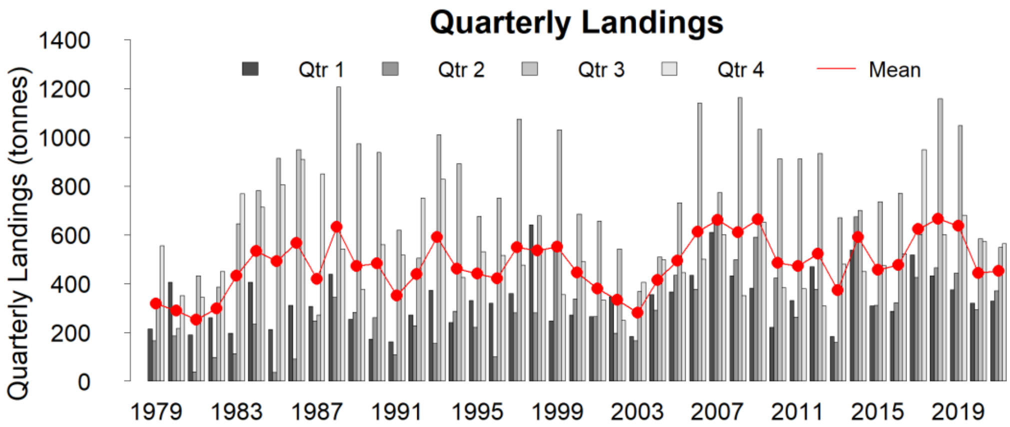


Figure 11.6.2 *Nephrops*, Firth of Forth (FU 8), Landings by quarter and sex from Scottish *Nephrops* trawlers.

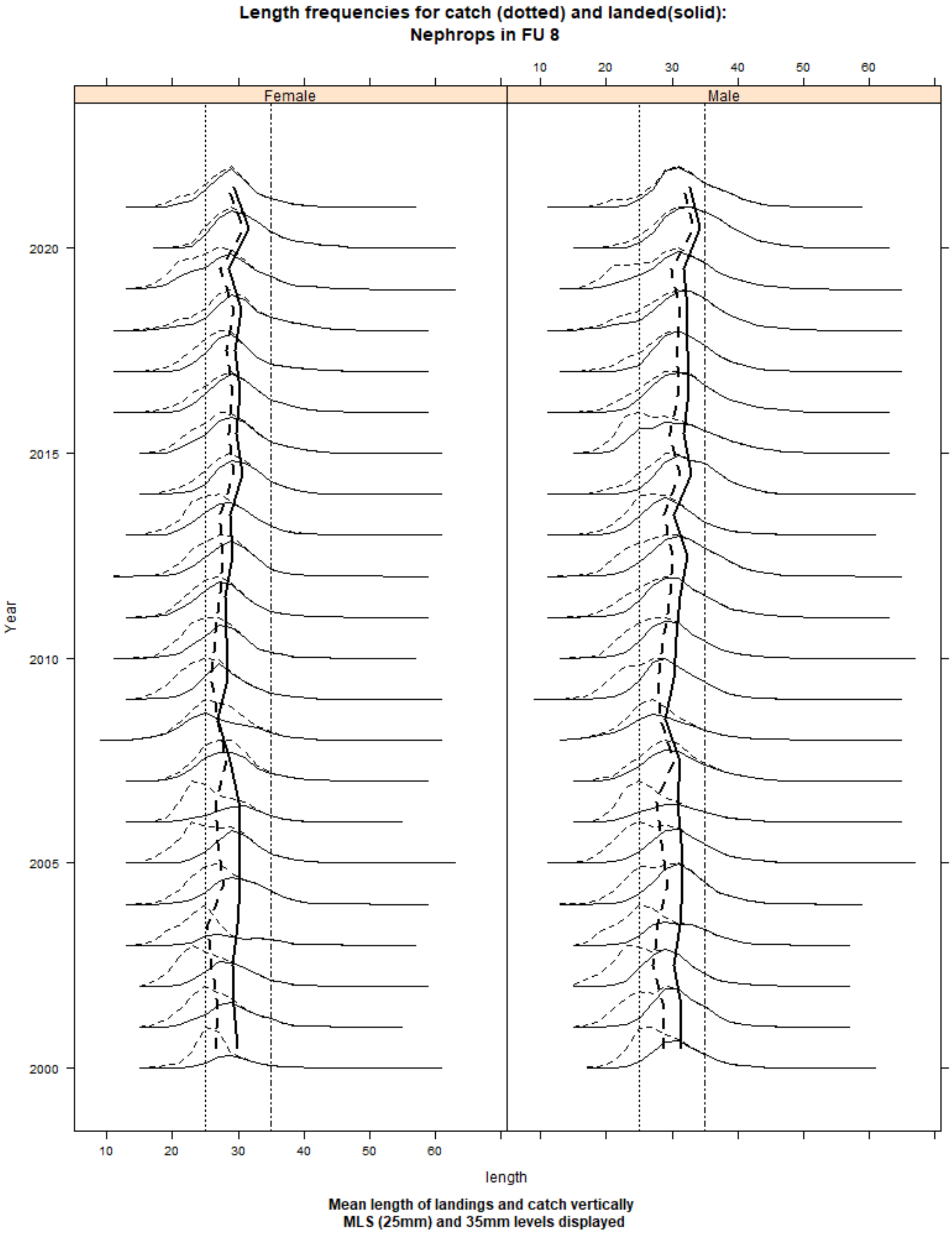


Figure 11.6.3 ***Nephrops*** **Firth of Forth (FU 8) Length composition of catch of males (right) and females left from 2000 (bottom) to 2021 (top). Mean sizes of catch and landings are displayed vertically.**

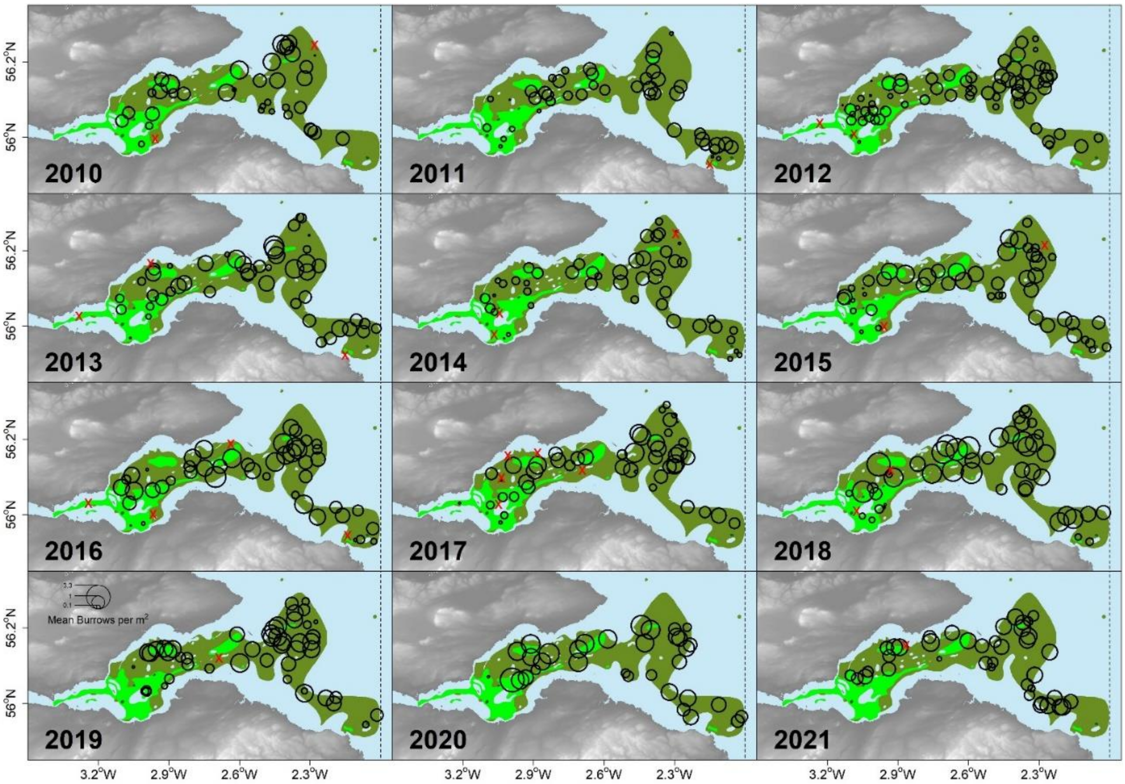


Figure 11.6.4 ***Nephrops*****, Firth of Forth (FU 8). TV survey distribution and relative density (2010–2021). There was no TV survey in 2022. Green and brown areas represent areas of suitable sediment for** ***Nephrops*****. Density proportional to circle radius. Red crosses represent zero observations.**

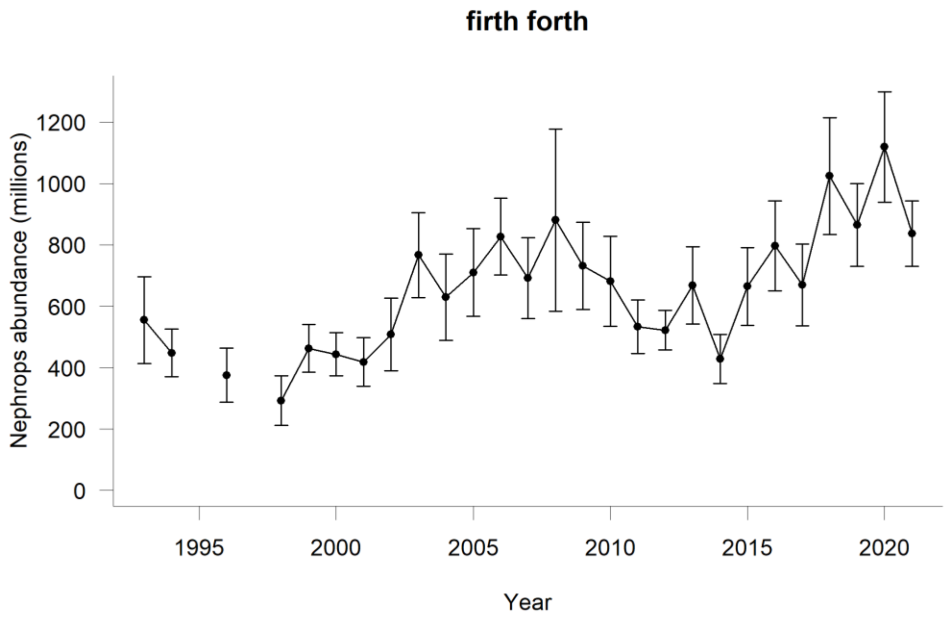


Figure 11.6.5 ***Nephrops*****, Firth of Forth (FU 8), Time series of TV survey abundance estimates with 95% confidence intervals, 1993–2021.**

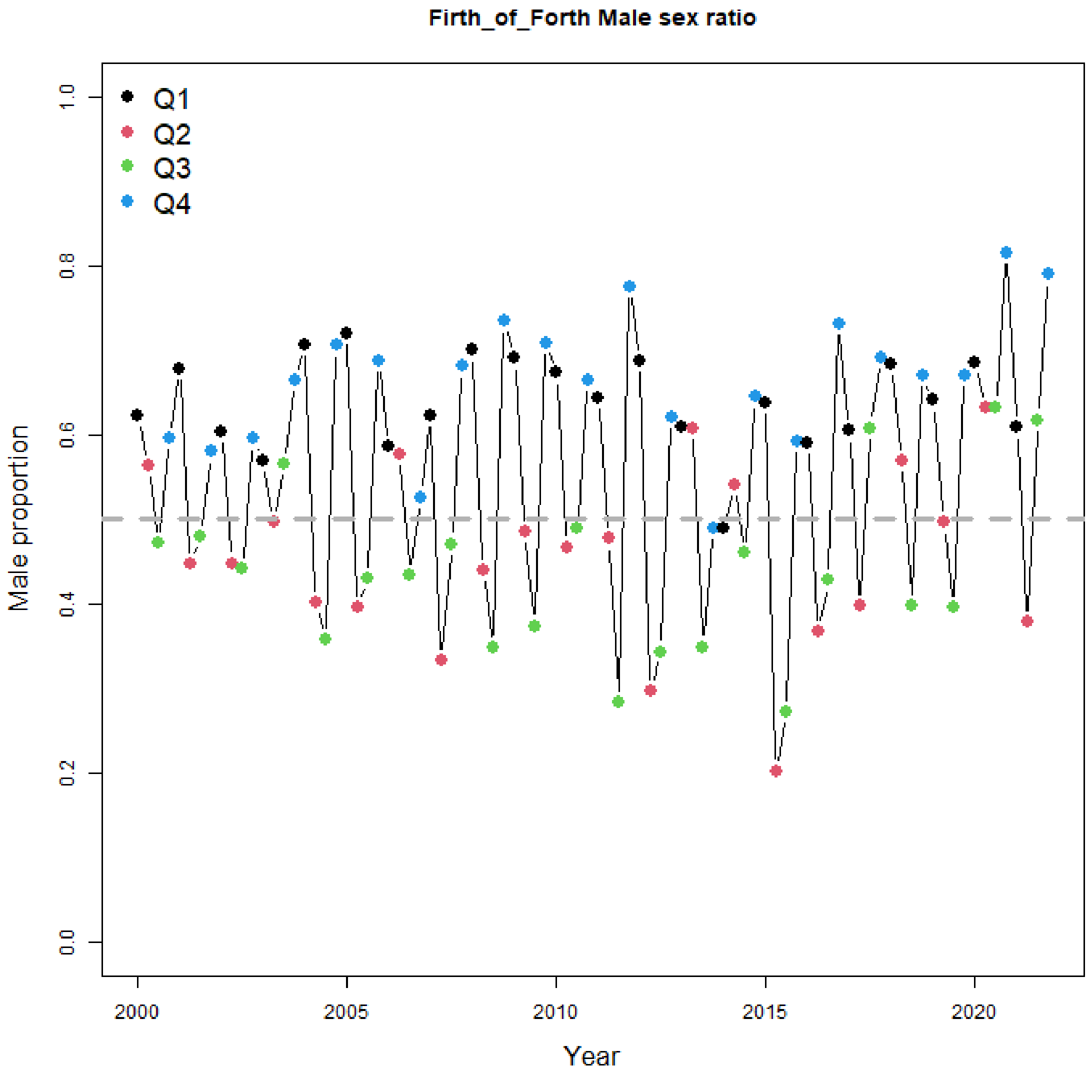


Figure 11.6.6 *Nephrops*, Firth of Forth (FU 8), Quarterly sex ratio (by number) in catches.

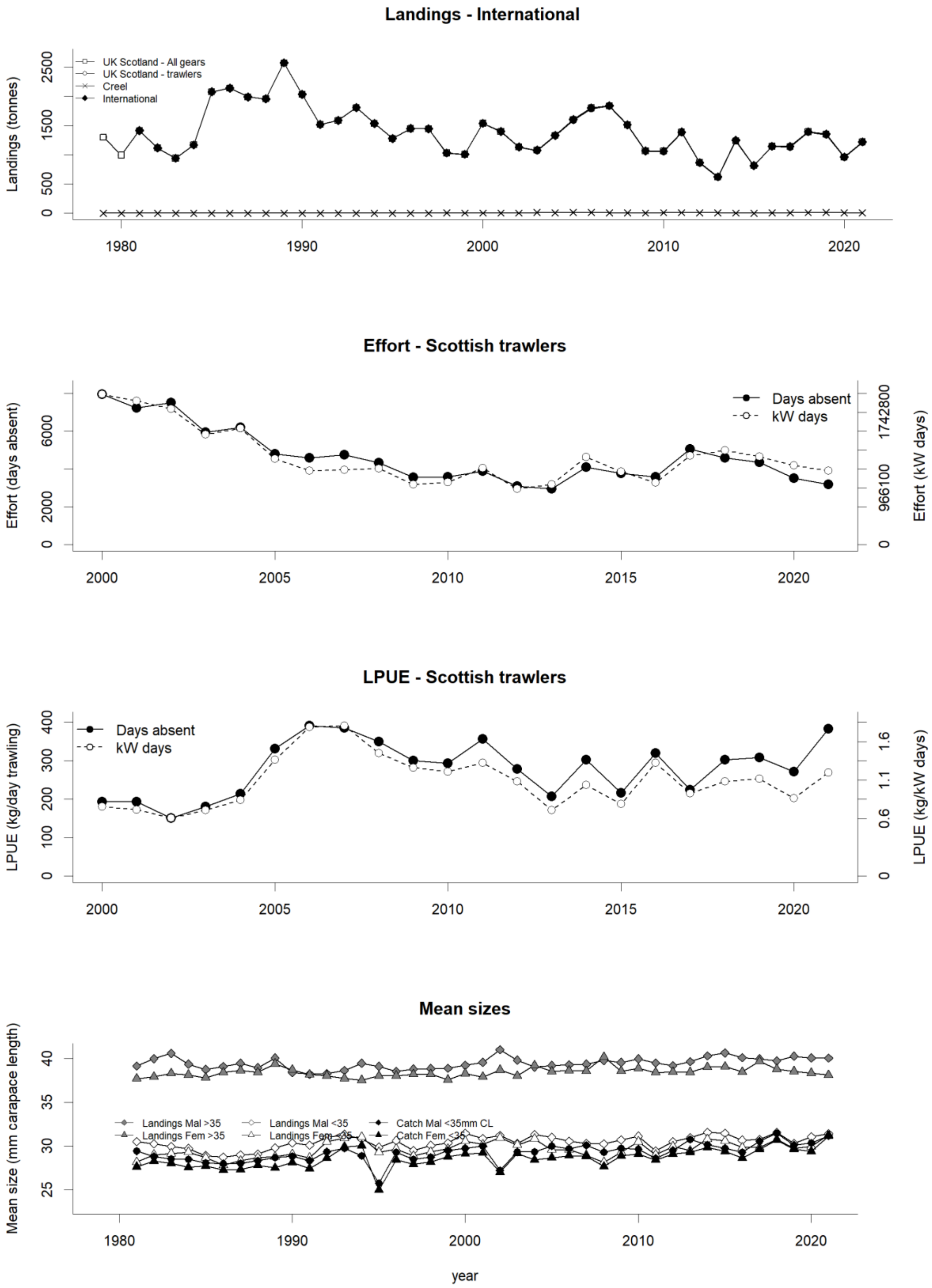


Figure 11.7.1 ***Nephrops*****, Moray Firth (FU 9), Long term landings and mean sizes. Note that the effort and LPUE from Scottish trawlers cover a shorter period 2000–2021.**

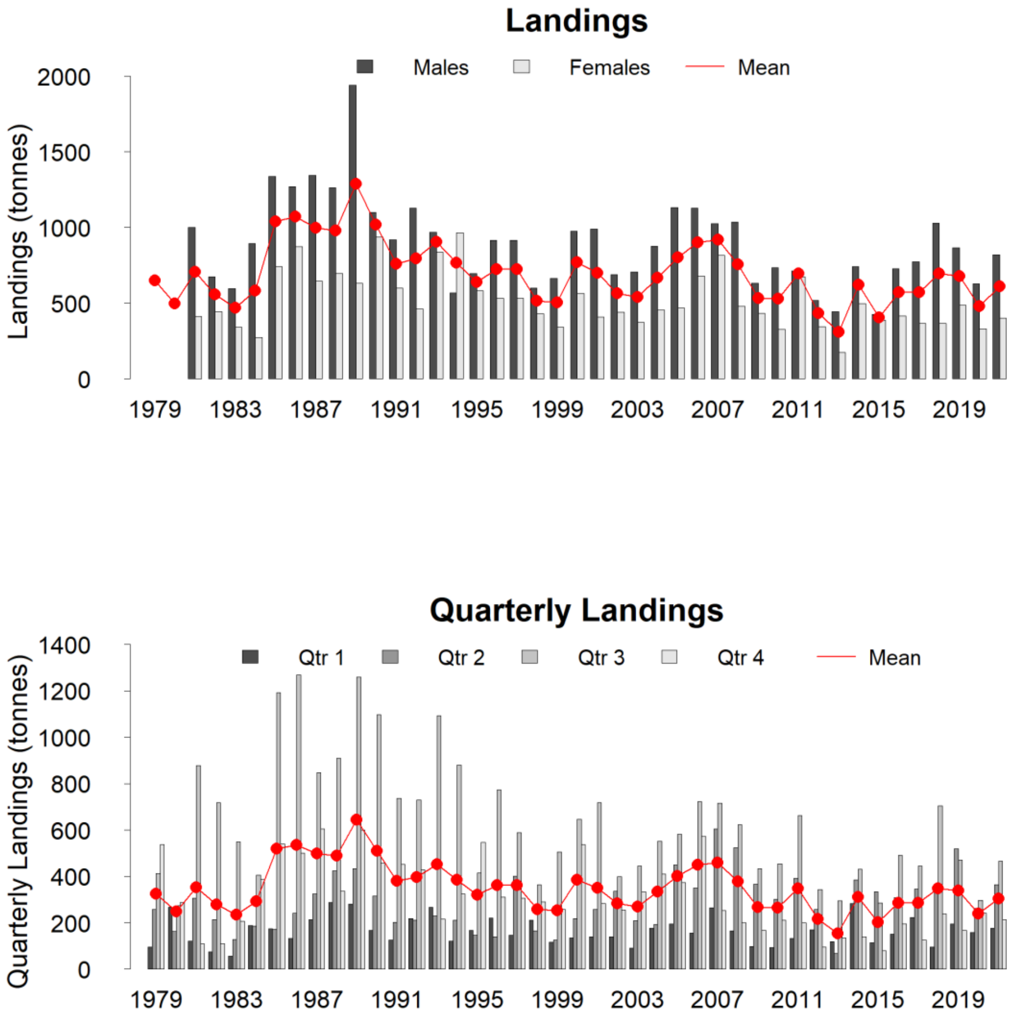


Figure 11.7.2 *Nephrops*, Moray Firth (FU 9), Landings by quarter and sex from Scottish *Nephrops* trawlers.

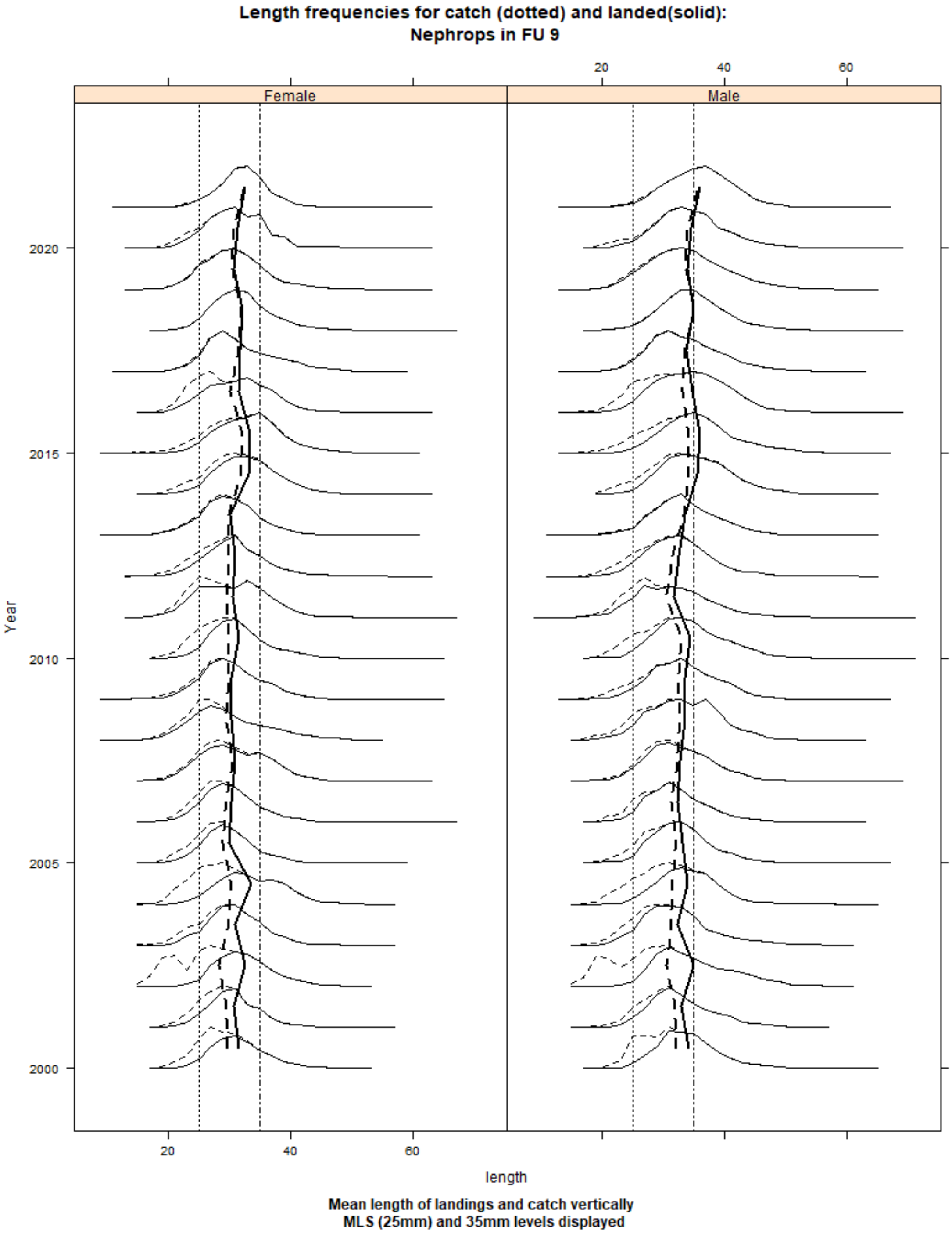


Figure 11.7.3 ***Nephrops*** **Moray Firth (FU 9) Length composition of catch of males (right) and females left from 2000 (bottom) to 2021 (top). Mean sizes of catch and landings are displayed vertically.**

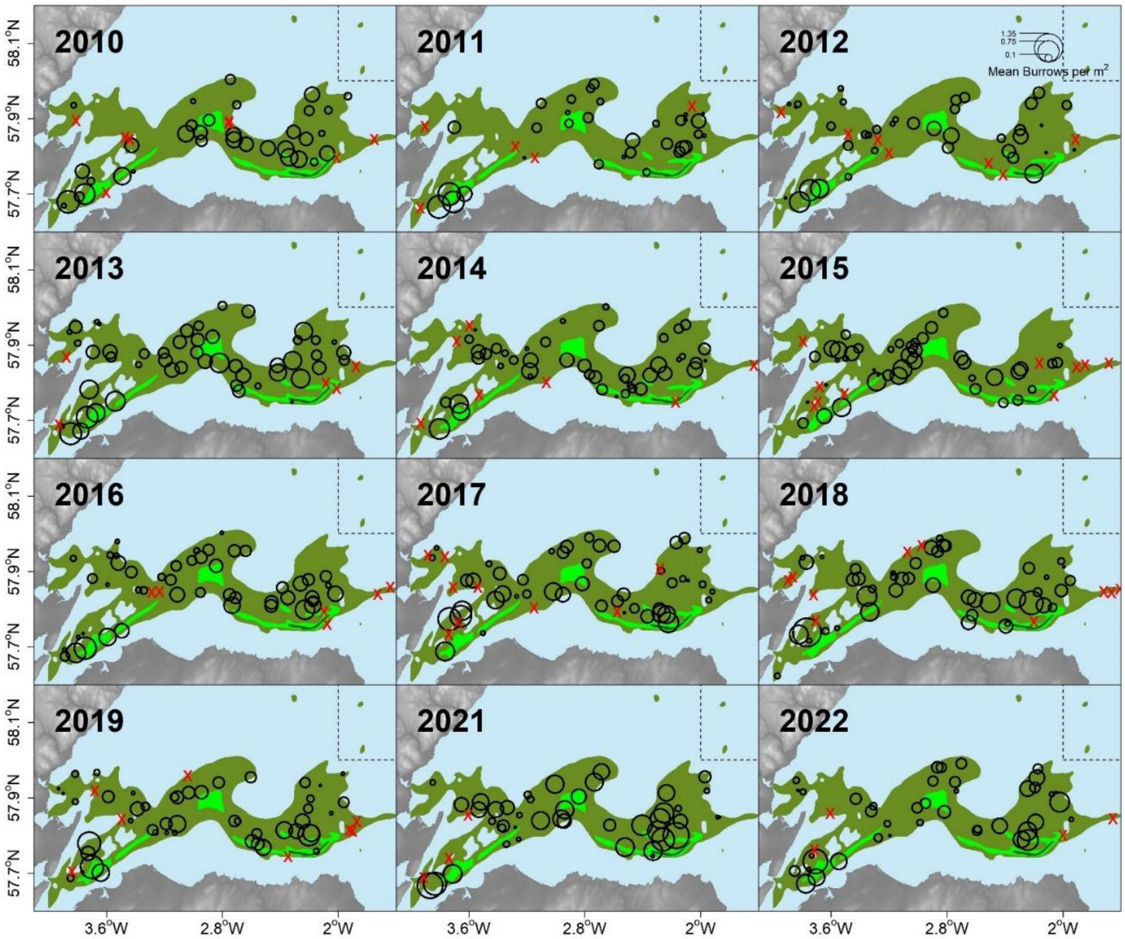


Figure 11.7.4 ***Nephrops*****, Moray Firth (FU 9). TV survey distribution and relative density (2010–2022). There was no TV survey in 2020. Green and brown areas represent areas of suitable sediment for** ***Nephrops*****. Density proportional to circle radius. Red crosses represent zero observations.**

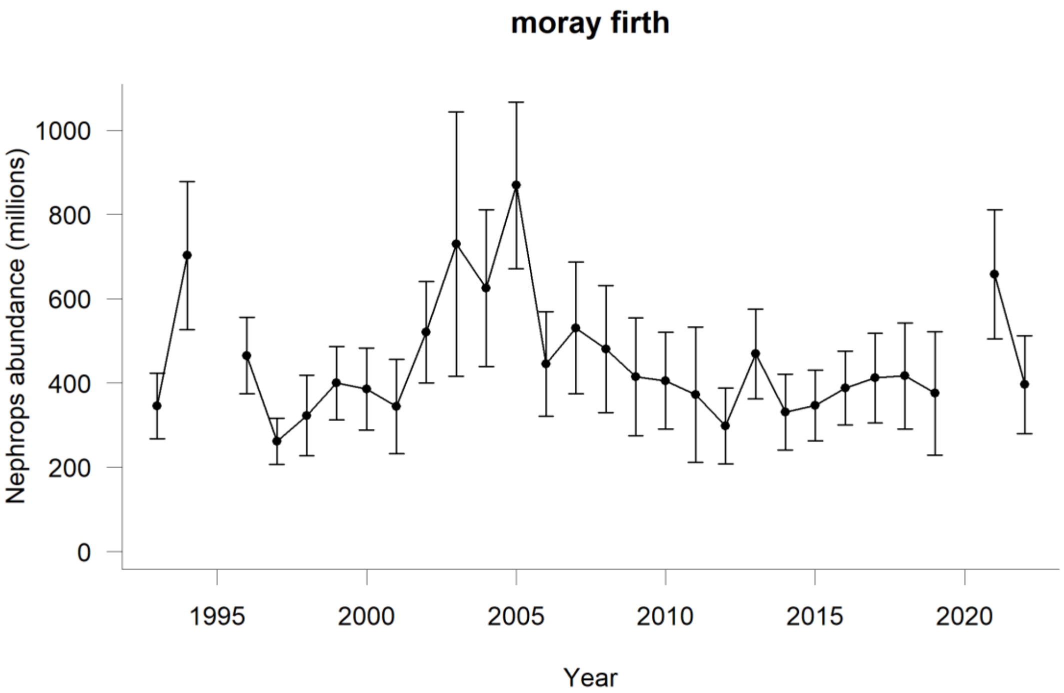


Figure 11.7.5 *Nephrops*, Moray Firth (FU 9), Time series of TV survey abundance estimates with 95% confidence intervals, 1993–2022.

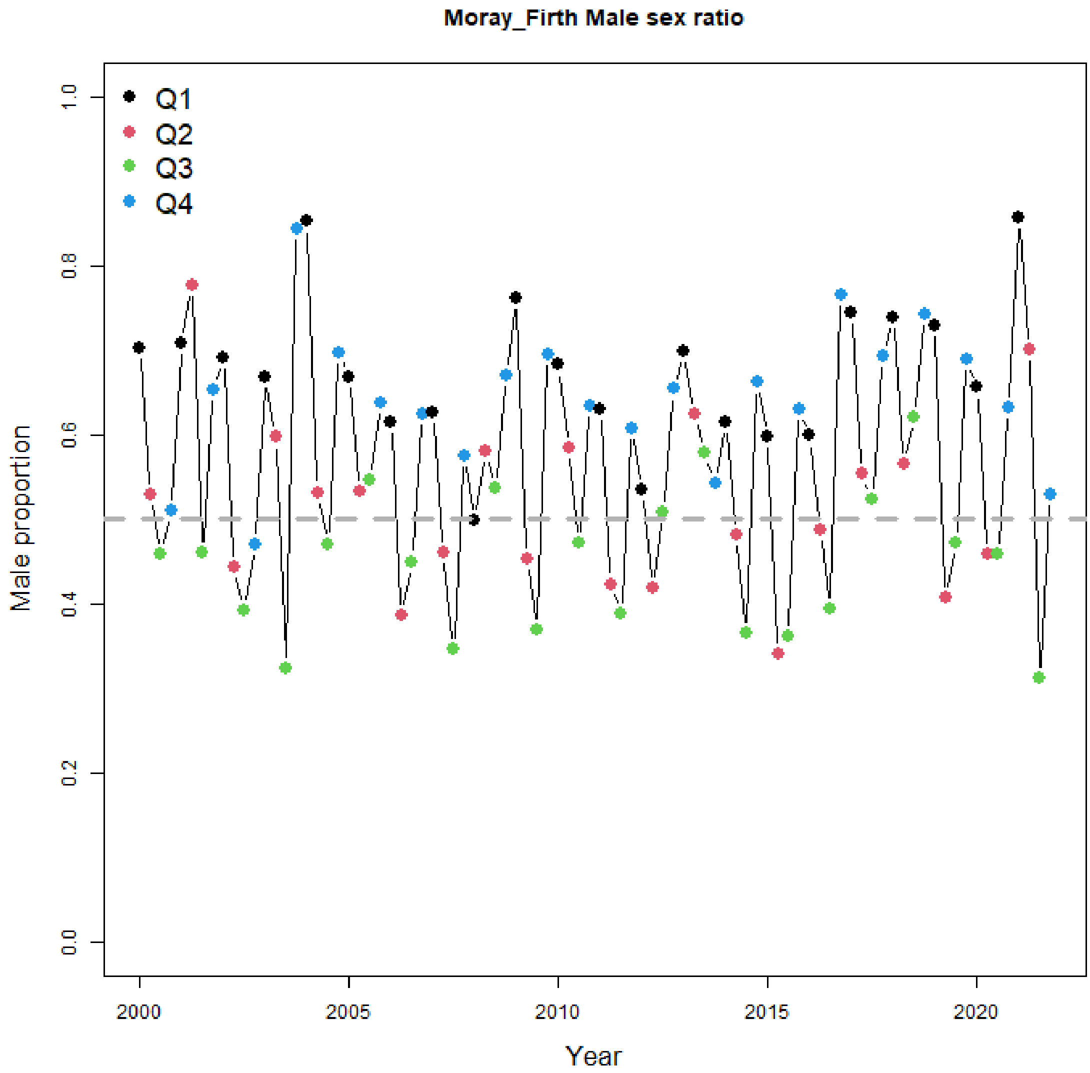


Figure 11.7.6 *Nephrops*, Moray Firth (FU 9), Quarterly sex ratio (by number) in catches.

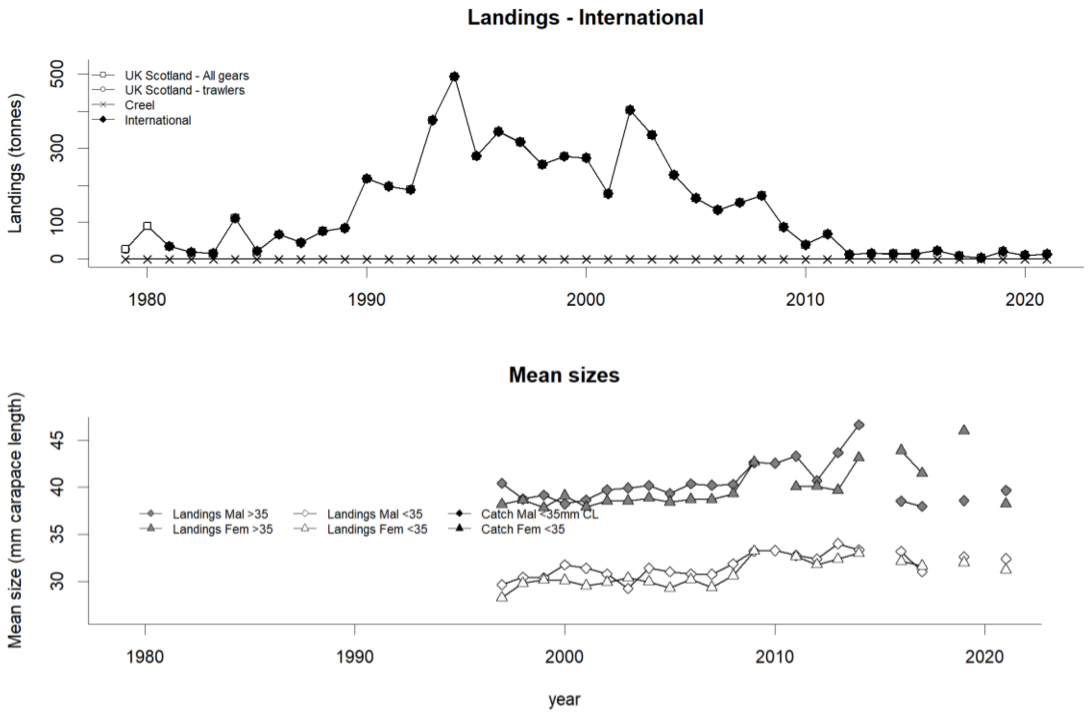


Figure 11.8.1 ***Nephrops*****, Noup (FU 10), Long term landings and mean sizes (no females in samples in 2010 and no samples in 2015, 2018 and 2020).**

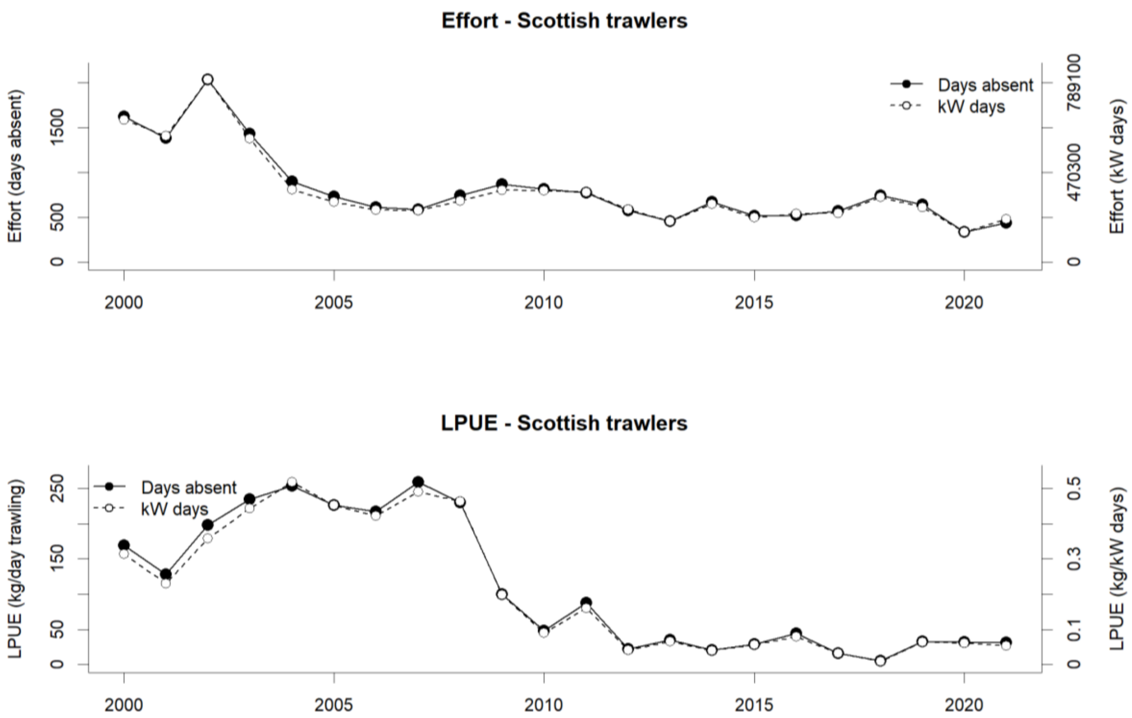


Figure 11.8.2 ***Nephrops*****, Noup (FU 10), Effort (days, kWday) and LPUE (kg/day, kg/kWdays), data from year 2000.**

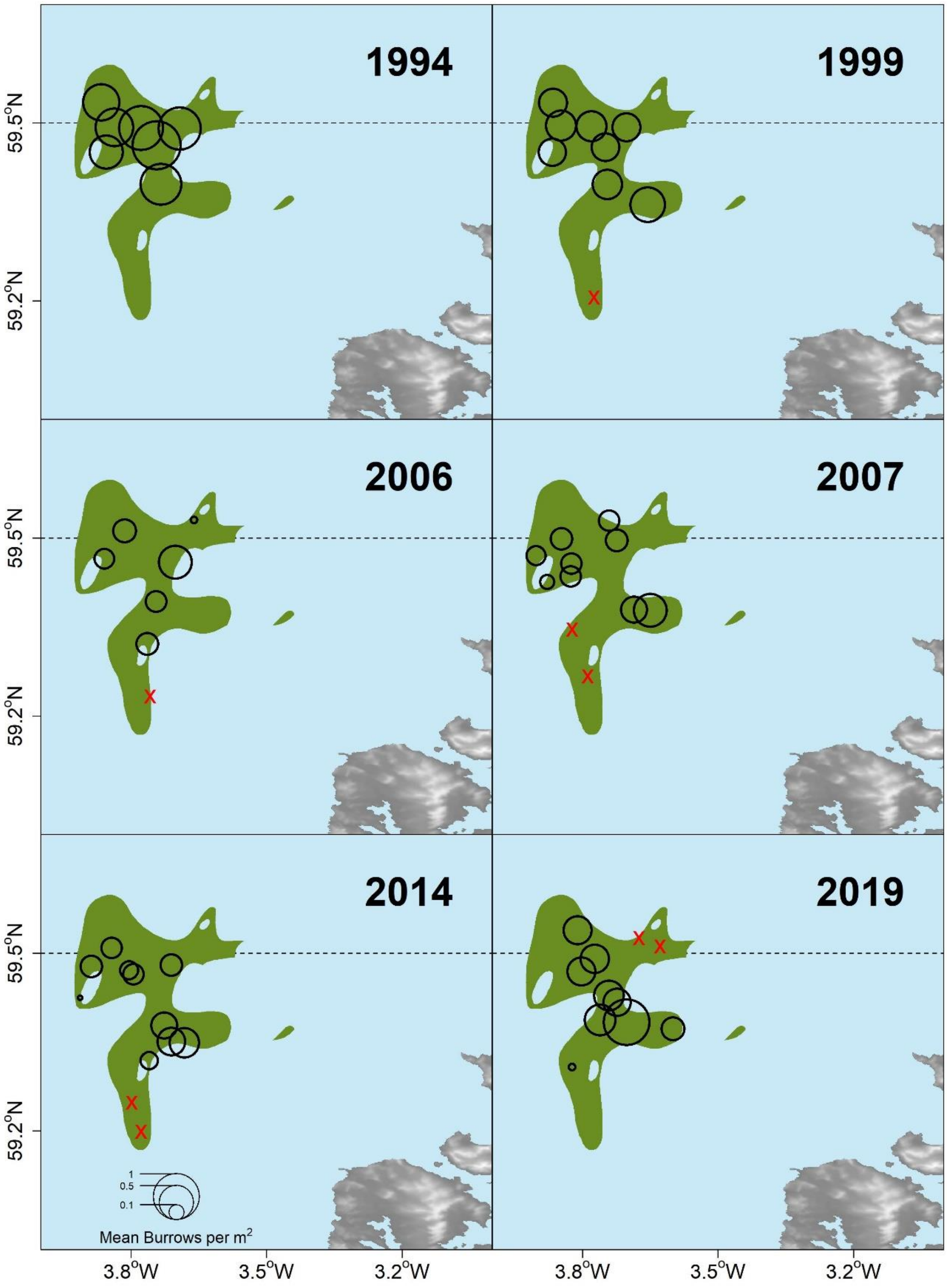


Figure 11.8.3 *Nephrops*, Noup (FU 10). TV survey distribution and relative density (1994, 1999, 2006, 2007, 2014 and 2019). Green and brown areas represent areas of suitable sediment for *Nephrops*. Density proportional to circle radius. Red crosses represent zero observations.

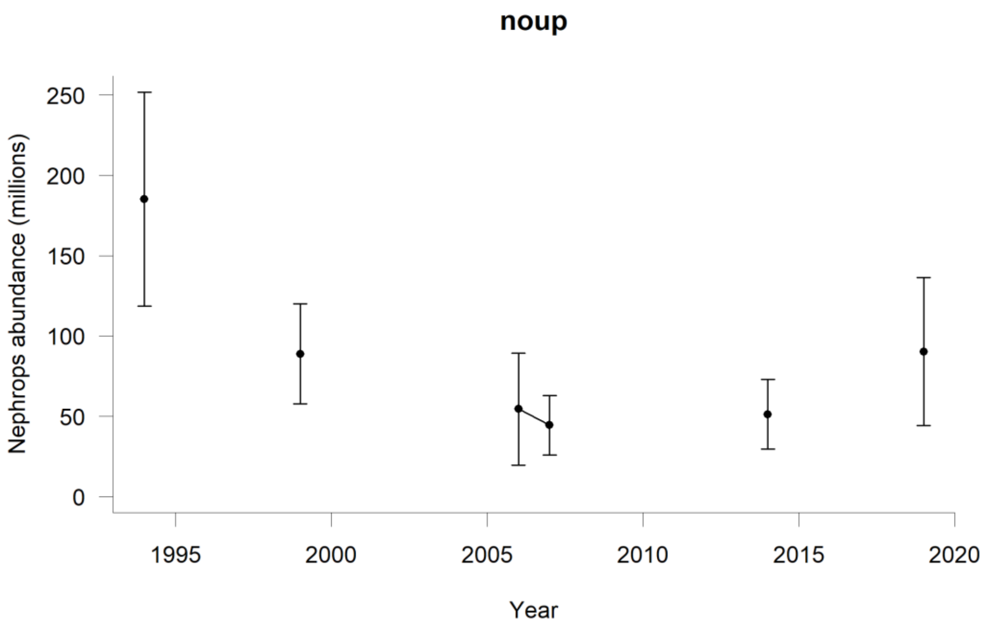


Figure 11.8.4 *Nephrops*, Noup (FU 10), Time series of TV survey abundance estimates (absolute conversion factor = 1.35, from Fladen), with 95% confidence intervals, 1994, 1999, 2006–2007, 2014 and 2019.

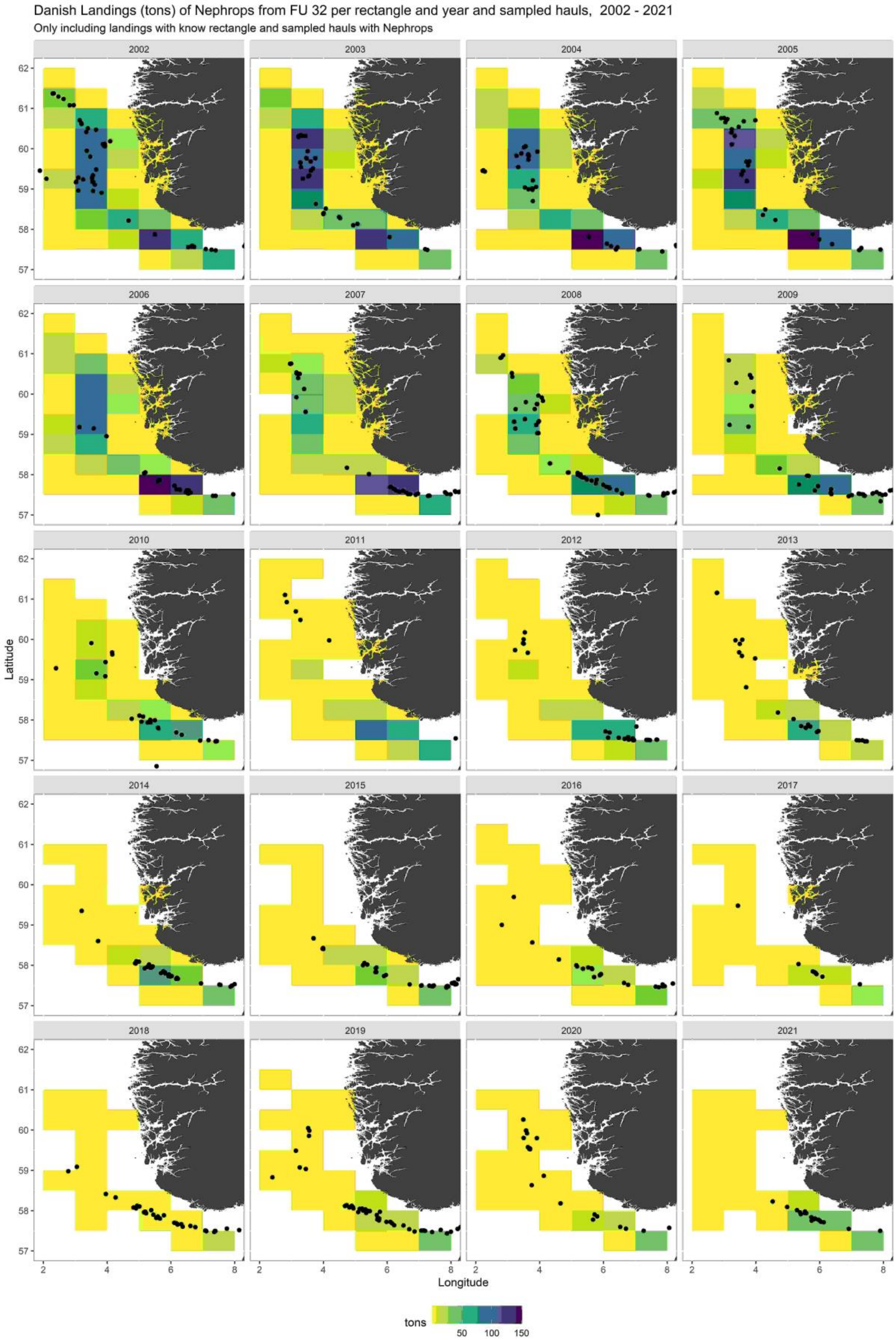


Figure 11.9.1. ***Nephrops*** **Norwegian Deep (FU 32). Danish landings of** ***Nephrops*** **by ICES statistical square, 2000–2021. Dots represent hauls with** ***Nephrops*** **from the Danish at-sea-sampling program.**

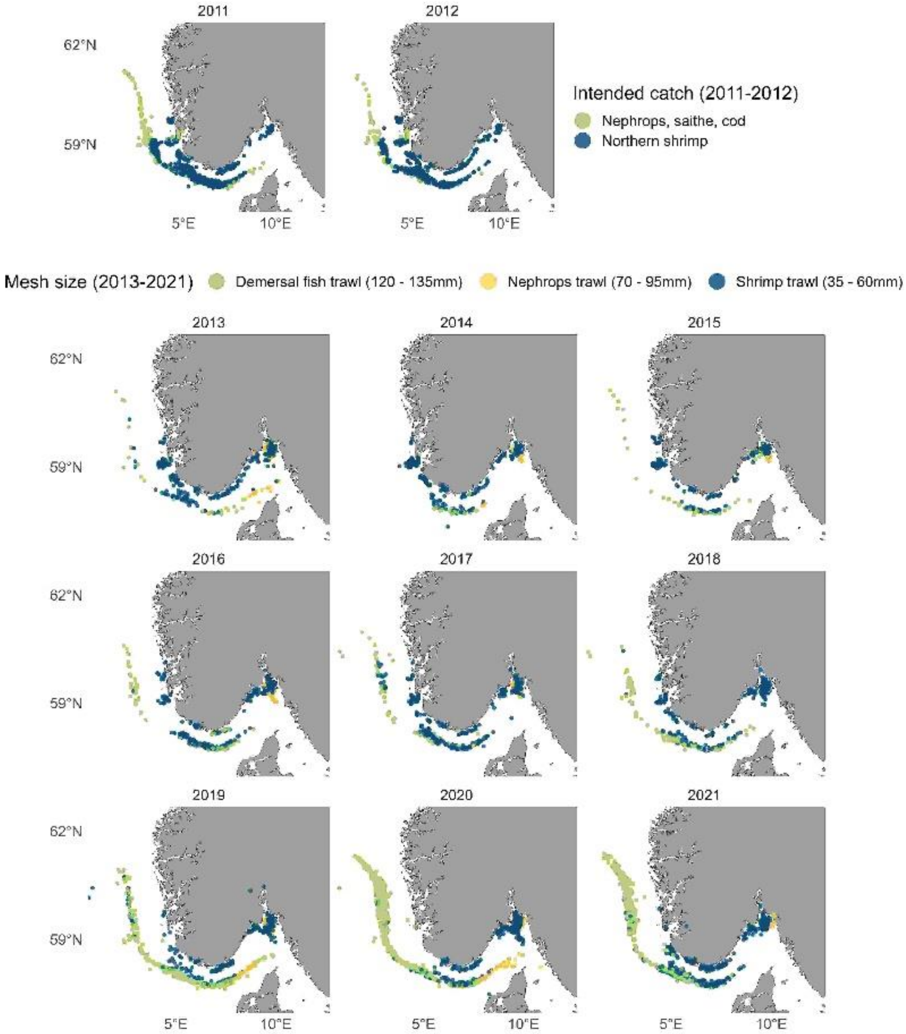


Figure 11.9.2. *Nephrops* Norwegian Deep (FU 32): Positions of trawl hauls with *Nephrops* in the catch from Norwegian bottom trawlers ≥ 15 m (large mesh and small mesh shrimp trawlers), 2011–2021. Information on mesh size was not available in 2011–2012, and type of trawl was determined from information on intended catch.

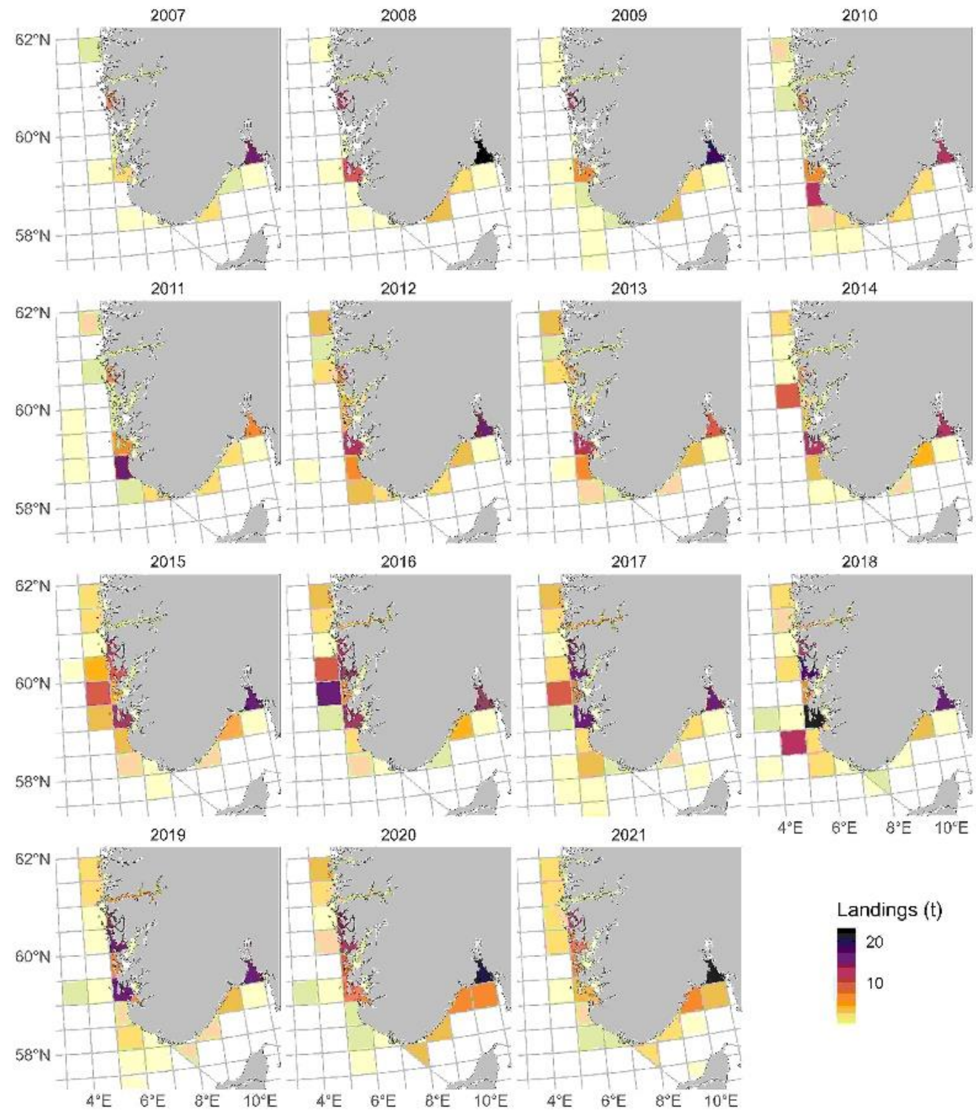


Figure 11.9.3. ***Nephrops*** **Norwegian Deep (FU 32): Norwegian creel landings by ICES statistical square, 2009–2021.**

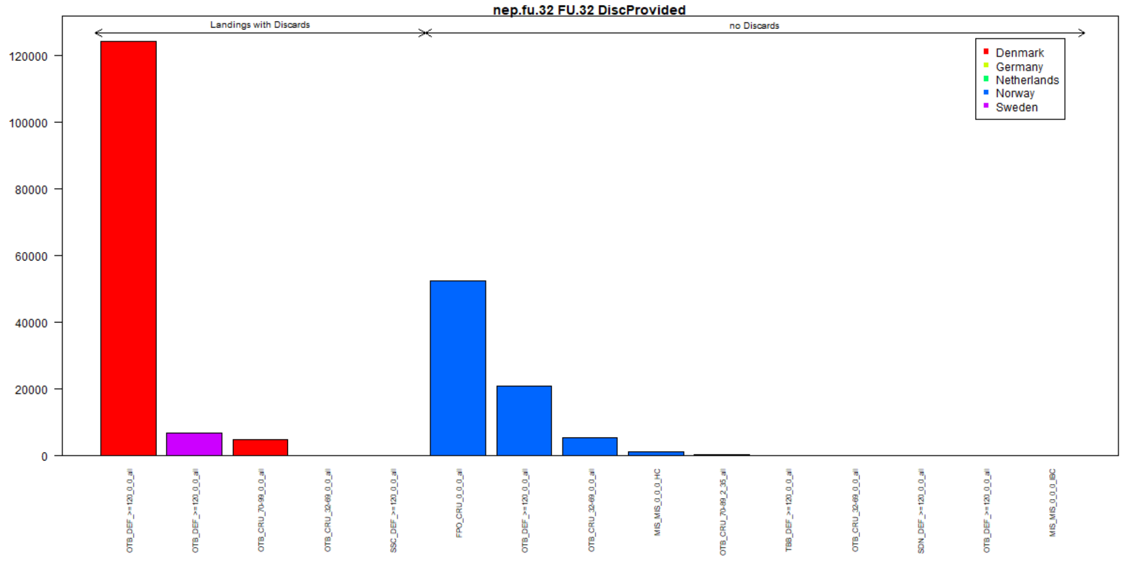


Figure 11.9.4. *Nephrops* Norwegian Deep (FU 32): Landings (kg) by country and métier in 2021 associated with discards as uploaded into InterCatch.

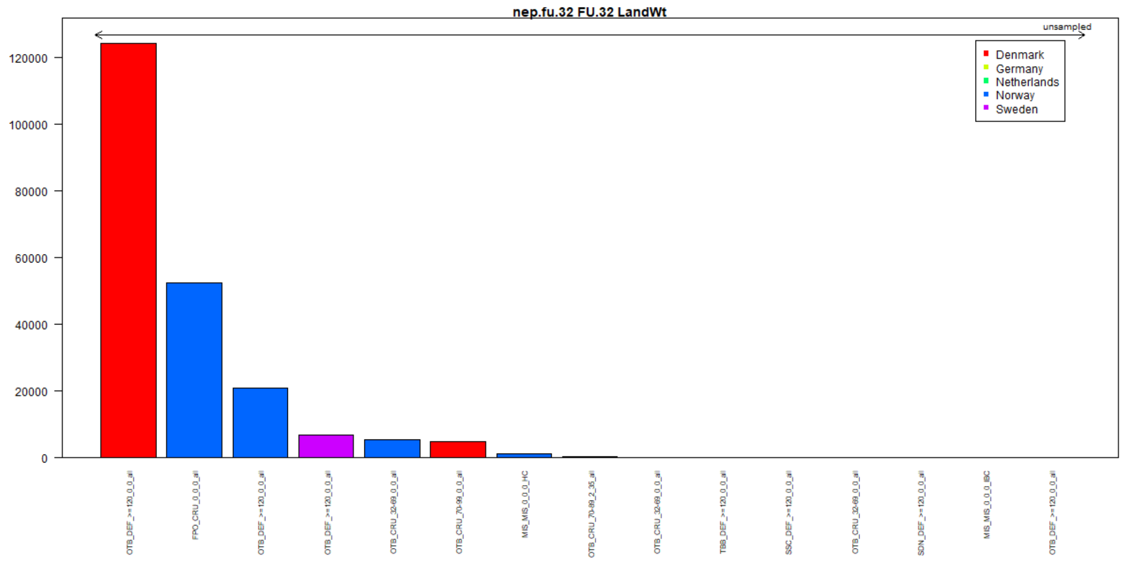


Figure 11.9.5. *Nephrops* Norwegian Deep (FU 32): Landings (kg) by country and métier in 2021 with length samples as uploaded into InterCatch.

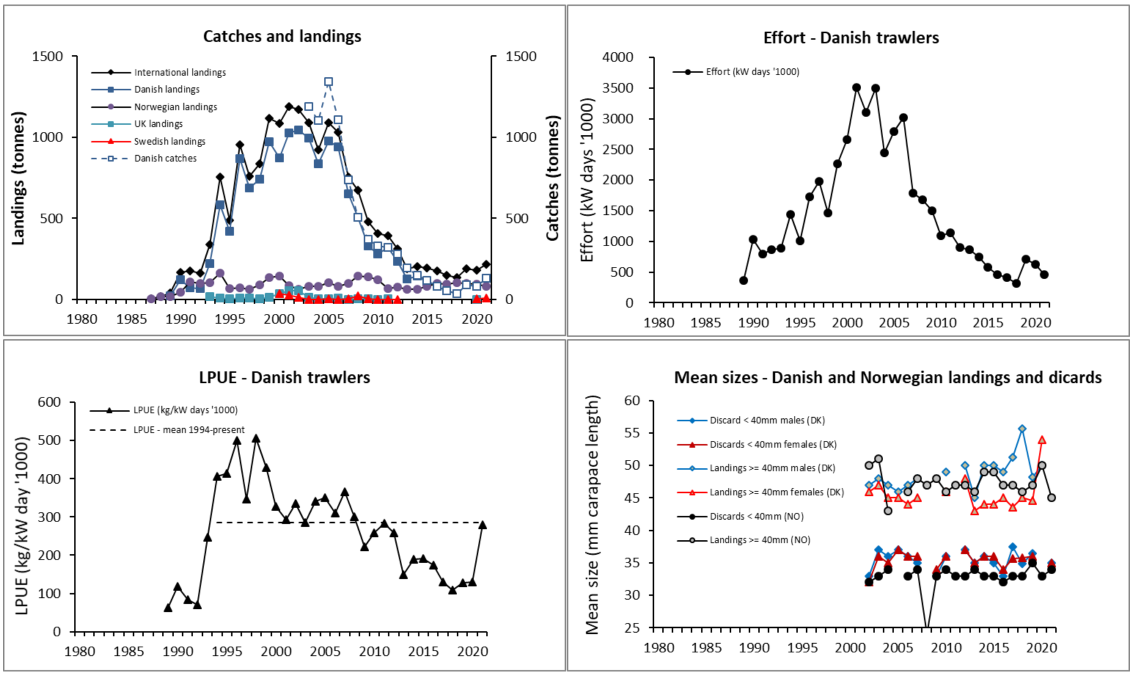


Figure 11.9.6. *Nephrops* Norwegian Deep (FU 32). Catches and landings, Danish effort, Danish LPUE, and mean size in discards (< 40 mm) and landings (≥ 40 mm). Mean sizes in Norwegian (NO) landings and discards are from inspections by the Norwegian Coast Guard of both Norwegian and Danish vessels and catches.

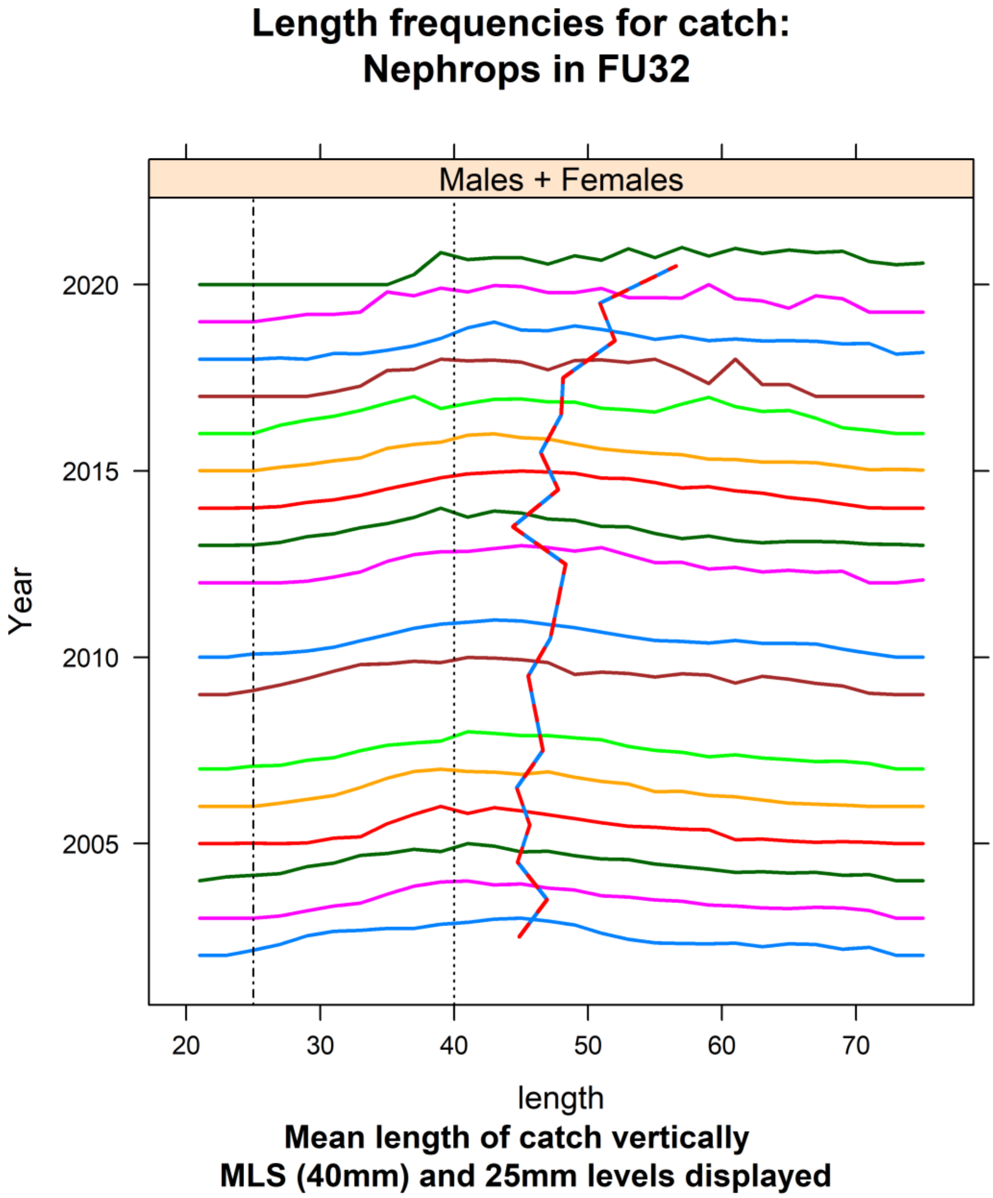


Figure 11.9.7. ***Nephrops*** **Norwegian Deep (FU 32): Size distribution in Danish catches, 2002–2020. There was no Danish sampling of discards in 2020. The figure was not updated this year as there was no Danish sampling of landings in 2021.**

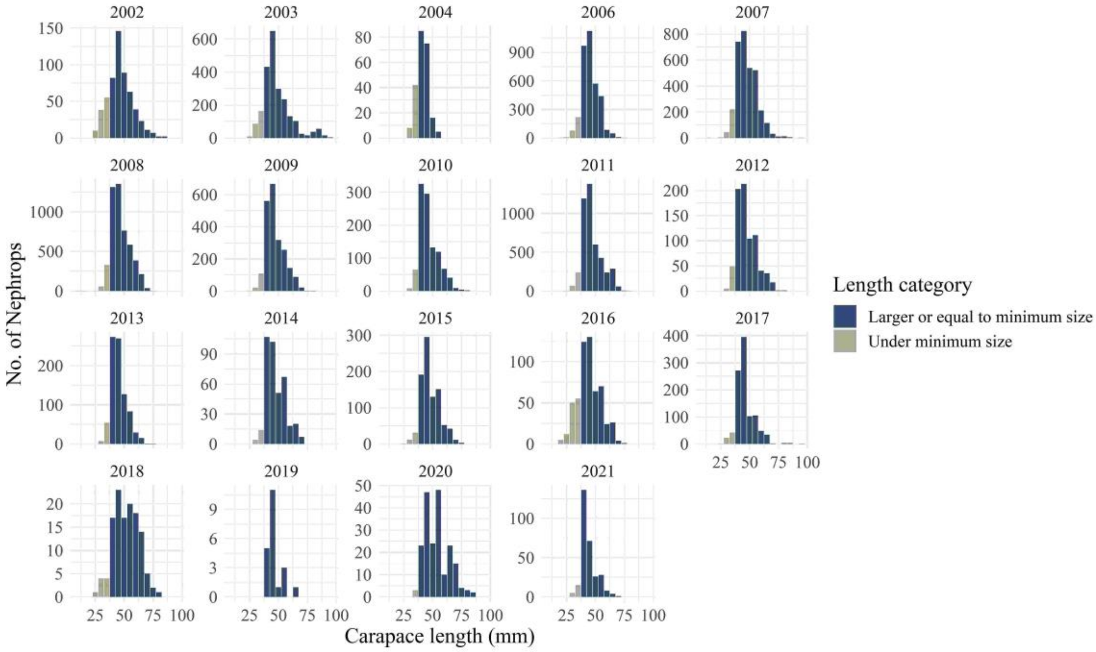


Figure 11.9.8. ***Nephrops*** **Norwegian Deep (FU 32): Annual length frequency distributions from inspections by the Norwegian Coast Guard of Danish and Norwegian trawlers, 2002–2021.**

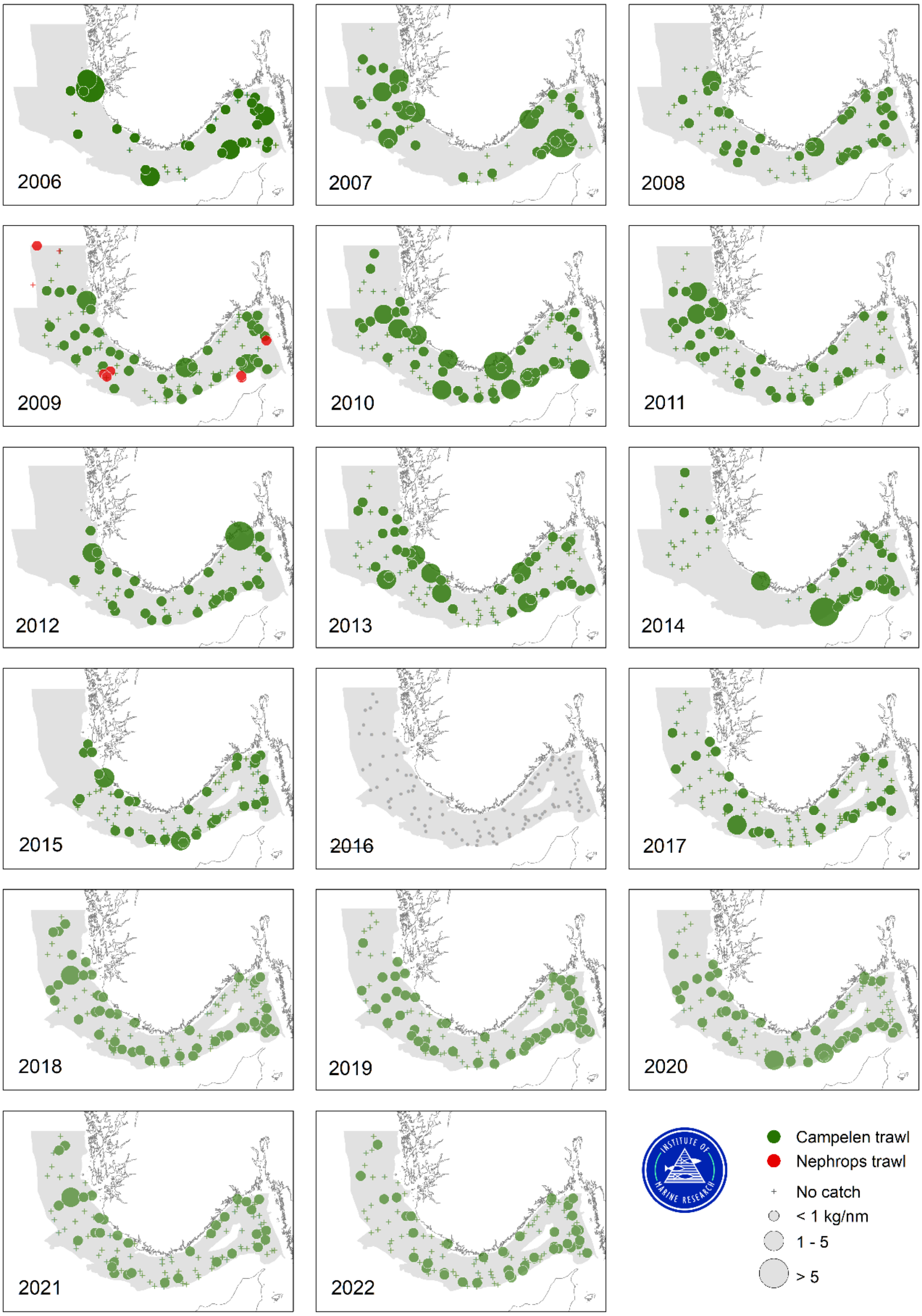


Figure 11.9.9. *Nephrops* Norwegian Deep (FU 32): Distribution of *Nephrops* in Norwegian bottom trawl shrimp survey, 2006–2022. The 2016-data are omitted from the time series due to technical problems with the trawl gear in this year's survey.

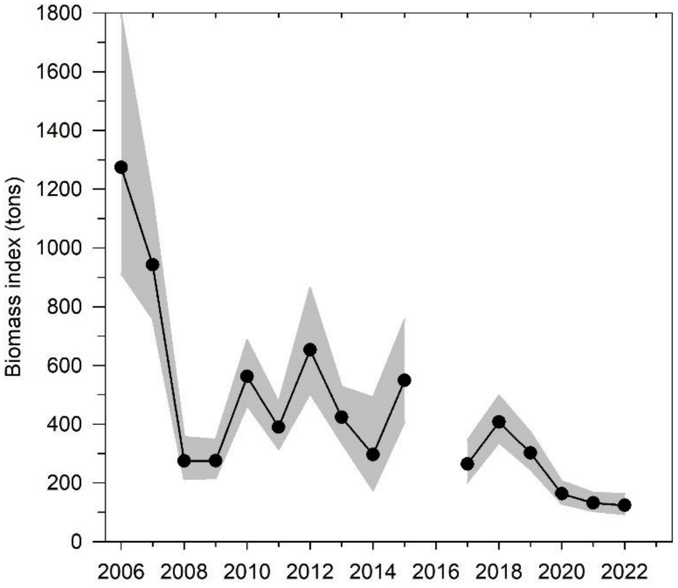


Figure 11.9.10. *Nephrops* Norwegian Deep (FU 32): Biomass index (tonnes) (2006–2022) from the Norwegian bottom trawl shrimp survey. The 2016–data are omitted from the time series due to technical problems with the trawl gear at this year's survey.

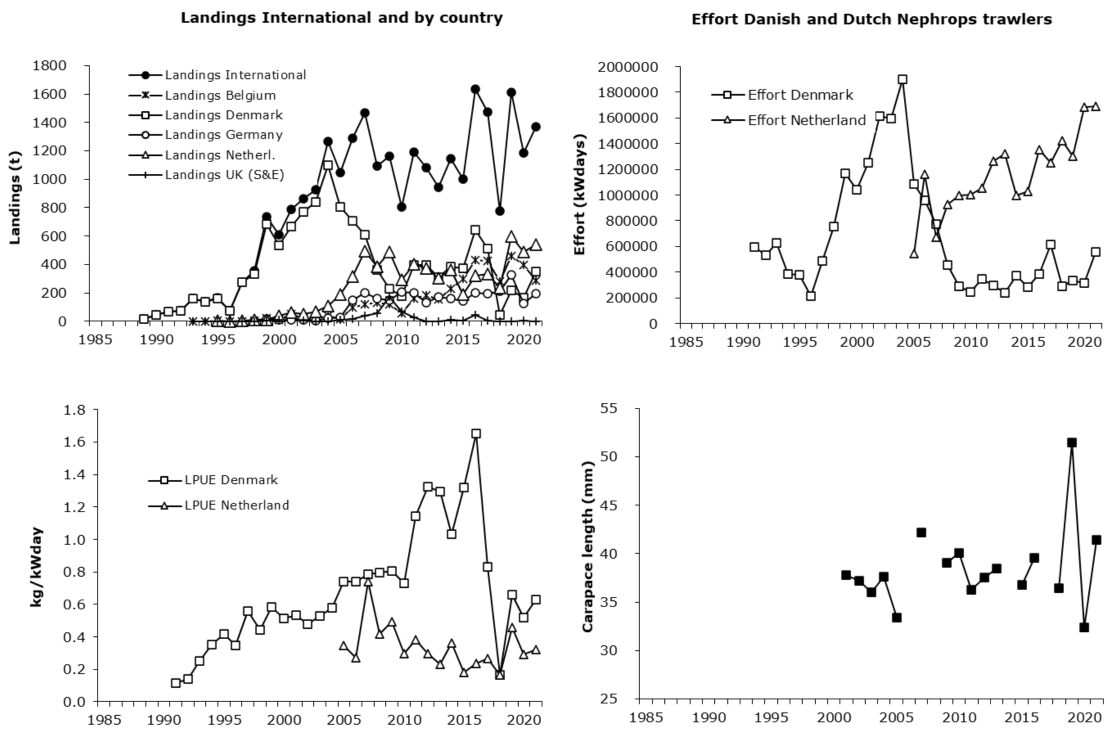


Figure 11.10.1. *Nephrops* in FU 33 (Off Horns Reef): Landings, effort, LPUE and mean size.

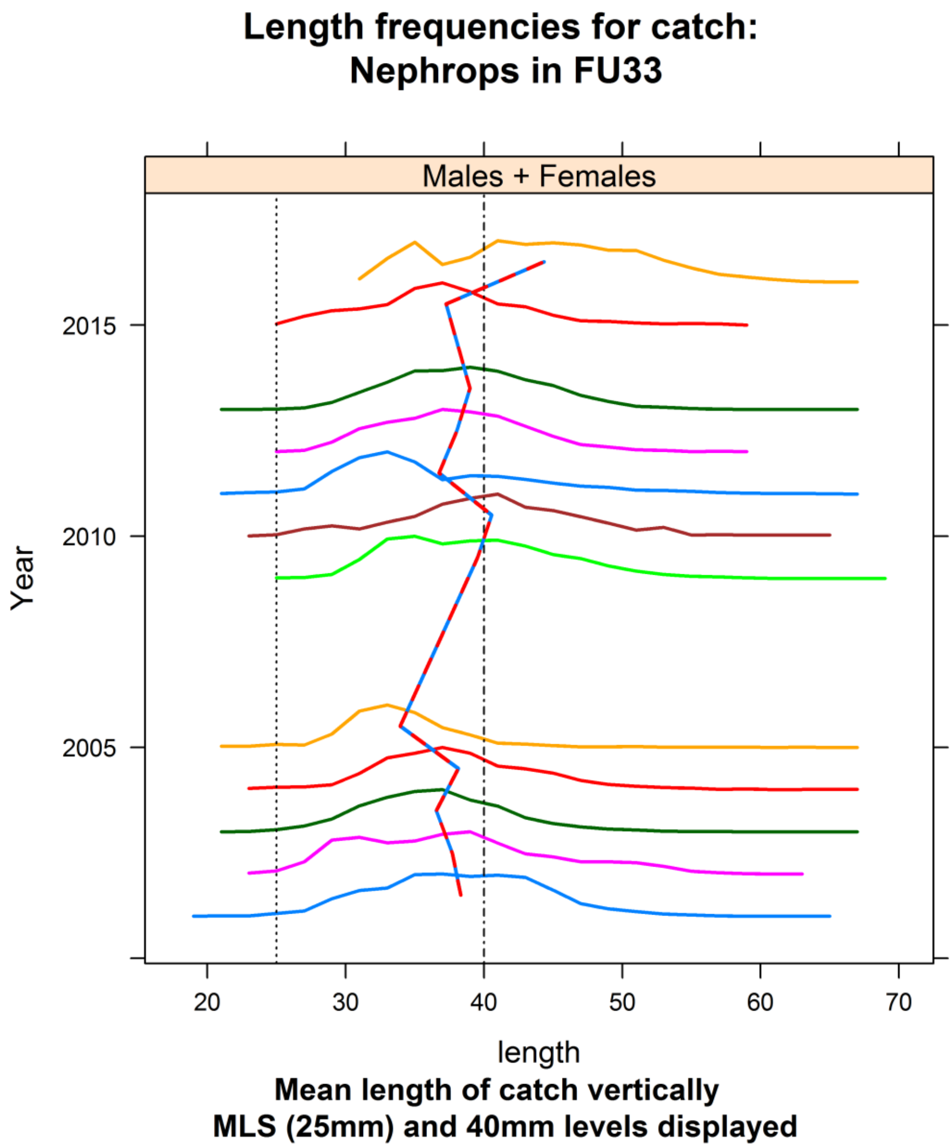


Figure 11.10.2. ***Nephrops*** **in FU 33 (Off Horn's Reef): Size distribution in Danish catches.**

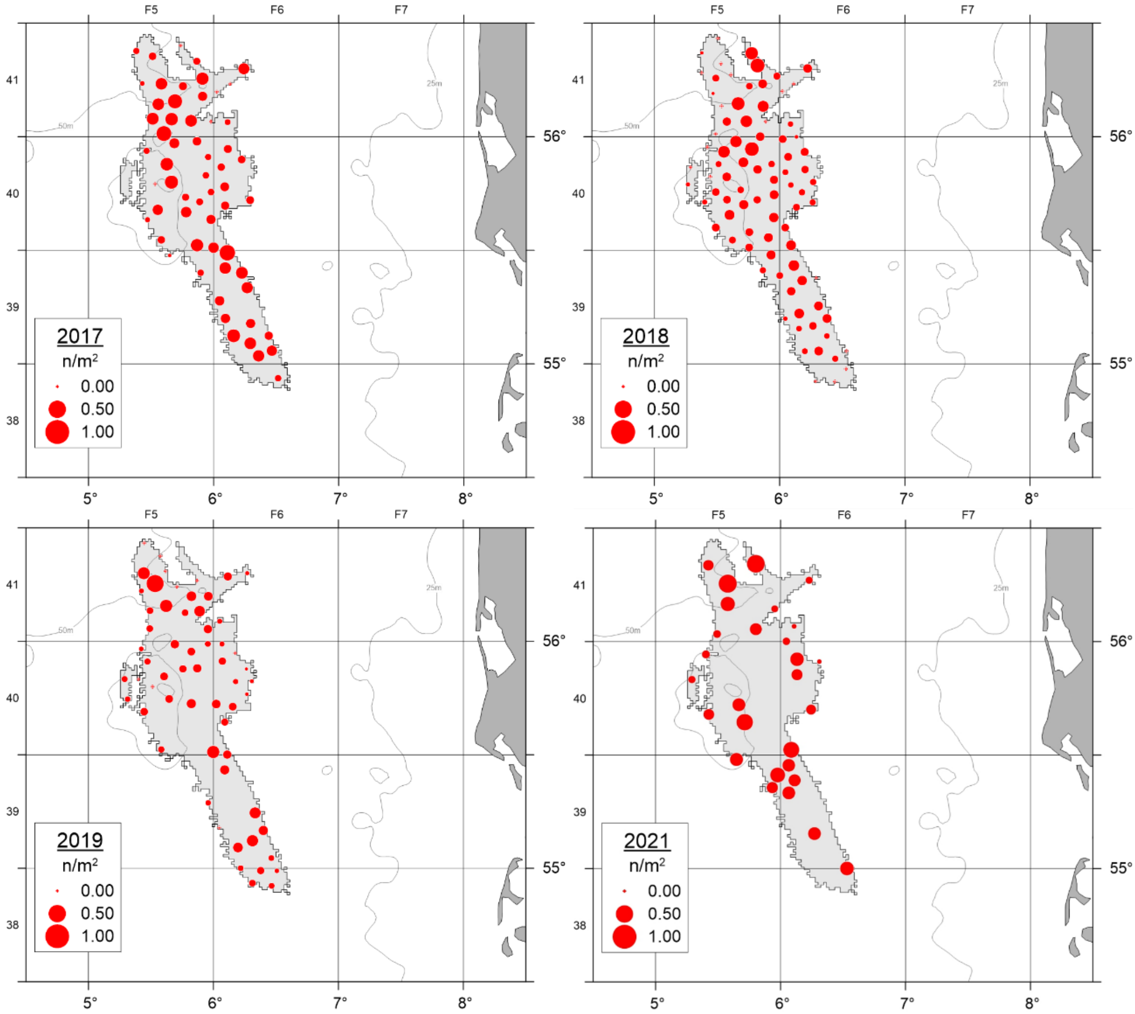


Figure 11.10.3. FU 33 (Off Horn's Reef) *Nephrops* burrow density by station for each UWTV survey year.

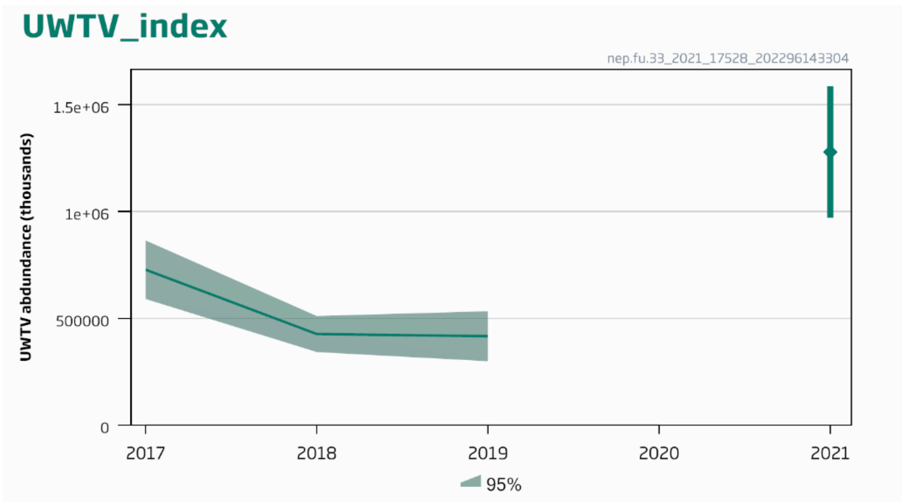


Figure 11.10.4. *Nephrops*, Off Horn's Reef (FU 33), Time series of TV survey abundance estimates (absolute conversion factor = 1.1, from FU 3 and 4), with 95% confidence intervals, from 2017 to 2021.

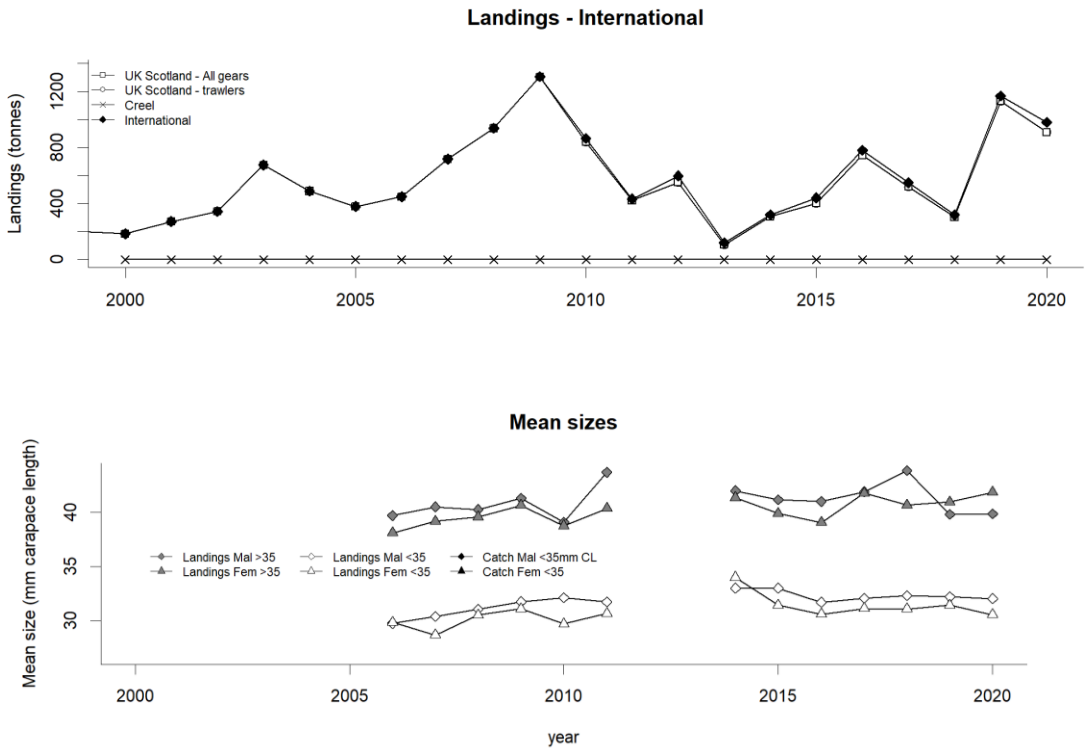


Figure 11.11.1. ***Nephrops*****, Devil's Hole (FU 34). Long term landings and mean sizes, data from year 2000.**

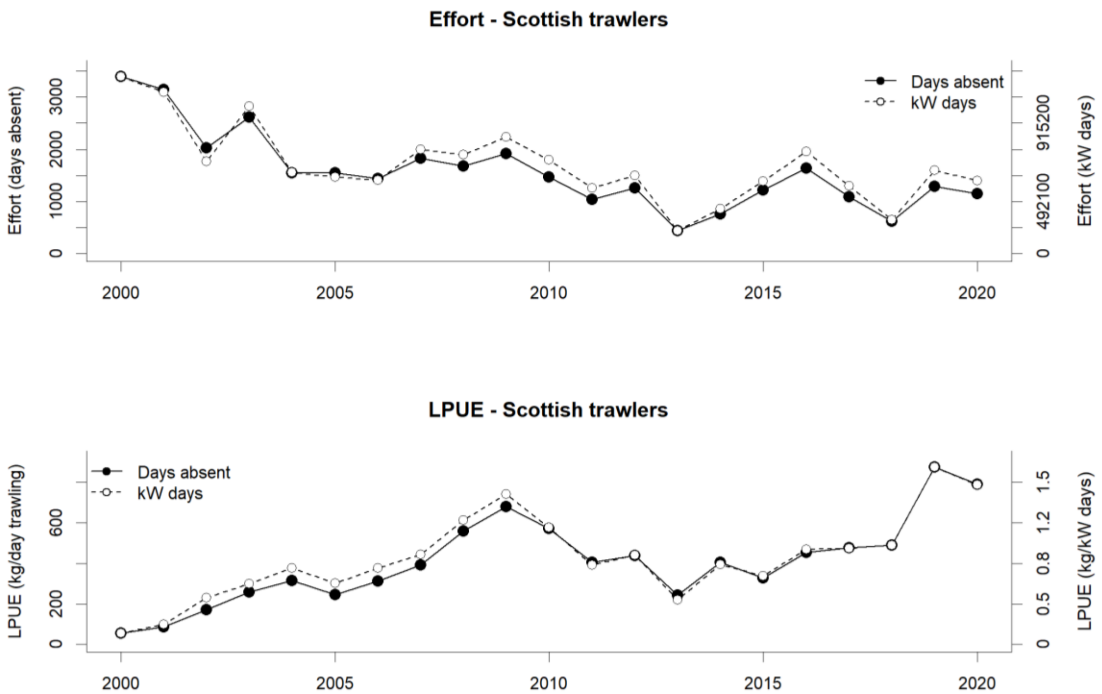


Figure 11.11.2. ***Nephrops*****, Devil's Hole (FU 34). Effort (days, kWday) and LPUE (kg/day, kg/kWdays), data from year 2000.**

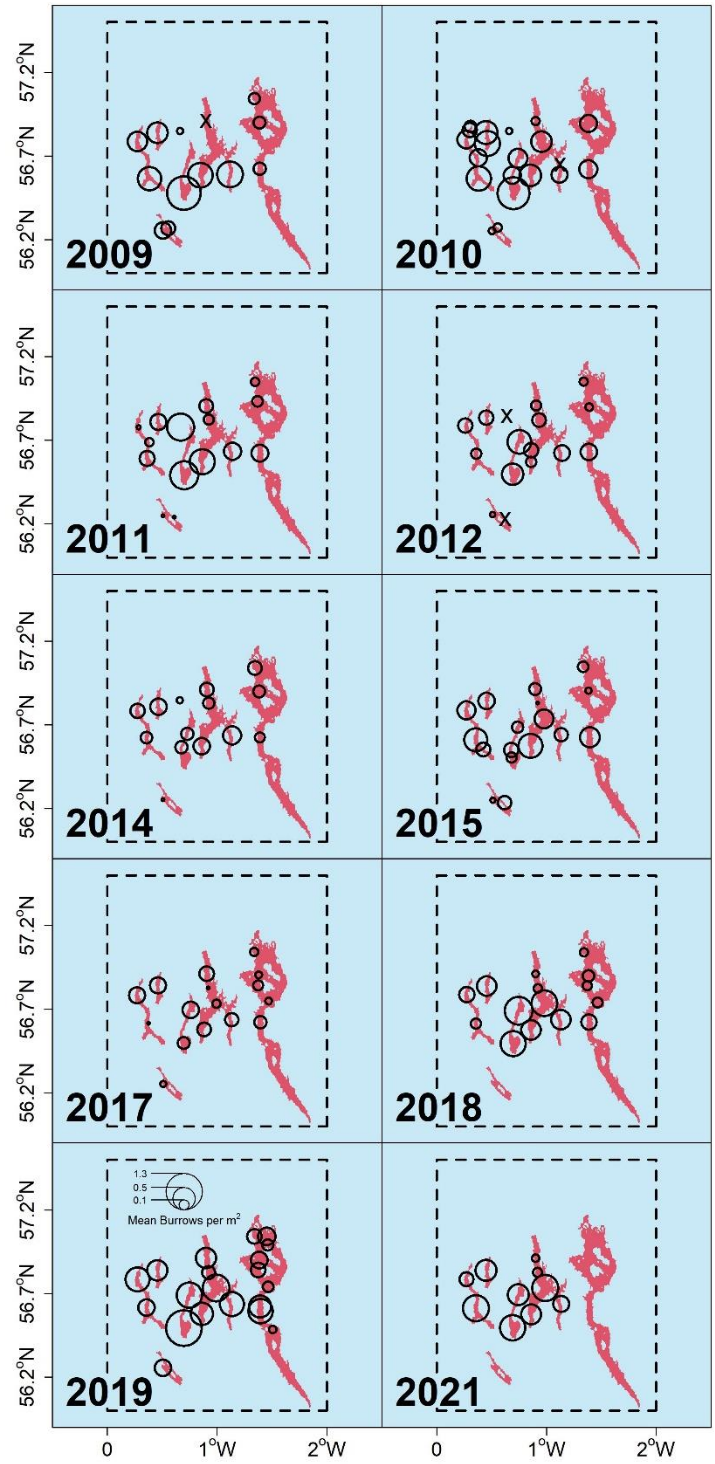


Figure 11.11.3. ***Nephrops*****, Devil's Hole (FU 34). UWTV survey distribution and relative density (2009–2021). No surveys in 2013, 2016, 2020 and 2022. Survey station locations generated from Vessel Monitoring System (VMS) data (WKNEPH, 2013). Density proportional to circle radius.**

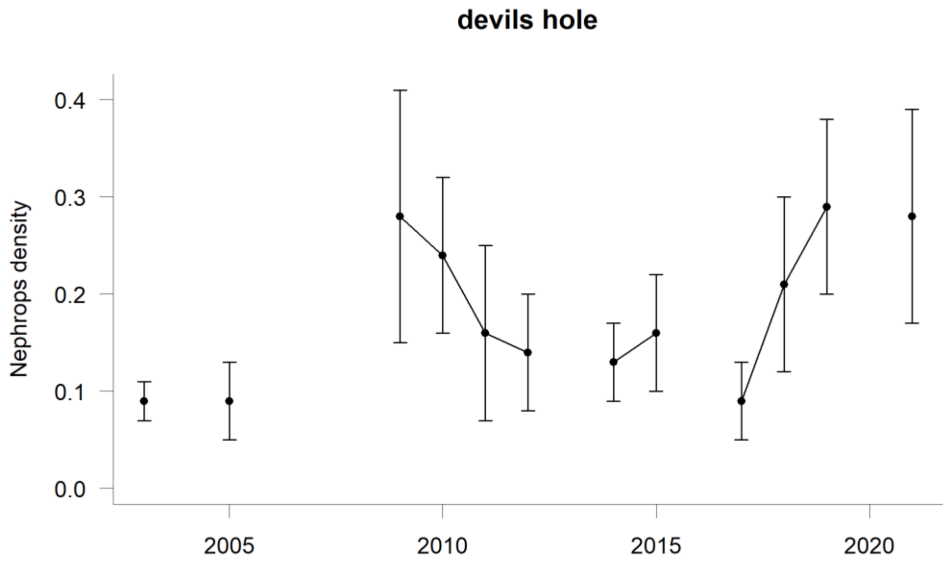


Figure 11.11.4. ***Nephrops*****, Devil's Hole (FU 34). Time series of UWTV survey density estimates with 95% confidence intervals, 2003, 2005, 2009–2021.**

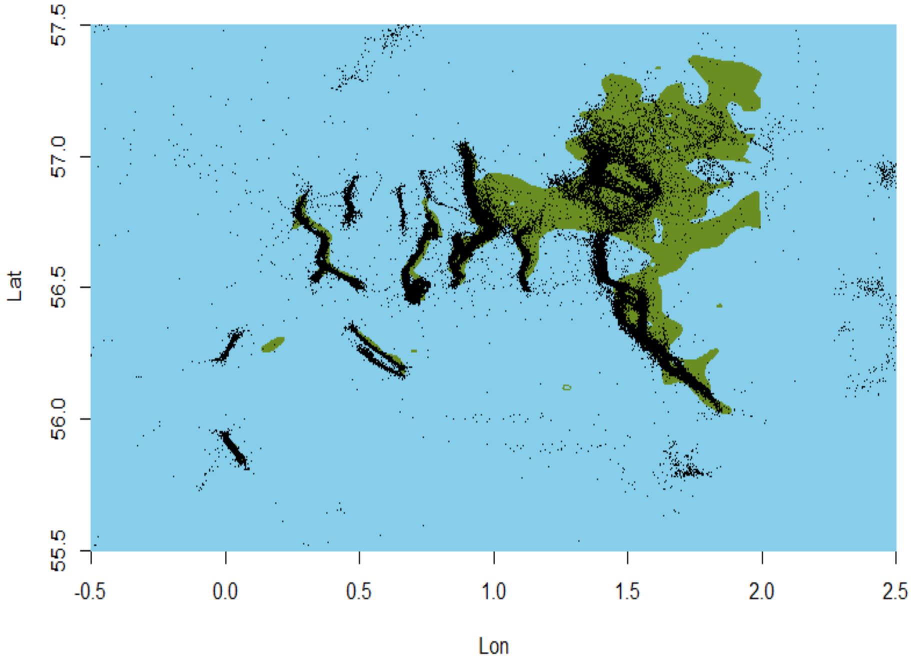


Figure 11.11.5. ***Nephrops*****, Devil's Hole (FU 34). Comparison of BGS sediment map with VMS data from Scottish trawlers (2007–2011) filtered for** ***Nephrops*** **landings > 30% of total, speeds of 0.5–3.8 knots and mesh size 70–99 mm.**

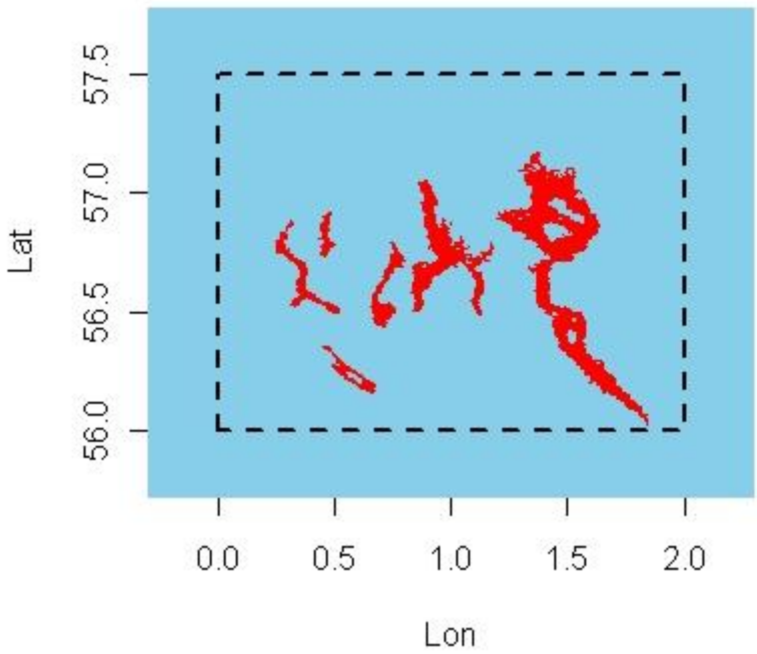


Figure 11.11.6. ***Nephrops*****, Devil's Hole (FU 34). Union of 2007–2011 annual VMS polygons (from alpha convex hull) with VMS data filtered for *Nephrops* landings > 30 % of total, speeds of 0.5–3.8 knots and mesh size 70–99 mm.**

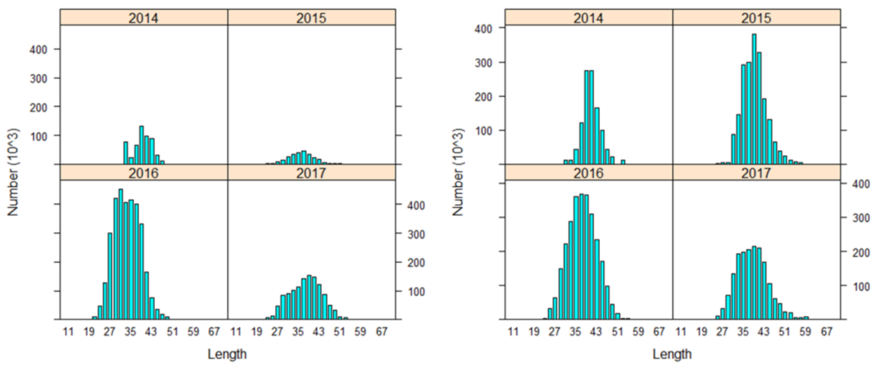


Figure 11.11.7. ***Nephrops*****, Devil's Hole (FU 34). Landings length distributions for females (left) and males (right) obtained from Intercatch and used to run the LBI screening methods (2014–2017).**

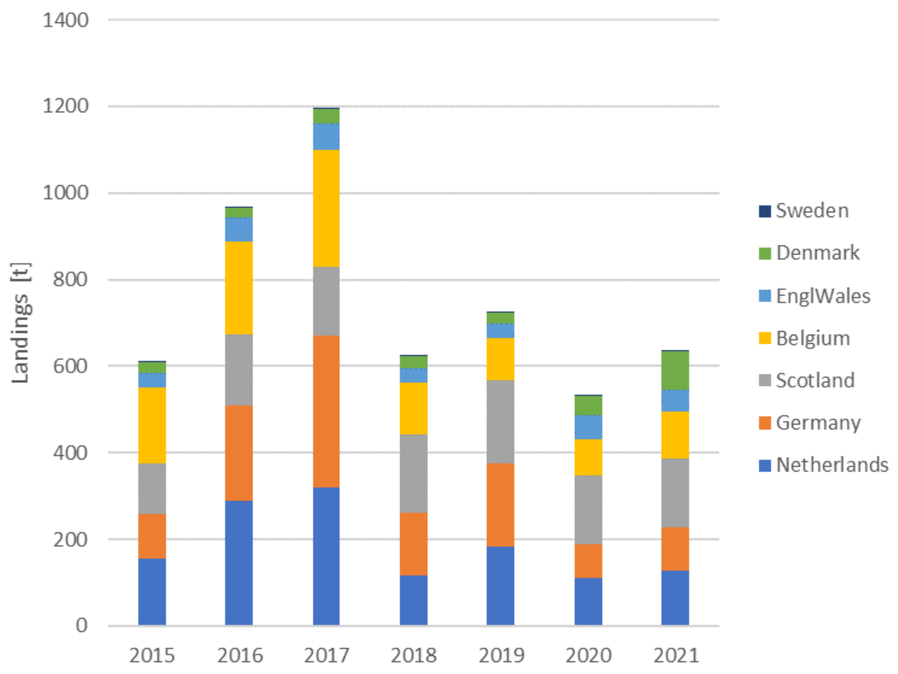


Figure 11.12.1. ***Nephrops*****, Subarea 27.4 outside FUs. Annual landings by country.**

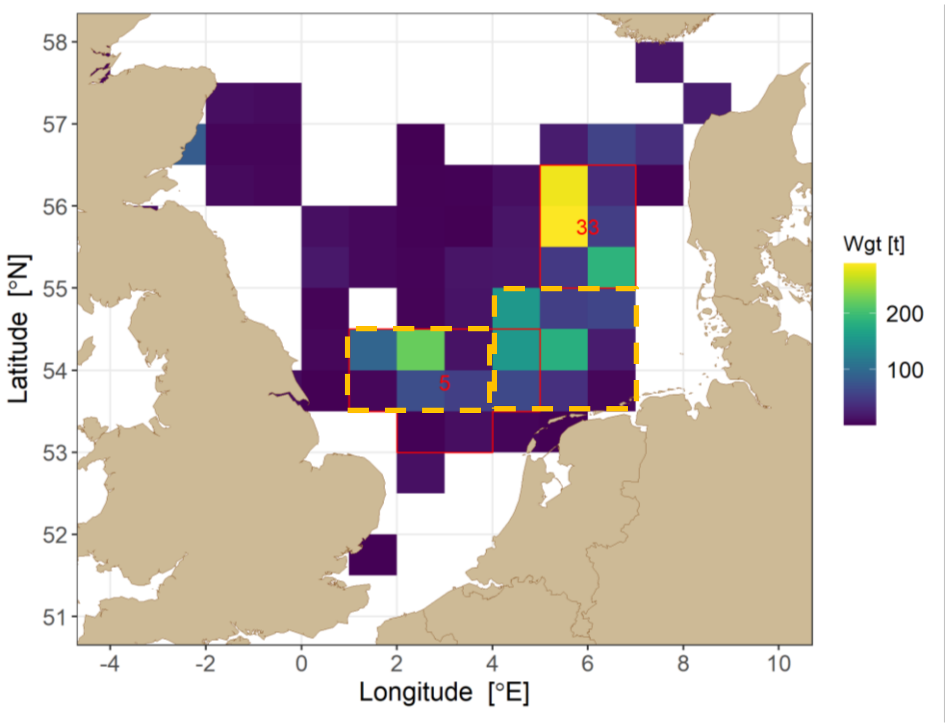


Figure 11.12.2. ***Nephrops*****, Subarea 27.4 outside FUs, and inside FUs 5 and 33. Average annual landings 2017—2021 by rectangle in tonnes. Current outlines of FUs 5 and 33 are indicated by the solid red lines. The dashed orange lines indicate the outline of a potentially redefined FU 5, together with the outline of a new functional unit towards the east, linking up with FU 33 from the south.**

3 Brill in Subarea 27.4, Divisions 27.3.a, 27.7.d and 27.7.e (bll.27.3a47de)

Brill (*Scophthalmus rhombus*) is assessed in the Working Group on the Assessment of Demersal Stocks in the North Sea and Skagerrak (WGNSSK) since 2013. Because only official landings and survey data were available, brill in subarea 27.4, divisions 27.3.a, 27.7.d, e was defined as a category 3 stock (ICES, 2021). For this stock, advice was based on the LPUE trends of the Dutch beam trawl fleet (vessels > 221 kW). From 2022 onwards, the WKLIFE X methods were applied and advice is given using the *chr* rule (ICES, 2020). From 2020 onwards, the European Commission requests annual advice for this stock instead of biennial.

3.1 General

3.1.1 Stock definition

The genetic structure of brill over its entire distribution area was characterized by Vandamme (2014). Genetic variation was found to be of intermediate to high levels, but the results show almost no differentiation between potential biological populations and/or management units. Therefore, brill in 3.a, 4 and 7.d, e is still treated as a single stock that could potentially have an even wider geographical spread. More information can be found in the Stock Annex.

3.1.2 Biology and ecosystem aspects

A general description of the available information on the biology and ecosystem aspects can be found in the Stock Annex.

3.1.3 Fisheries

Brill is mainly a high value bycatch species in fisheries for plaice and sole. Nine countries are involved in the fisheries: Belgium, Denmark, France, Germany, Ireland, The Netherlands, Norway, Sweden and UK (England, Northern Ireland, Scotland and the Channel Islands). The Netherlands landed most brill in 2021 (37%), followed by the UK (19.1%) and France (15.2%). Most brill is caught by the TBB fleet (58%), followed by the OTB, SDN and SSC fleet (26%) and the GTR and GNS fleet (13.4%).

3.1.3.1 Management

No explicit management objectives have been defined for the brill stock in 3.a, 4, 7.d, e, and no specific management objectives or plans are known to ICES. As a primarily bycatch species, regulations related to effort restrictions for the most important fleets catching brill (e.g. beam trawlers) are likely to impact the stock. Fishing effort has been restricted in the past for demersal fleets in a number of EC regulations (e.g. EC Council Regulation Nos. 2056/2001, 51/2006, 41/2007, and 40/2008). The most recent one includes the ban of pulse trawling from 1st of July 2021 onwards (EC Council Regulation No. 2019/1241).

A combined EU TAC for turbot and brill is set in areas 2.a and 4 and applies to EU fisheries (see table below).

Historical overview of combined TACs for brill *(Scophthalmus rhombus)* and turbot *(Scophthalmus maximus)* in Division 27.2.a and Subarea 27.4.

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
TAC	9000	9000	6750	5738	4877	4550	4323	4323	5263	5263	5263	4642
Year	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	
TAC	4642	4642	4642	4642	4488	5924*	7102	8122	6498	5848	5487	

*** the TAC was increased from 4937 to 5924 at the end of 2017.**

The management area (particularly the inclusion of Area 2.a) does not correspond to either of the stock areas defined by ICES for turbot and brill. Moreover, turbot (27.4) and brill (27.3a47de) cover different stock areas and have quantitative single species advice, but there is a combined TAC. This impedes sustainable management of one or both stocks. In 2018, ICES was requested to evaluate the role of TAC in the management of turbot and brill in the North Sea (ICES, 2018). It was concluded that turbot and brill should be managed using single-species TACs covering an area appropriate to the relevant stock distribution (for brill: Subarea 4, and divisions 3.a and 7.d–e; for turbot: Subarea 4). A TAC combining two high-value species (turbot and brill) under a low TAC can, in some instances, lead to the highgrading of the lesser-valued species (brill). Additionally, the advised catch for the entire brill stock seems to be used as the advice for Subarea 27.4 and Division 27.2a. This means that the advice is applied in the wrong way, involving a greater risk of overfishing the brill stock.

The combined TAC for brill and turbot has been restrictive in 2007, 2015 and 2016 (average overshoot 218 ± 197 tonnes; Figure 3.1). In 2016, some of the Member States with a share in the TAC, such as Belgium, Germany and The Netherlands asked for an advance of their quota for 2017, in order to prevent further overshooting (±10%). The TAC in 2017 was 4937 tonnes, but at the end of the year, it was increased to 5924 tonnes (±20%; 10% to compensate for the advance from 2016 and 10% for 2017). There were several reasons to justify this increase: a) after the inter-benchmark of turbot, a new advice (for 2018) was given, which meant a 148% increase against the previous TAC (2017)[1], b) similar to 2016, member states were asking an advance of their quota for next year (2018), c) observations and catches of fishermen did not seem to confirm the assessment (delay with data). Although no new advice was given in 2018 (no re-opening), the TAC for 2019 was increased to 8122 tonnes. The reason for this remains unclear. The combined TAC for brill and turbot was not restrictive for the most recent period (2017-2021). In 2021, the TAC was undershot by 36% (Figure 3.1).

No restriction on the minimum length for landing brill is imposed by the EC. Some authorities or producer organizations have however installed Minimum Conservation Reference Sizes (MCRS) for brill. Dutch producer organizations increased the MCRS when the TAC was limiting (e.g. from 27 cm to 30 cm in 2016 and later even to 32 cm). Moreover, weekly landings of turbot and brill are often capped to stay within the TAC (especially when the TAC is limiting). Following increases in advice in 2018-2019, PO measures were relaxed. An overview is shown in the table below.

[1] At WGNSSK 2018, a mistake was discovered in the final inter-benchmark run of turbot. This involved an even higher increase.

Dutch PO-measures			
Year	**Date**	**Max kg per week/trip**	**MCRS**
2016	January - March	-	27 cm
2016	April – May	-	30 cm
2016	May – September	-	32 cm
2016	October – November	375 kg	32 cm
2016	November – December	600 kg	32 cm
2017	January – February	-	32 cm
2017	March – October	800 kg	32 cm
2017	November - December	2000 kg	30 cm
2018	January – August	2000 kg	30 cm
2018	September - October	2500 kg	30 cm
2018	October - December	3000 kg	27 cm
2019	January – December	3000 kg	27 cm
2020	January - December	3000 kg	27 cm
2021	January - December	3000 kg	27 cm

Since 1 January 2019, brill is fully under the landing obligation. In 2021, Dutch producer organisations capped landings weekly for both turbot and brill to 3000 kg and had a MCRS of 27 cm. Belgium applied a MCRS of 30 cm from 1 January 2017. However, this was raised to 32 cm from 23/12/2020 onwards.

3.1.3.2 ICES advice

3.1.3.2.1 ICES advice for 2021

From 2020 onwards, the European Commission requests annual advice for the brill stock. Therefore, the previous biennial advice was replaced by the advice below.

The ICES advice for 2021 was:

ICES advises that when the precautionary approach is applied, catches in 2021 should be no more than 2047 tonnes.

The stock status was presented as follows:

	Fishing pressure				Stock size			
		2017	2018	2019		2017	2018	2019
Maximum sustainable yield	F_{MSY} proxy	✓	✓	✓ Below proxy	MSY $B_{trigger}$ proxy	✓	✓	✓ Above trigger
Precautionary approach	F_{pa},F_{lim}	✓	✓	✓ Below possible reference points	B_{pa},B_{lim}	✓	✓	✓ Above possible reference points
Management plan	F_{MGT}	–	–	–	B_{MGT}	–	–	–

3.1.3.2.2 ICES advice for 2022

The ICES advice for 2022 was:

ICES advises that when the precautionary approach is applied, catches in 2022 should be no more than 1878 tonnes.

The stock status (although no longer included in the advice sheet) was presented as follows:

	Fishing pressure				Stock size			
		2018	2019	2020		2018	2019	2020
Maximum sustainable yield	F_{MSY}	✓	✓	✓ Below	MSY $B_{trigger}$	✓	✓	✓ Above
Precautionary approach	F_{pa}, F_{lim}	✓	✓	✓ Below possible reference points	B_{pa}, B_{lim}	✓	✓	✓ Above possible reference points
Management plan	F_{MGT}	–	–	–	B_{MGT}	–	–	–

3.2 Data

From 2015 onwards, also discards by metier were requested from all countries contributing to this stock through InterCatch. For the WGNSSK data call in 2017 all available age and length data were requested through InterCatch for three years back in time (2014–2016). For the WGNSSK data calls from 2018 onwards, similarly both age and length data were requested from discards and landings.

3.2.1 Landings

Tables 3.1–3 summarize the official brill landings by country for Division 3.a, Subarea 27.4, and divisions 27.7.d-e respectively (Source: ICES Fishstat). The total official landings by area can be consulted in Table 3.4 and Figure 3.2. Over the period 1950–1970, total landings remained constant under 1000 tonnes (range from 582 to 947 tonnes), followed by a gradual increase to 2121 tonnes in 1977. From 1978 onwards, total landings remained higher than 1500 tonnes (range: 1517-3141 tonnes). In 1993, a maximum of 3141 tonnes was caught. From 2010-2020, total annual landings fluctuated around an average of 2209 tonnes (range: 1895-2538 tonnes). In 2015, landings peaked at 2538 tonnes to decrease again to 1895 tonnes in 2020 as lowest point of the last decade. In 2021, landings decreased even further to similar levels as 1999.

Subarea 27.4 accounts for the major part of the landings (Figure 3.3), on average generating 67±7% of the total landings over the time series (range: 50–86%). The English Channel and the Skagerrak-Kattegat area are responsible for average contributions to the international brill landings of 20±11% and 12±10% respectively. Skagerrak-Kattegat was responsible for a higher relative importance in the total landings during the first two decades of the time series, and the English Channel has gained importance since the late seventies. In 2021, the relative proportion of landings in Subarea 27.4 consisted of 57% of the total landings, for Division 27.3a 9% and for Division 27.7.d, e 34% (Table 3.5).

From 2014 onwards, data are available in InterCatch. Figure 3.4 shows the ICES catch estimates (both discards and landings provided through InterCatch) and the official catch statistics by country for 2021. The Belgian official landings appear much higher than what is provided to InterCatch. This appeared to be an error. The Netherlands fished the majority of the catches (predominantly in Subarea 4), followed by the UK and France (Table 3.6). Denmark is responsible for the majority of the landings in Division 27.3a. Belgium and UK (England) have the highest landings in Division 27.7d and 27.7e respectively (Table 3.6). The most important gear types landing brill are TBB and OTB, followed by GTR and GNS (Table 3.7). Industrial bycatch landings (MIS_MIS_0_0_0_IBC) were uploaded in 2020 (2003 kg from Denmark, Germany and Sweden) and in 2021 (601 tonnes from Denmark). No discards were raised for these strata.

For the WGNSSK data call in 2017, available age and length data were requested through InterCatch for three years back in time (2014–2016). From 2018 onwards, the WGNSSK data call also asked for both age and length. Data quality of age readings has been verified in 2019 by an international otolith exchange coordinated by WGBIOP and appeared very successful (ICES, 2019). For assessment purposes age/length allocations in InterCatch did not need to be performed.

However, during WGNSSK 2022, length distributions were needed to investigate the use of the *chr* rule as basis for advice. Lengths were allocated per catch category (landings and discards (incl. BMS) separately) and all gears and areas were grouped using the mean weight weighted by numbers at age. Length allocation of industrial bycatch was done using all available strata from landings, discards and BMS landings.

3.2.2 Discards

Due to its high value, brill is not expected to be discarded a lot by fishermen as long as the quota have not been fully taken. Since January 2019, the stock is completely under the landing obligation.

Discard data from 2014–2021 are available in InterCatch. The proportion of landings for which discard weights are available in 2021 was 50%, which is comparable to previous years. The proportion of imported discards is however on a decreasing trend: 68% in 2019, 44% in 2020 and 21% in 2021 (table below). It is unclear what the exact reason is.

Catch category	Survey	CATON (kg)	Percentage
BMS landing	Imported data	124	100
Discards	Imported data	31790	21
	Raised discards	119692	79
Landings	Imported data	1546651	100
Logbook registered discard	Imported data	0	NA
TOTAL		**1698257**	

Discards raising was performed on a gear level, regardless of season, area or country.

- The following groups were distinguished based on the gear:
  - TBB
  - OTB, SSC and SDN
  - GTR and GNS
- The remaining gears were combined in a REST group

All discard rates were retained during the raising (none were excluded for example due to being higher than average). Raised discards by country for 2021 are shown in Figure 3.4.

An overview of the overall discards and discard rates from 2014–2021 are shown in Table 3.8 and for 2019-2021 broken down by country and Subarea/Division in Table 3.9 and 3.10 respectively. There is no obvious trend over the period 2014–2021. However, discard rates are overall higher in the years 2018-2019. Discard rates are higher than the overall rate for e.g. Sweden (26% in 2021), France (21% in 2021), Denmark (17.6% in 2021), Norway (16.3% in 2021) and Germany (14.9% in 2021). Additionally, higher discard rates were observed in the northern part of the stock area in 2019 (28% in 27.3a) and 2020 (31% in 27.3a). However, in 2021 the discard rate has decreased to 13.5%. Brill in the greater North Sea is still considered as a data limited stock. This means that countries might apply different thresholds to supply their data to InterCatch than for stocks that are not data limited. For Germany, the larger discard rate in 2019 (41%) was influenced by 1 sampled trip having a very high discard rate. In a future benchmark, InterCatch raising procedures need to be investigated.

For assessment purposes age/length allocations in InterCatch did not need to be performed. However, during WGNSSK 2022, length distributions were needed to investigate the use of the *chr* rule as basis for advice. Lengths were allocated per catch category (landings and discards (incl. BMS) separately) and all gears and areas were grouped using the mean weight weighted by numbers at age. Length allocation of industrial bycatch was done using all available strata from landings, discards and BMS landings. Due to the new length allocations, discard estimates differed from what was used before. This will be investigated more closely during the next benchmark.

3.2.3 BMS landings

The brill stock is under the landing obligation since January 2019.

The official catch statistics have reported BMS landings from 2018 onwards, with 681 kg in 2018, 2036 kg in 2019, 779 kg in 2020 and 489 kg in 2021.

In InterCatch, only 4 kg were reported in 2019 (0 kg prior to 2019), 9 kg in 2020 and 124 kg in 2021. BMS landings are raised together with discards as is described in §3.2.2.

3.2.4 Logbook registered discards

No logbook registered discards were uploaded to InterCatch.

3.2.5 Tuning series

3.2.5.1 Survey Data

General

Catches of brill are generally very low during surveys. These low catch numbers often result in an underrepresentation of some year or length classes (mainly the older or bigger ones), leading to a poor quality of the resulting survey abundance series and indices, and poor agreement among different surveys.

WGNEW 2012 (ICES, 2012) tested four surveys for their potential use in describing stock trends of brill in the greater North Sea. Three of these surveys take place in the North Sea (IBTS_TRI_Q1, BTS_TRI_Q3 and BTS_ISI_Q3) and one in the English Channel (CGFS_Q4). Time series of total numbers of brill caught by the three North Sea surveys and the Channel are depicted in WGNEW 2012 (ICES, 2012), but only the BTS_ISI_Q3 was found to catch a sufficient number of individuals to be useful in the context of evaluating stock trends of North Sea brill. WGNEW 2013 and the following WGNSSK-meetings did not go into these surveys again, with exception for the BTS_ISI_Q3 and BITS_HAF_Q1&4 that were updated because of their use as indicators in the advice in the North Sea and the Skagerrak respectively. Plots and tables for these surveys were also updated during WGNSSK 2022.

North Sea (Subarea 27.4)

The abundance indices (numbers per hour) for brill in the BTS_ISI_Q3 in 27.4 are spatially plotted per rectangle and for several years in Figure 3.5 and over time in Figure 3.6 and Table 3.11. The recorded numbers per hour are low (max. 2.95 individuals per hour in 2014) and inter-annual variation is large. In the period 2001-2008, however, consistently lower catches were realised (approximately 1 individual per hour). After a low in 2017, the CPUE increased again in 2018 and 2019. However, in 2020 the CPUE decreased again to the level of approximately 1 individual per hour. In 2021, this decrease continued. Due to a revised input, the cpue has changed in the early part of the time series.

The numbers at length are shown in Figure 3.7. No obvious shifts in length distributions are apparent over the time series (1987–2020), but a decrease in the numbers caught since the 1990s is unmistakable.

Kattegat (Division 27.3.a21)

The abundance indices (numbers per hour) for brill in the BITS_HAF quarter 1 (Q1) and quarter 4 (Q4) are spatially plotted per rectangle and for several years in Figure 3.8 and 3.10 respectively. The index plotted over time for quarter 1 and 4 is shown in Figure 3.11 and Table 3.12 and. Note that the quarter 1 survey includes the 2022 data point.

The quarter 1 index shows a gradual increase from 1996 to 2006. Up until 2015, the series fluctuates around 3 fish per hour. In 2017, the index reaches the highest point of the time series (approximately 8 fish per hour) to decrease again in 2018 (around 1 fish per hour). In 2019-2021, approximately 4 fish per hour are caught. In 2022, the index decreases again to levels similar to 2018. The quarter 4 index shows a gradual increase from 1999 to 2007. In the period 2007–2013, the index fluctuates around 4 fish per hour. In 2014–2015, the index increases up to 6 fish per hour to decrease in 2017 to just above 4 fish per hour. The highest point in the time series is observed in 2018 when almost 11 fish per hour are caught. In 2019, the index decreases to approximately 7 fish per hour. In 2020, a small increase to almost 8 fish per hour is observed. In 2021, the index decreases to levels similar to the beginning of the time series. Both indices show more or less the same trend over the time series. In the most recent years, there is a lag of 1 year between the quarter 1 and 4 index (Figure 3.11). The quarter 1 index showed an increase in 2017, while the quarter 4 index showed this peak one year later in 2018.

The corresponding length distributions for the BITS_HAF in quarter 1 and 4 in 27.3.a21 are shown in Figure 3.9 and 3.12. In some years, at least 2 cohorts are visible, e.g. 2018 in Q4. In quarter 1 of 2022 and in quarter 4 for 2021 numbers at length are lower than the year before.

Note that the BITS is performed using another research vessel since 2016 (Havfisken I and Havfisken II).

English Channel (Divisions 27.7.d, e)

Unfortunately, no useful survey index could be identified for the evaluation of the brill sub-stock in the English Channel during previous WGNEW meetings (ICES, 2010; 2012; 2013).

3.2.5.2 Commercial LPUE series

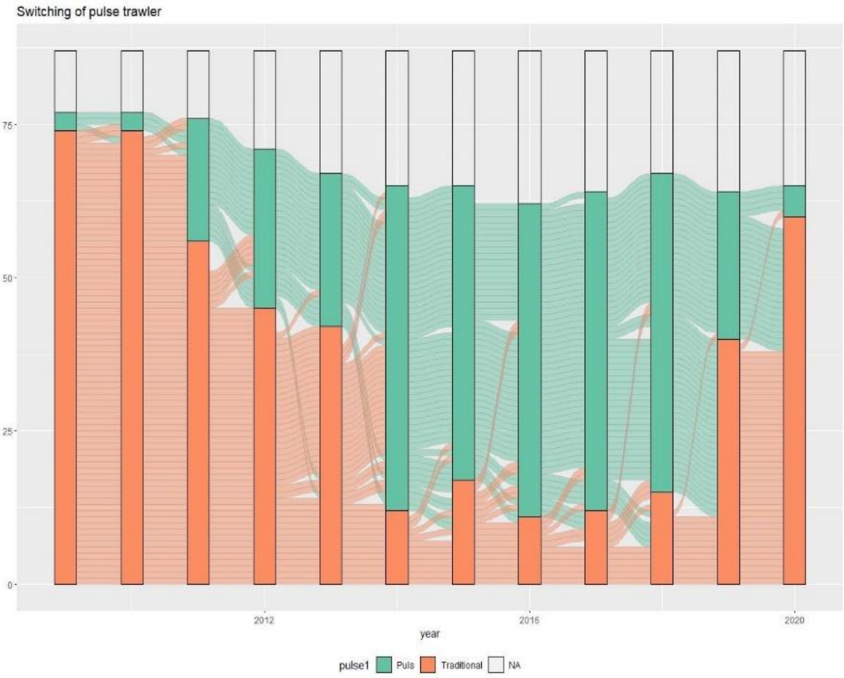
Although the survey indices presented above are useful indicators when evaluating the state of the brill stock in (parts of) the stock area, the spatial coverage of both surveys was evaluated as insufficiently spanning the stock area, and the catches too low, to use these surveys as a basis for catch advice by previous WGNEW and WGNSSK meetings.

A corrected Landings Per Unit of Effort (LPUE) series from the Dutch beam trawl fleet > 221 kW was presented and discussed for the first time during WGNEW 2013 (ICES, 2013 for interpretation), and has been used as the basis for the advice since. This LPUE was standardized for engine power and corrected for targeting behaviour. The standardisation for engine power is relevant as trawlers are likely to have higher catches with higher engine powers, as they can trawl heavier gear or fish at higher speeds. The correction for targeting behaviour relies on reducing the effects of spatial shifts in fishing effort by calculating the fishing effort by ICES rectangle and subsequently averaging these over the entire fishing area. More information on the data that were used (EU logbook auction data and market sampling data), the calculation of the LPUE's, the standardization of engine power, the correction for targeting behaviour and the results can be found in van der Hammen *et al*. (2011).

The Dutch LPUE series used during the WGNSSK 2022 is shown in Figure 3.13 and Table 3.13. The series shows a gradual increase in the LPUE (kg/day) up to 2012, dropping slightly over the period 2013–2014, but increasing again in 2015. In the period 2016–2018, a stronger decrease is observed (from 58 to 40 kg/day). While in 2019, an increase in the LPUE index is observed up to 49 kg/day, 2020 and 2021 noted again a decrease to 43 and 32 kg/day respectively.

During this year's update of the Dutch LPUE series, it was noted that rectangles are removed from the calculation when they are not fished in a certain year. For the period 2002-2021, the number of rectangles decreased from 85 to 46. However, changes to the index over the last years were considered minimal. The calculation method for this index should be improved during a benchmark.

Furthermore, the Dutch fleet has been subject to substantial changes in the most recent years as a result of the ban on pulse trawling (EC Council Regulation No. 2019/1241). The figure below shows the transition of the beam trawl fleet from traditional beam trawlers to pulse trawlers and back over the period 2009-2020 (see §1.10). It is unclear what the effect of this transition is on the Dutch LPUE series. This should be investigated in depth during the next benchmark.



3.2.5.3 Dutch industry survey

Available fisheries independent surveys have a low catchability for large flatfish, which does not benefit the turbot and brill assessments. In 2018, the Dutch fishermen's association, VisNed, together with Wageningen Marine Research initiated an industry survey to monitor turbot and brill in the North Sea.

After a trial year (2018), the survey design was optimised. The survey area in the central and southern North Sea was selected based on CPUE data. Areas not available for fishing (e.g. N2000, wind parks) were excluded (Schram *et al.*, 2021). A 5 by 5 km grid was applied to the survey area and 60 grid cells were randomly selected from this grid (new selection every year). These 60 grid cells were divided among 3 vessels based on their regular fishing grounds (Schram *et al.*, 2021). All vessels fished with the same gear (beam trawl) in autumn (quarter 3). Fishermen were allowed to start fishing at any location in the selected grid cell, they could fish any route and were allowed to exit the cell, but not the survey area. The haul duration was the same as for regular commercial hauls, 100-120 minutes.

In every haul, all turbot and brill were counted. Length, weight and sex were registered. Otoliths were collected per length class to determine age (the number of otoliths depended on sex and length class; Schram *et al.*, 2021). Fishing conditions were recorded, including a description of the gear and a list of all hauls.

In 2020, an alternative approach was used because no scientists could board the fishing vessels due to the Covid-19 pandemic. All sampled fish were therefore processed by the scientific team at the auction.

In 2021, 55 of the 60 hauls could be realised, catching 339 brill. A comparison with previous years and surveys with research vessels is given in the table below (Schram *et al.*, 2021). The numbers of brill caught during this industry survey were approximately 10 times higher than caught during the BTS (ISI/TRI Q3) survey (Figure 3.14).

Species	Survey	Year	Total N° caught	Total N° hauls	Occurrence (%)	CPUE (N°/h)
Brill	BSAS	2019	785	50	100	9.1
		2020	454	59	81.4	4.8
		2021	339	55	85.5	3.0
	BTS	2018	67	82	35.4	1.8
		2019	85	73	53.4	2.7
		2020	47	74	33.8	1.7
	SNS	2018	30	45	31.1	0.8
		2019	10	44	14	0.4
		2020	0	46	0	0.0

Length measurements ranged from 24 cm to 54 cm for brill in 2021 (Figure 3.15). Ageing was done over 1 cm-classes for 135 brill in 2021, with most of them within ages 1 to 3 (Figure 3.16).

Once a period of 5 years is covered, the index of this new survey is a potential candidate to include in the brill assessment (indicative of trends).

3.3 Advice

3.3.1 Exploration of the different methods for advice

WKLIFE X (ICES, 2020) investigated the performance of harvest control rules across life-history types through simulation and management strategy evaluation (MSE) for data-limited stocks. During WGNSSK 2022, different methods to give advice were explored and discussed as a result of the WKLIFE X methods agreed upon by ACOM (ICES, 2020).

- 2 : 3 rule using the Dutch commercial lpue index + SPiCT to evaluate stock status against proxy reference points
- WKLIFE X: SPiCT
- WKLIFE X: *Chr* rule

All of them will be discussed below. The working group decided to move forward with the *chr* rule to give advice for 2023 following the WKLIFE X decision tree (Annex 3 in ICES, 2020).

3.3.1.1 2 : 3 rule

From 2017 onwards, advice has been given based on the 2:3 rule applied to the Dutch commercial LPUE series in combination with a Surplus Production in Continuous Time (SPiCT) model to investigate the status of the stock against proxy reference points.

This year (WGNSSK 2022), applying the 2:3 rule would have led to a -19.1% decrease. No uncertainty cap would be applied as the ratio would not imply a change of more than 20%.

To decide whether the precautionary buffer would have to be applied, the Surplus Production in Continuous Time (SPiCT) model was run as described under §3.3.3. Relative fishing pressure and relative biomass were respectively below and above MSY proxy reference points (B/B_{MSY} = 0.5 and F/F_{MSY} = 1; Figure 3.17).

The 2:3 was not used to provide advice as the *chr* rule was perceived more precautionary and the SPiCT assessment was rejected (see further).

3.3.1.2 WKLIFE X: SPiCT

A Surplus Production Model in Continuous Time (SPiCT, Pedersen and Berg, 2017) was run applying the procedure and settings as agreed during the WGNSSK 2017 (ICES, 2017a), using the default priors.

A fishery independent survey time series (BTS_ISI_Q3 trimmed to 1987–2021; Table 3.11), a standardized LPUE from the Dutch beam-trawl fleet (with vessels > 221 kW; including age 0 and 1; 1995–2021; Table 3.13), and a landings time series (trimmed to 1987-2021; Table 3.14) were used as input for the model. The landings series includes official landings from 1987–2013 and InterCatch landings from 2014 onwards. The BITS surveys in quarter 1 and 4 were not used in the SPiCT run as was decided during WGNSSK 2017 (ICES, 2017a).

A summary of the SPiCT assessment is given in Figure 3.17 and in Table 3.15. The model diagnostics are shown in Figure 3.18.

The retrospective analysis demonstrates a stable assessment. Although one peel did not converge, the other peels fall within the confidence bounds (Figure 3.19). The Mohn's Rho values for F/F_{MSY} (-0.001) and B/B_{MSY} (-0.035) were acceptable.

To evaluate whether the SPiCT assessment can be accepted to give advice, a number of technical criteria are put forward (WKLIFE X ICES, 2020).

1) The optimisation has converged (Table 3.15).
2) All variance parameters of the model parameters are finite.

```
> all(is.finite(fit$sd))
[1] TRUE
```

3) No violation of model assumptions based on one-step-ahead residuals (Figure 3.18).
4) No consistent patterns in the retrospective analysis and within the confidence bounds (Figure 3.19). However, one peel did not converge.
5) The shape of the production curve should not be too skewed (Figure 3.17). B_{MSY}/K (where K is the carrying capacity estimate) is 0.29, which is between the recommended 0.1-0.9 range. However, low values of B_{MSY}/K allow for an infinite population growth rate.
6) The main variance parameters should not be unrealistically high. Confidence intervals for B/B_{MSY} and F/F_{MSY} should not span more than 1 order of magnitude. This was not the case although brill is a fast-growing species with a Von Bertalanffy k = 0.43.

```
> calc.om(fit) # ok?-----------------------------
        lower  est upper CI range order magnitude
B/Bmsy   0.70 1.06  1.59     0.89               1
F/Fmsy   0.47 0.71  1.08     0.61               1
```

7) Initial values did not influence the parameter estimates. The optimisation should converge to the same estimates when starting from different initial parameter values. This was the case.

To improve the shape of the production curve, modifications to the settings were explored as suggested in the technical criteria (WKLIFE X ICES, 2020).

```
# option 1
inp$priors <- list(logn = c(log(2),0.0001,1)) # last zero = use the log 2, if 0 then deactivate logn prior
# no convergence!

# option 2
inp$priors$logn <- c(log(1.478), 0.6, 1) # Thorson et al 2012
# works
# criteria 4: only 1 peel converged
# criteria 5: calc.bmsyk(fit) = 0.3469914 = better
# criteria 7: some differences in resmat table, eg sdc, sdf,...

#option 3:
inp$priors$logn <- c(log(2), 0.5, 1) # tighter Schaefer
# criteria 4: only 1 peel converged
# criteria 5: alc.bmsyk(fit) = 0.3891239 = better
```

The first suggested option led to no convergence of the SPiCT model. The other two options gave a better B_{MSY}/K estimate resulting in a slightly less skewed production curve. However, performance against the other criteria was poorer.

The working group decided <u>not to accept</u> this SPiCT assessment as basis for the advice. The shape of the production curve should be investigated further as it is unrealistic to assume an infinite population growth rate for this stock. Furthermore, a dedicated benchmark for this stock is needed to investigate whether other data could be used as input for the SPiCT assessment. Especially tuning fleets from the 3a, 7d and 7e area should be reconsidered.

3.3.1.3 WKLIFE X: *chr* rule

Following the decision tree (Annex 3 in WKLIFE X ICES, 2020), when the SPiCT assessment is not accepted, the next step is to investigate if there is an index of abundance, length data and information on k. For brill, the Dutch commercial lpue index is available, length data from 2014 onwards have been supplied to InterCatch and k has been determined in van der Hammen *et al.* (2013) to be 0.48 for males and 0.38 for females.

When **<u>k</u>** is found to be equal or larger than 0.32 and smaller than 0.45, the *chr* rule needs to be applied with m=0.5. When taking the average of both sexes, k is equal to 0.43 (van der Hammen *et al.*, 2013).

The *chr* formula contains different factors to determine the catch in the advice year:

$$C_{y+1} = I_{y-1} \times F_{proxyMSY} \times b \times m$$

where

- y = 2022
- C_{y+1} = the catch in the advice year, 2023
- I_{y-1} = the index value of 2021. For brill we use the Dutch commercial LPUE index as shown in Figure 3.13 and Table 3.13.
- m = the multiplier applied to the harvest control rule to maintain the probability of the biomass declining below B_{lim} to less than 5%. This multiplier is set to 0.5 for the *chr* rule.
- b = the biomass safeguard. The most recent index data I_{2021} needs to be compared to $I_{trigger}$ with $I_{trigger}$ = 1.4 x I_{loss} and I_{loss} = the lowest observed index value. For brill I_{loss} = 13.387 kg/day, being the index value in 1997 (Table 3.13); $I_{trigger}$ is therefore = 18.742 kg/day, which is smaller than I_{2021} = 32.243. Therefore, b should be set equal to 1. (values not rounded to allow checking of the calculations).

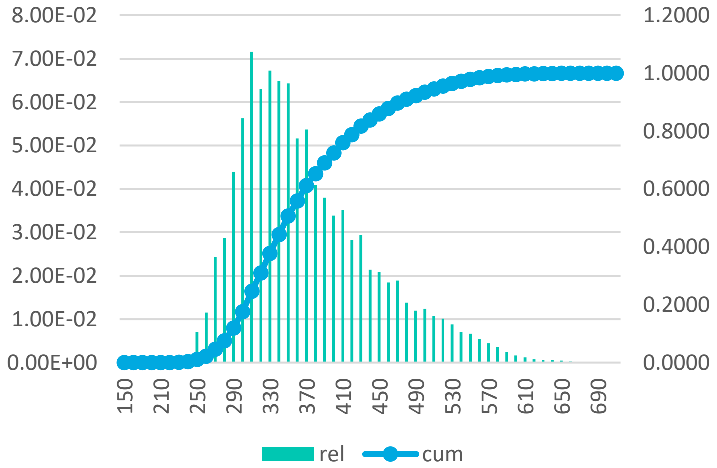
- $F_{proxyMSY}$ = The harvest rate for the set of years for which the fishing pressure proxy relative to the MSY proxy indicator ratio L_{mean} / $L_{F=M}$ is larger than 1. We calculate the $F_{proxyMSY}$ in different steps.
  - First, we calculate the length at first capture (Lc) by year, which is defined as the first length class where abundance is more than or equal to half of the maximum abundance. Length data is available through InterCatch from 2014 onwards (note that the number of length samples and the origin (which countries) has not yet been evaluated during a benchmark). For this calculation, both landings and discards data were used. Lc per year is shown in the table below.

Year	Lc (mm)
2014	170
2015	230
2016	290
2017	210
2018	210
2019	210
2020	240
2021	230

  - Second, we calculate L_{inf} (length infinity) using a formula provided by Garcia-Carreras *et al.* (2016).

$$\log_{10} L_\infty = 0.068260\ (\pm 0.010451) + 0.969112\ (\pm\ 0.006318)\ \log_{10} L_{\max}$$

    L_{max} was calculated as the 99th percentile of the length frequency distribution = 542.69 mm. For this calculation we filtered only on the landings data.



    Using the formula, L_{inf} = 522.82 mm (values not rounded to allow checking of the calculations).
  - Third, the target reference length $L_{F=M}$ = 0.75Lc + 0.25L_{inf} is calculated per year and shown in the table below.

Year	$L_{F=M}$ (mm)
2014	258
2015	303
2016	348
2017	288
2018	288
2019	288
2020	311
2021	303

- Fourth, the mean length above Lc is calculated.

Year	L_{mean} > Lc (mm)
2014	317
2015	348
2016	374
2017	343
2018	320
2019	308
2020	337
2021	299

- Fifth, the quantity f is calculated as the ratio of the mean length above Lc and $L_{F=M}$. Calculations were done with unrounded values. For all years except in 2021 the fishing pressure proxy relative to the MSY proxy indicator ratio L_{mean} / $L_{F=M}$ (f) was larger than 1.
- Sixth, the harvest rate (ratio of catch over index) is calculated.
- Finally, the $F_{proxyMSY}$ being the mean of the harvest rates for the period 2014-2020 (where quantity f >1) is 49.05994.

Year	Lc (mm)	Linf (mm)	$L_{F=M}$ (mm)	L_{mean} > Lc (mm)	Quantity f	Index (I)	Catch (C)	Harvest rate (C/I)
2014	170	522.82	258	317	1.227780	46.6672	2150.40	46.07947
2015	230	522.82	303	348	1.147467	63.4756	2700.38	42.54196
2016	290	522.82	348	374	1.072831	57.5123	2711.46	47.14578
2017	210	522.82	288	343	1.189663	50.1951	2415.33	48.11896
2018	210	522.82	288	320	1.111065	39.7183	2305.17	58.03806
2019	210	522.82	288	308	1.067611	49.0276	2564.39	52.30498
2020	240	522.82	311	337	1.085820	42.7165	2101.24	49.19038
2021	230	522.82	303	299	0.987113	32.2425	1698.26	52.67133

When inserting all factors in the *chr* formula we end up with a catch for 2023 equal to 790.9083 tonnes, without consideration of the uncertainty cap.

The *chr* rule was used to provide advice for 2023.

3.3.2 2023 advice

3.3.2.1 Advice based on 2 : 3 rule

The catch advice based on the 2:3 rule is 1520 tonnes. This means a 19.1% decrease compared to the advised catch for 2022 (1878 tonnes). The change in advice is the result of a decline in the biomass index.

The discard rate is calculated taking a simple average over the discard rates from the last three years (2019-2021).

Year	Landings	Discards	Catch	Discard Rate
2019	2147	417	2564	0.163
2020	1872	229	2101	0.109
2021	1547	151	1698	0.089
average				0.120

Index A (2020–2021)		46 kg day^{-1}
Index B (2017–2019)		37 kg day^{-1}
Index ratio (A/B)		0.81
Uncertainty cap	Not applied	-
Advised catch for 2022		1878 tonnes
Discard rate (2019–2021)		12.0%
Precautionary buffer	Not applied	-
Catch advice **		1520 tonnes
Projected landings corresponding to catch advice ***		1337 tonnes
% advice change^		−19.1%

** [Advised catch for 2022] × [index ratio].

*** [Advised catch for 2022] × [index ratio] × [1–discard rate].

^ Advice value for 2023 relative to the advice value for 2022.

3.3.2.2 Advice based on SPiCT forecast

Although the SPiCT assessment was not accepted to provide advice, the SPiCT forecast is described for completeness.

WKLIFE X recommends using the fractile rule with 35th percentile of the predicted catch distribution for stocks with an accepted SPiCT assessment. In theory, this should be more precautionary than the median rule suggested by WKMSYCat34 and the 2 over 3 rule (ICES, 2017b; 2020).

Four catch scenarios were explored, not specifying any intermediate year assumptions. Considering that the input data are only landings, the output of the forecast will also be landings advice. An overview is given in the table below. The Fsq scenario implies that the F process continues after the intermediate year. F_{MSY} is defined as F/F_{MSY} equal to 1.

F in 2023-2024	Landings advice 2023	B/B_{MSY} (2024)	F/F_{MSY} (2023-2024)
F = 0	0	2.2	0.00
F = Fsq	1965	1.30	0.71
F_{MSY}	2473	1.06	1.00
F_{MSY} 35% fractile	**2326**	1.13	0.91

The SPiCT forecast resulted in a landings advice of 2326 tonnes, which is 44% higher than the landings advice for 2022 (1613tonnes). The output of the SPiCT assessment suggest that the brill stock is currently in a good state compared to proxy reference points. Consequently, it is not unusual to expect higher advice using the SPiCT forecast. However, questions arose concerning the SPiCT input data and the unrealistic production curve.

3.3.2.3 Advice based on *chr* rule

The calculated catch advice for 2023 using the *chr* rule was 791 tonnes, which is a decrease of 58% compared to the previous advised catch (1878 tonnes). When this difference is larger than +20% or -30%, the advice should be capped to +20 or -30% respectively. Therefore, the catch advice based on the *chr* rule is 1315 tonnes. The change in advice is due to the change from the 2:3 rule to the *chr* rule and to the change in the biomass index.

The discard rate calculation is described under §3.3.2.1.

Previous catch advice A_y (advised catch for 2022)		1878 tonnes
Biomass index		
I: most recent biomass index (I_{2021})		32.2 kg × day^{-1}
MSY proxy harvest rate		
$F_{MSY\ proxy}$: MSY proxy harvest rate (average of the ratio of catch to biomass index for the years for which f>1, where f = $L_{mean}/L_{F=M}$)		49.1
Biomass safeguard		
Index trigger value ($I_{trigger}$=1.4*I_{loss})		18.7 kg × day^{-1}
b: index relative to trigger value, min{$I_{2022}/I_{trigger}$, 1}		1.00
Precautionary multiplier to maintain biomass above B_{lim} with 95% probability		
m: multiplier (generic multiplier based on life history)		0.5
Uncertainty cap (+20%/-30% compared to A_y, only considered if b=1)	Applied	-30%
Discard rate		12.0%
Catch advice for 2023**		1315 tonnes
% advice change***		-30%

** Formula: I × $F_{MSY\ proxy}$ × b × m, limited by uncertainty cap if applicable

*** Advice value for 2023 relative to the advice value for 2022 (1878 tonnes).

3.4 Biological reference points

The table below summarises all known reference points for brill in area 27.3a47de and their technical basis.

Framework	Reference point	Value	Technical basis	Source
MSY approach	$I_{trigger}$	18.7	1.4 × I_{loss}: the lowest value of the biomass index (Table 8) multiplied by 1.4.	ICES (2022)
	$F_{MSY\ proxy}$	49.1	Average of the ratio of catch to biomass index for the years for which the fishing pressure proxy relative to MSY proxy (f) >1, where f = $L_{mean}/L_{F=M}$ (Table 8 and Figure 2).	ICES (2022)
	F_{lim}	Not defined		
	F_{pa}	Not defined		
Management plan	SSB_{mgt}	Not defined		
	F_{mgt}	Not defined		

3.5 Quality of the assessment

→ The index used as basis for the advice is a commercial biomass index (Dutch beam-trawl fleet, vessels > 221 kW) used as an indicator of stock size. During WGNSSK 2022, questions arose about the quality of this index. Both the calculation method and the impact of technological creep and the changes in the Dutch fleet should be investigated during a next benchmark.

→ When the TAC is limiting, Dutch producer organizations increase the minimum market landing size and cap the weekly landings to stay within the TAC, which has likely biased the commercial biomass index downwards for 2016. These measures were relaxed in 2018 and 2019 following an upward revision in the TAC at the end of 2017 (§3.1.3.1 Management).

→ The current surveys in this area are not designed for catching brill, especially large brill. A survey, both with adequate catchability of large flatfish and covering the entire distribution area of the stock, would improve the assessment. The Dutch industry survey initiative is a step in the right direction. Furthermore, other candidates for tuning fleets in area 3a, 7d or 7e should be investigated.

3.6 Management considerations

Brill is mainly a bycatch species in fisheries for plaice and sole. ICES was requested to evaluate the role of the TAC in the management of turbot and brill in the North Sea (ICES, 2018). ICES concluded that turbot and brill should be managed using single-species TACs covering an area appropriate to the relevant stock distribution (for brill: ICES Division 3.a, Subarea 4, and divisions 7.d and 7.e). A TAC combining two high-value species (turbot and brill) under a low TAC can, in some instances, lead to highgrading of the lesser-valued species (brill).

The assessment uses a commercial biomass index based only on landings; as a result, the index and the advice may be affected by the discard pattern.

3.7 Benchmark issue list

Issue	Problem/Aim	Work needed / possible direction of solution	Data needed to be able to do this: are these available / where should these come from?	External expertise needed at benchmark type of expertise / proposed names
(New) data to be considered and/or quantified	Additional M - predator relations	Not at the moment		
	Prey relations	Not at the moment		
	Ecosystem drivers	Not at the moment		
	Other ecosystem parameters that may need to be explored?	Not at the moment		
New data	Currently a limited amount of brill data is available in InterCatch. Ask all countries involved in the fisheries to provide all available brill data on landings, discards, @age, @length including historical data.	Process data in InterCatch, potentially use model to bridge gaps in time series (cfr. Turbot assessment). Investigate InterCatch raising procedures also accounting for area or quarter, besides gear, depending on the available data.	Data from all countries involved in brill fisheries.	Expert in modelling (cfr. Turbot assessment)
Tuning series	Check whether BITS and BTS ISI still give an adequate estimation of the stock trends (cfr earlier analysis by WGNEW in 2012). Check whether there is survey information available in the 7d, e part of the stock area.	Analyse DATRAS data	Data available in DATRAS.	Survey experts
	Make the Dutch commercial tuning series more robust to changes in the fleet composition. Check whether this series can be extended, should be age-structured and should include age 0 and 1. Investigate the calculation method especially related to the loss of rectangles, when not fished.	Model Dutch LPUE series	Dutch catch, effort and fleet information	Dutch experts in LPUE modelling
	Check whether any commercial tuning series could be used in the assessment (besides the Dutch LPUE series currently used) especially in area 3a, 7d and 7e.	Analyse data and construct index	Catch and effort information from all countries involved in the brill fisheries	Experts from each Member State providing the data
	Check the potential use of the recently initiated Dutch industry survey.	Analyse data	Data from the Dutch industry survey	Dutch experts on the brill-turbot industry survey

Issue	Problem/Aim	Work needed / possible direction of solution	Data needed to be able to do this: are these available / where should these come from?	External expertise needed at benchmark type of expertise / proposed names
Discards	Discards are not included in the assessment	Considering that discarding of larger length classes occurs when the TAC is restrictive, it should be verified whether the NL LPUE could be revised to a CPUE index.	Discard data from all countries involved in the brill fisheries	Dutch experts to revise the LPUE index
Biological Parameters	When using length-based indicators, correct information on length at maturity (L_{mat}), and length von Bertalanffy growth curve ($L_{inifinity}$) are needed. Determine the sex ratio in the stock area.	van der Hammen et al (2011) suggested values for L_{inf} and L_{mat} based on Dutch market samples; check whether these are representative for the entire fleet fishing on brill	Data from surveys and commercial sampling on maturity (at age/length per sex) and on individual weights (at age/length per sex)	Experts on biological parameters, stock coordinator
Assessment method	Further investigate SPiCT as assessment model. Explore other settings and use other input data. Recalculate the currently used LBI method if more data is submitted.	Investigate all available data and use them in SPiCT or length-based indicator analyses	A longer time-series of age and/or length data is needed from all countries involved in the fisheries.	Experts on length-based indicators and SPiCT
Biological Reference Points	Determine MSY (proxy) reference points	Depending on the assessment method and available data	See issue ‘assessment method’	Experts in computation of reference points

3.8 References

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Table 3.1: BLL 27.3a47de – Official landings (tonnes) of brill in Subdivision 27.3a (Skagerrak/Kattegat) by country, over the period 1950–2021 (Source: ICES Fishstat); *Preliminary.

Year	BEL	GER	DNK	NLD	NOR	SWE	BMS	TOTAL
1950	0	0	234	0	0	85		319
1951	0	0	260	0	4	73		337
1952	0	0	170	0	1	65		236
1953	0	0	175	0	0	71		246
1954	0	0	155	0	1	78		234
1955	0	0	150	0	0	62		212
1956	0	0	163	0	0	50		213
1957	0	0	110	0	0	38		148
1958	0	0	166	0	0	37		203
1959	0	0	175	0	0	58		233
1960	0	0	272	0	0	46		318
1961	0	0	255	0	0	50		305
1962	0	0	207	0	0	0		207
1963	0	0	120	0	0	0		120
1964	0	0	106	0	0	0		106
1965	0	0	155	0	0	0		155
1966	0	0	187	0	0	0		187
1967	0	0	106	0	0	0		106
1968	0	0	100	0	0	0		100
1969	0	0	99	0	0	0		99
1970	0	0	97	0	0	0		97
1971	0	0	104	0	0	0		104
1972	0	0	120	0	0	0		120
1973	0	0	131	0	0	0		131
1974	0	0	200	0	0	0		200
1975	0	0	167	1	0	19		187
1976	1	0	185	26	0	12		224
1977	1	0	276	99	0	12		388
1978	0	0	178	27	0	11		216
1979	0	0	156	17	0	11		184
1980	2	0	69	1	0	10		82
1981	0	0	54	0	0	5		59
1982	1	0	64	1	0	8		74
1983	0	0	73	3	0	7		83
1984	0	0	89	0	0	8		97
1985	0	0	100	0	0	10		110
1986	0	0	94	0	0	13		107
1987	0	0	93	0	0	12		105
1988	0	0	91	0	0	10		101

Year	BEL	GER	DNK	NLD	NOR	SWE	BMS	TOTAL
1989	0	0	88	0	0	9		97
1990	1	0	116	0	0	11		128
1991	1	0	81	0	7	10		99
1992	1	0	123	0	7	15		146
1993	2	0	184	0	10	16		212
1994	0	0	191	0	12	19		222
1995	0	0	124	0	13	14		151
1996	0	0	94	0	12	6		112
1997	0	0	83	0	11	12		106
1998	0	0	108	0	10	14		132
1999	0	0	126	0	13	18		157
2000	0	0	112	0	12	17		141
2001	0	0	73	0	13	12		98
2002	0	0	66	0	12	12		90
2003	0	0	99	1	12	16		128
2004	0	0	119	4	15	18		156
2005	0	0	101	3	16	13		133
2006	0	1	105	3	16	14		140
2007	0	1	119	3	15	22		160
2008	0	2	138	1	13	28		181
2009	0	1	98	1	14	32		146
2010	0	1	95	1	9	16		122
2011	0	1	103	0	15	12		131
2012	0	0	89	0	16	15		120
2013	0	0	70	0	9	13		92
2014	0	0	59	0	8	11		79
2015	0	0	104	11	8	21		145
2016	0	0	125	7	8	28		168
2017	0	0	131	4	8	27		170
2018	0	0	90	9	9	17	<1	125
2019	0	1	93	26	3	15	<1	139
2020*	0	1	112	29	3	17	<1	162
2021*	0	2	101	20	3	16	<1	142

Table 3.2: BLL 27.3a47de – Official landings (tonnes) of brill in Subarea 27.4 by country, over the period 1950–2021 (Source: ICES Fishstat); *Preliminary.

Year	BEL	GER	DNK	FRA	GBR	NLD	NOR	SWE	BMS	TOTAL
1950	34	0	39	0	183	108	1	19		384
1951	23	0	53	0	322	93	1	19		511
1952	21	0	65	0	350	117	3	9		565
1953	23	0	49	0	376	130	0	11		589
1954	19	0	53	0	330	106	14	7		529
1955	23	0	51	0	357	137	3	0		571
1956	28	0	47	0	276	156	0	9		516
1957	32	0	27	0	247	154	0	8		468
1958	43	0	42	0	223	162	0	10		480
1959	41	0	30	0	219	125	0	9		424
1960	55	0	37	0	235	150	1	8		486
1961	102	0	40	0	264	166	0	9		581
1962	97	0	42	0	238	214	0	0		591
1963	79	0	59	0	307	175	0	0		620
1964	79	0	46	0	161	279	0	0		565
1965	71	0	56	0	127	281	0	0		535
1966	100	0	63	0	119	264	0	0		546
1967	138	0	29	0	105	137	0	0		409
1968	152	0	43	0	110	274	0	0		579
1969	145	0	47	0	102	364	0	0		658
1970	114	0	42	0	76	386	0	0		618
1971	187	0	72	0	94	720	0	0		1073
1972	213	0	65	0	51	665	0	0		994
1973	185	0	55	0	39	710	0	0		989
1974	135	0	68	0	44	905	0	0		1152
1975	164	0	76	13	44	925	0	0		1222
1976	148	0	65	10	45	940	0	0		1208
1977	166	0	88	17	60	1079	0	0		1410
1978	175	0	123	26	84	967	0	0		1375
1979	188	0	154	10	103	908	0	0		1363
1980	129	0	104	8	45	747	0	0		1033
1981	148	0	66	5	42	957	0	0		1218
1982	182	0	53	11	41	1007	0	0		1294
1983	182	0	62	23	28	1153	0	0		1448
1984	190	0	73	30	29	1200	0	0		1522
1985	187	0	71	35	46	1370	0	0		1709
1986	131	0	76	4	46	950	0	0		1207
1987	140	0	50	17	48	715	0	0		970
1988	102	0	33	18	52	880	0	0		1085

Year	BEL	GER	DNK	FRA	GBR	NLD	NOR	SWE	BMS	TOTAL
1989	112	0	43	9	58	1080	0	0		1302
1990	168	0	139	24	82	480	0	0		893
1991	205	38	145	28	147	1111	8	0		1682
1992	203	59	77	34	218	1196	22	1		1810
1993	291	63	118	38	268	1647	14	0		2439
1994	208	90	109	28	235	1235	11	0		1916
1995	194	67	55	24	145	943	6	0		1434
1996	206	47	64	15	175	732	8	0		1247
1997	129	48	38	1	135	590	16	0		957
1998	160	58	58	11	172	808	16	0		1283
1999	161	51	91	0	156	805	16	0		1280
2000	167	77	93	16	141	998	16	0		1508
2001	182	66	67	12	158	1075	13	0		1573
2002	145	58	52	10	120	907	10	0		1302
2003	145	70	57	9	119	934	12	0		1346
2004	140	66	77	7	168	772	19	0		1249
2005	120	62	89	7	138	716	28	0		1160
2006	105	55	75	9	154	765	12	0		1175
2007	110	47	52	12	156	854	9	0		1239
2008	117	42	86	5	93	650	11	0		1004
2009	109	54	96	8	105	786	4	0		1162
2010	104	75	97	12	136	1072	4	0		1499
2011	101	57	122	13	137	1061	6	0		1496
2012	110	71	126	12	122	1084	7	0		1532
2013	101	63	123	10	118	972	4	0		1390
2014	99	69	96	9	117	857	9	0		1255
2015	154	115	122	7	136	1159	1	0		1695
2016	175	90	131	8	156	965	1	0		1526
2017	138	76	121	7	116	1000	2	0		1460
2018	98	80	96	6	100	805	2	0	<1	1188
2019	116	132	90	5	112	932	1	0	2	1387
2020*	84	99	95	2	91	809	1	0	<1	1183
2021*	122	59	110	1	66	573	1	0	<1	932

Table 3.3: BLL 27.3a47de – Official landings (tonnes) of brill in Subdivisions 27.7.d, e (English Channel) by country, over the period 1950–2021 (Source: ICES Fishstat); *Preliminary.

Year	BEL	DNK	FRA	GBR	IRL	NLD	XCI	BMS	TOTAL
1950	11	0	0	48	0	0	0		59
1951	8	0	0	70	0	0	0		78
1952	6	0	0	66	0	0	0		72
1953	2	0	0	60	0	0	0		62
1954	1	0	0	59	0	0	0		60
1955	4	0	0	57	0	0	0		61
1956	2	0	0	58	0	0	0		60
1957	4	0	0	66	0	0	0		70
1958	2	0	0	65	0	0	0		67
1959	1	0	0	58	0	0	0		59
1960	6	0	0	46	0	0	0		52
1961	1	0	0	46	0	0	0		47
1962	3	0	0	52	0	0	0		55
1963	1	0	0	50	0	0	0		51
1964	0	0	0	60	0	0	0		60
1965	2	0	0	46	0	0	0		48
1966	0	0	0	53	0	0	0		53
1967	1	0	0	66	0	0	0		67
1968	3	0	0	54	0	0	0		57
1969	2	0	121	67	0	0	0		190
1970	10	0	0	49	0	0	0		59
1971	18	0	0	48	0	0	0		66
1972	20	0	0	52	0	3	0		75
1973	20	0	0	70	0	0	0		90
1974	25	0	0	56	0	0	0		81
1975	24	0	55	56	0	0	2		137
1976	41	0	170	72	0	0	2		285
1977	45	0	197	77	0	0	4		323
1978	58	3	227	120	0	0	3		411
1979	55	0	262	140	0	0	2		459
1980	64	2	213	118	3	0	2		402
1981	83	0	271	130	0	0	6		490
1982	105	0	225	149	0	1	7		487
1983	107	0	234	181	0	1	3		526
1984	114	0	226	186	0	0	5		531
1985	94	0	213	177	0	0	10		494
1986	115	0	183	147	0	0	11		456
1987	126	0	216	141	0	0	10		493
1988	112	0	202	133	0	0	5		452

Year	BEL	DNK	FRA	GBR	IRL	NLD	XCI	BMS	TOTAL
1989	89	0	213	121	0	0	2		425
1990	99	0	249	187	0	0	8		543
1991	81	0	249	140	0	0	0		470
1992	82	0	223	151	0	0	7		463
1993	78	0	256	152	0	0	4		490
1994	88	0	227	170	0	0	5		490
1995	91	0	248	200	1	0	18		558
1996	105	0	240	253	0	0	10		608
1997	107	0	185	198	1	0	10		501
1998	70	0	196	173	0	2	10		451
1999	97	0	0	127	0	3	13		240
2000	164	0	260	232	1	4	17		678
2001	212	0	256	251	0	2	17		738
2002	204	0	268	227	0	1	16		716
2003	217	0	287	238	1	1	15		759
2004	165	0	259	223	1	3	15		666
2005	138	0	267	183	0	2	21		611
2006	180	0	281	170	0	3	14		648
2007	205	0	325	199	0	1	13		743
2008	155	0	224	199	0	2	16		595
2009	131	0	278	171	0	1	13		594
2010	145	0	340	198	0	1	15		700
2011	141	0	304	202	0	0	18		665
2012	120	0	263	228	0	1	12		624
2013	142	0	238	213	0	1	11		605
2014	166	0	245	219	0	1	13		645
2015	162	0	278	248	0	2	9		698
2016	143	0	286	284	0	1	6		721
2017	135	0	276	246	0	2	3		663
2018	128	0	280	248	1	2	55		714
2019	103	0	287	262	0	3	5	<1	660
2020*	91	0	209	246	0	2	1	<1	550
2021*	84	0	234	228	0	3	0	<1	549

Table 3.4: BLL 27.3a47de – Total official landings (tonnes) of brill in the 27.3a47de (Greater North Sea) over the period 1950–2021, subdivided into Subarea 27.4 and Divisions 27.3.a and 27.7.d, e (Source: ICES Fishstat). *Preliminary.

Year	3.a	4	7.de	TOTAL
1950	319	384	59	762
1951	337	511	78	926
1952	236	565	72	873
1953	246	589	62	897
1954	234	529	60	823
1955	212	571	61	844
1956	213	516	60	789
1957	148	468	70	686
1958	203	480	67	750
1959	233	424	59	716
1960	318	486	52	856
1961	305	581	47	933
1962	207	591	55	853
1963	120	620	51	791
1964	106	565	60	731
1965	155	535	48	738
1966	187	546	53	786
1967	106	409	67	582
1968	100	579	57	736
1969	99	658	190	947
1970	97	618	59	774
1971	104	1073	66	1243
1972	120	994	75	1189
1973	131	989	90	1210
1974	200	1152	81	1433
1975	187	1222	137	1546
1976	224	1208	285	1717
1977	388	1410	323	2121
1978	216	1375	411	2002
1979	184	1363	459	2006
1980	82	1033	402	1517
1981	59	1218	490	1767
1982	74	1294	487	1855
1983	83	1448	526	2057
1984	97	1522	531	2150
1985	110	1709	494	2313
1986	107	1207	456	1770
1987	105	970	493	1568
1988	101	1085	452	1638

Year	3.a	4	7.de	TOTAL
1989	97	1302	425	1824
1990	128	893	543	1564
1991	99	1682	470	2251
1992	146	1810	463	2419
1993	212	2439	490	3141
1994	222	1916	490	2628
1995	151	1434	558	2143
1996	112	1247	608	1967
1997	106	957	501	1564
1998	132	1283	451	1866
1999	157	1280	240	1677
2000	142	1508	678	2327
2001	98	1573	738	2409
2002	89	1302	716	2108
2003	129	1346	759	2233
2004	156	1249	666	2071
2005	133	1160	611	1904
2006	140	1175	648	1963
2007	160	1239	743	2142
2008	181	1004	595	1781
2009	146	1162	594	1902
2010	122	1499	700	2321
2011	131	1496	665	2292
2012	120	1532	624	2276
2013	92	1390	605	2088
2014	79	1255	645	1978
2015	145	1695	698	2537
2016	168	1526	721	2415
2017	170	1460	663	2292
2018	125	1188	714	2027
2019	139	1387	660	2186
2020*	162	1183	550	1895
2021*	142	932	549	1623

Table 3.5: BLL 27.3a47de – Overview of absolute landings per area over the last 12 years with an indication of the relative proportion by area (Source: ICES Fishstat).

	Absolute landings (tonnes)				Relative proportion		
Year	3a	4	7de	TOTAL	3a	4	7de
2010	122	1499	700	2321	0.05	0.65	0.30
2011	131	1496	665	2292	0.06	0.65	0.29
2012	120	1532	624	2276	0.05	0.67	0.27
2013	92	1390	605	2087	0.04	0.67	0.29
2014	79	1255	645	1979	0.04	0.63	0.33
2015	145	1695	698	2538	0.06	0.67	0.28
2016	168	1526	721	2415	0.07	0.63	0.30
2017	170	1460	663	2293	0.07	0.64	0.29
2018	125	1188	714	2027	0.06	0.59	0.35
2019	139	1387	660	2186	0.06	0.63	0.30
2020	162	1183	550	1895	0.09	0.62	0.29
2021	142	932	549	1623	0.09	0.57	0.34

Table 3.6: BLL 27.3a47de – Overview of 2021 catches (in tonnes) reported to InterCatch (ICES) by country and area (rounded to the nearest tonne).

	3a		4			7d			7e			Total			
COUNTRY	DIS	LAN	BMS	DIS	LAN	BMS	DIS	LAN	BMS	DIS	LAN	BMS	DIS	LAN	ALL
Belgium	0	0		2	53		0	94		0	0		3	148	150
Denmark	16	101		29	110		0	0		0	0		45	211	256
France	0	0		0	1		1	29		61	205		62	236	298
Germany	0	2		10	59		0	0		0	0		11	61	72
Ireland	0	0		0	0		0	0		0	0		0	0	0
Netherlands	1	22		10	552		0	2		0	0		11	576	587
Norway	1	3		0	1		0	0		0	0		1	4	5
Sweden	5	15		0	0		0	0		0	0		5	15	20
UK (England)	0	0	0	2	50	0	3	15	0	8	214	0	13	279	292
UK (Northern Ireland)	0	0		0	0		0	0		0	0		0	0	0
UK (Scotland)	0	0		0	16		0	1		0	0		0	17	17
Total	22	143	0	55	843	0	5	141		69	419	0	151	1547	**1698**

Table 3.7: BLL 27.3a47de – Overview of 2021 landings for the most important gear types per area (Source: InterCatch).

Gear type	3a	4	7d	7e	Total
DRB	0	0	5	2	7
FPO	0	0	0	0	0
GNS	10	61	5	8	84
GTR	1	1	4	80118	124
LLS	0	0	0	0	0
MIS	2	5	8	20	36
OTB	105	173	14	98	389
SDN	3	0	0	0	3
SSC	0	3	3	0	6
TBB	23	599	104	173	898
Total	**143**	**843**	**141**	**419**	**1547**

Table 3.8: BLL 27.3a47de – Overall discards and discard rates (all countries and métiers) for brill over the period 2014–2021 (Source: InterCatch).

Year	Discards	Discard rate
2014	231	0.107
2015	230	0.085
2016	267	0.099
2017	208	0.086
2018	349	0.151
2019	417	0.163
2020	229	0.109
2021	151	0.089

Table 3.9: BLL 27.3a47de – Discard rates for brill by country for 2019-2021 (source: InterCatch).

Country	Discard rate 2019	Discard rate 2020	Discard rate 2021
Belgium	0.063	0.079	0.0170
Denmark	0.197	0.28	0.176
France	0.154	0.192	0.21
Germany	0.41	0.125	0.149
Ireland			
Netherlands	0.160	0.049	0.0189
Norway	0.169	0.23	0.163
Sweden	0.40	0.26	0.26
UK (England)	0.065	0.053	0.046
UK (Northern Ireland)		0.21	0.064
UK(Scotland)	0.066	0.041	0.0163
Overall	**0.163**	**0.109**	**0.089**

Table 3.10: BLL 27.3a47de – Discard rates for brill by area for 2019-2021 (Source: InterCatch).

Subarea/ Division	Discard rate 2019	Discard rate 2020	Discard rate 2021
27.3.a	0.28	0.31	0.135
27.4	0.186	0.072	0.062
27.7.d	0.073	0.059	0.034
27.7.e	0.087	0.121	0.141
Overall	**0.163**	**0.109**	**0.089**

Table 3.11: BLL 27.3a47de – Survey index (N°/h) for brill in the BTS_ISI_Q3, Subarea 27.4.

Year	N°/hr	Year	N°/hr
1985	0.400	2004	0.938
1986	0.343	2005	0.696
1987	1.411	2006	0.963
1988	1.250	2007	1.244
1989	1.037	2008	0.588
1990	1.628	2009	1.556
1991	1.063	2010	2.435
1992	2.819	2011	2.677
1993	2.326	2012	1.177
1994	1.719	2013	0.833
1995	1.294	2014	2.950
1996	0.585	2015	1.702
1997	1.422	2016	1.070
1998	1.666	2017	0.870
1999	0.894	2018	1.448
2000	2.554	2019	2.000
2001	0.886	2020	0.935
2002	0.881	2021	0.582
2003	1.084		

Table 3.12: BLL 27.3a47de – Survey index (N°/h) for brill in the BITS_HAF_Q1 and BITS_HAF_Q4, Division 27.3a21 (Kattegat).

Year	Quarter 1 (N°/h)	Quarter 4 (N° /h)
1996	1.778	
1997	0.273	
1998	0.500	
1999	0.714	2.857
2000	1.071	0.316
2001	0.643	1.800
2002	1.929	2.071
2003	1.379	1.929
2004	2.000	3.310
2005	1.714	2.897
2006	3.867	4.759
2007	3.214	5.117
2008	2.733	4.400
2009	2.038	3.750
2010	2.897	4.839
2011	3.286	5.034
2012	2.533	3.000
2013	1.571	3.831
2014	2.857	6.090
2015	3.556	6.636
2016	4.857	4.667
2017	7.923	4.273
2018	1.077	10.870
2019	4.279	7.137
2020	3.619	7.815
2021	3.714	2.091
2022	0.892	

Table 3.13: BLL 27.3a47de – Commercial LPUE (kg/day) for brill by the Dutch beam trawl fleet > 221 kW, Subarea 27.4.

Year	LPUE (kg/day)
1995	19.670
1996	19.187
1997	13.387
1998	23.752
1999	22.973
2000	24.077
2001	26.099
2002	22.524
2003	27.012
2004	27.618
2005	26.455
2006	27.145
2007	33.039
2008	40.563
2009	41.188
2010	51.055
2011	53.432
2012	55.820
2013	54.805
2014	46.667
2015	63.476
2016	57.512
2017	50.195
2018	39.718
2019	49.028
2020	42.716
2021	32.243

Table 3.14: BLL 27.3a47de – Commercial landings (tonnes) for brill as input for SPiCT. Note that from 1987–2013 landings represent official landings. From 2014 onwards, landings as reported in InterCatch were used.

Year	Landings (tonnes)
1987	1568
1988	1638
1989	1824
1990	1564
1991	2251
1992	2419
1993	3141
1994	2628
1995	2143
1996	1967
1997	1564
1998	1866
1999	1677
2000	2328
2001	2409
2002	2107
2003	2234
2004	2071
2005	1904
2006	1963
2007	2142
2008	1781
2009	1902
2010	2321
2011	2292
2012	2276
2013	2088
2014	1920
2015	2470
2016	2444
2017	2207
2018	1956
2019	2147
2020	1872
2021	1547

Table 3.15: BLL 27.3a47de – SPiCT summary output from the analyses performed during the WGNSSK 2022.

```
Convergence: 0  MSG: relative convergence (4)
Objective function at optimum: 8.5595344
Euler time step (years):  1/16 or 0.0625
Nobs C: 35,  Nobs I1: 35,  Nobs I2: 27

Priors
     logn  ~  dnorm[log(2), 2^2]
 logalpha  ~  dnorm[log(1), 2^2]
  logbeta  ~  dnorm[log(1), 2^2]

Model parameter estimates w 95% CI
            estimate        cilow        ciupp    log.est
 alpha1    2.6192728    1.6227892 4.227653e+00  0.9628967
 alpha2    0.2325393    0.0326434 1.656520e+00 -1.4586960
 beta      0.1344100    0.0229752 7.863270e-01 -2.0068602
 r         0.6950551    0.1832846 2.635800e+00 -0.3637642
 rc        2.1561333    1.2918308 3.598699e+00  0.7683165
 rold      1.9563788    0.0676661 5.656331e+01  0.6710952
 m      2179.7688283 2020.5151852 2.351575e+03  7.6869741
 K      6955.4128432 2926.7065025 1.652976e+04  8.8472755
 q1        0.0006559    0.0003990 1.078300e-03 -7.3295170
 q2        0.0178829    0.0108676 2.942670e-02 -4.0239086
 n         0.6447237    0.2034808 2.042790e+00 -0.4389335
 sdb       0.1762718    0.1192758 2.605033e-01 -1.7357283
 sdf       0.1860342    0.1277159 2.709822e-01 -1.6818247
 sdi1      0.4617039    0.3596448 5.927250e-01 -0.7728315
 sdi2      0.0409901    0.0070840 2.371824e-01 -3.1944243
 sdc       0.0250049    0.0046465 1.345609e-01 -3.6886849

Deterministic reference points (Drp)
          estimate        cilow      ciupp   log.est
 Bmsyd 2021.924025 1200.6658575 3404.92464 7.6118048
 Fmsyd    1.078067    0.6459154    1.79935 0.0751693
 MSYd  2179.768828 2020.5151852 2351.57458 7.6869741
Stochastic reference points (Srp)
          estimate        cilow       ciupp    log.est  rel.diff.Drp
 Bmsys 2003.449150 1192.0829777 3367.054618 7.6026255 -0.0092215344
 Fmsys    1.077053    0.6500663    1.784499 0.0742284 -0.0009413971
 MSYs  2157.801638 2013.2122906 2312.775425 7.6768452 -0.0101803566

States w 95% CI (inp$msytype: s)
                   estimate        cilow       ciupp    log.est
 B_2021.94      2123.0180853 1249.6723215 3606.710105  7.6605940
 F_2021.94         0.7675132    0.4436580    1.327772 -0.2645996
 B_2021.94/Bmsy    1.0596815    0.7043023    1.594379  0.0579684
 F_2021.94/Fmsy    0.7126050    0.4703785    1.079569 -0.3388279

Predictions w 95% CI (inp$msytype: s)
                 prediction        cilow       ciupp    log.est
 B_2023.00      2489.5125828 1439.8905359 4304.266710  7.8198422
 F_2023.00         0.7675135    0.3948759    1.491803 -0.2645992
 B_2023.00/Bmsy    1.2426133    0.8018301    1.925705  0.2172167
 F_2023.00/Fmsy    0.7126053    0.4069719    1.247768 -0.3388276
 Catch_2022.00  1793.7136912 1353.5456317 2377.022784  7.4920434
 E(B_inf)       2709.5623415           NA          NA  7.9045424
```

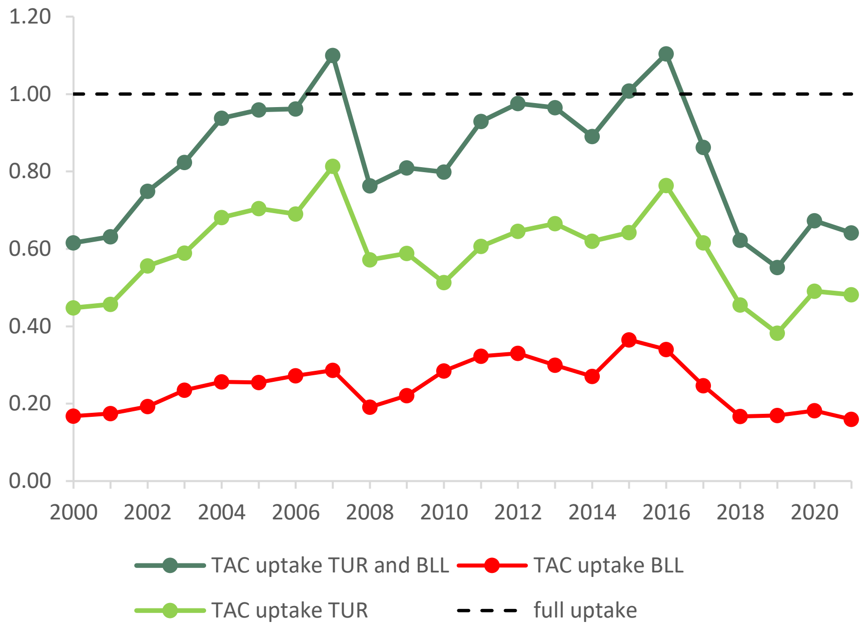

Figure 3.1: BLL 27.3a47de – TAC uptake for both brill and turbot in area 2.a and 4.

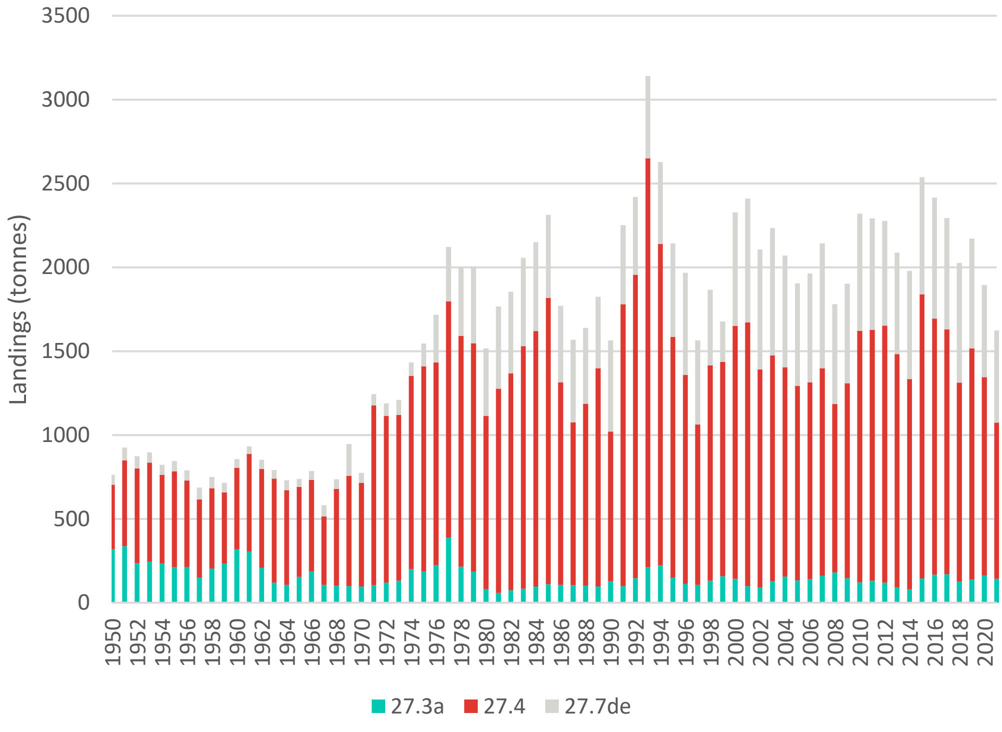

Figure 3.2: BLL 27.3a47de – Official landings (tonnes) over the period 1950–2021, as officially reported (Rec 12; ICES Fishstat).

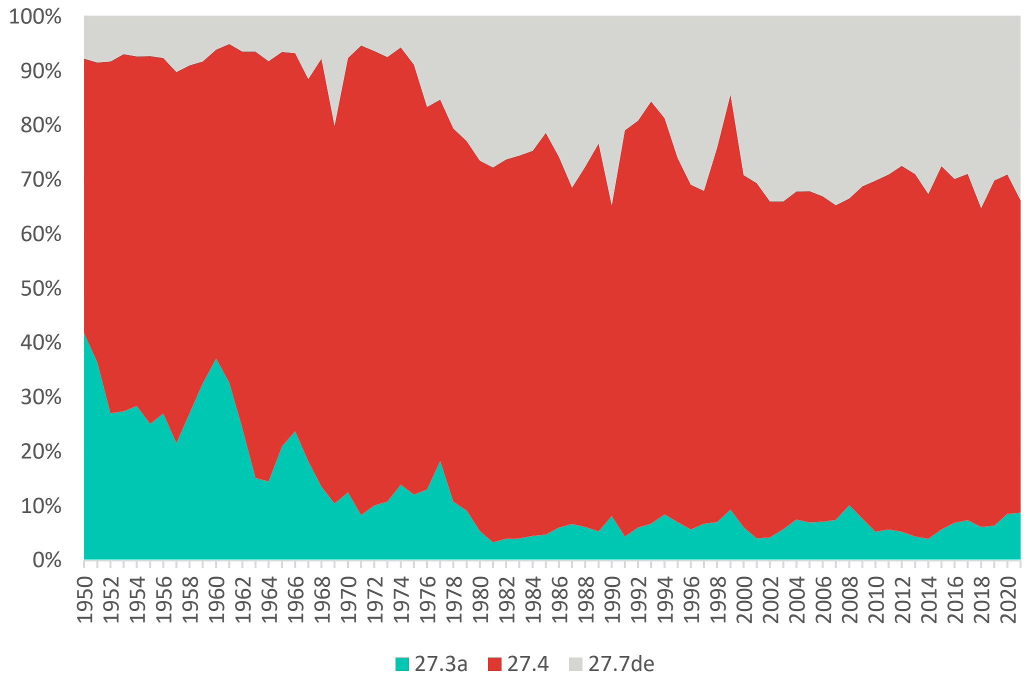

Figure 3.3: BLL 27.3a47de – Relative contribution of the official landings for brill from Subarea 27.4, Division 27.3.a and 27.7.d,e to the total international landings (tonnes) in the Greater North Sea over the period 1950–2021 (Source: ICES Fishstat).

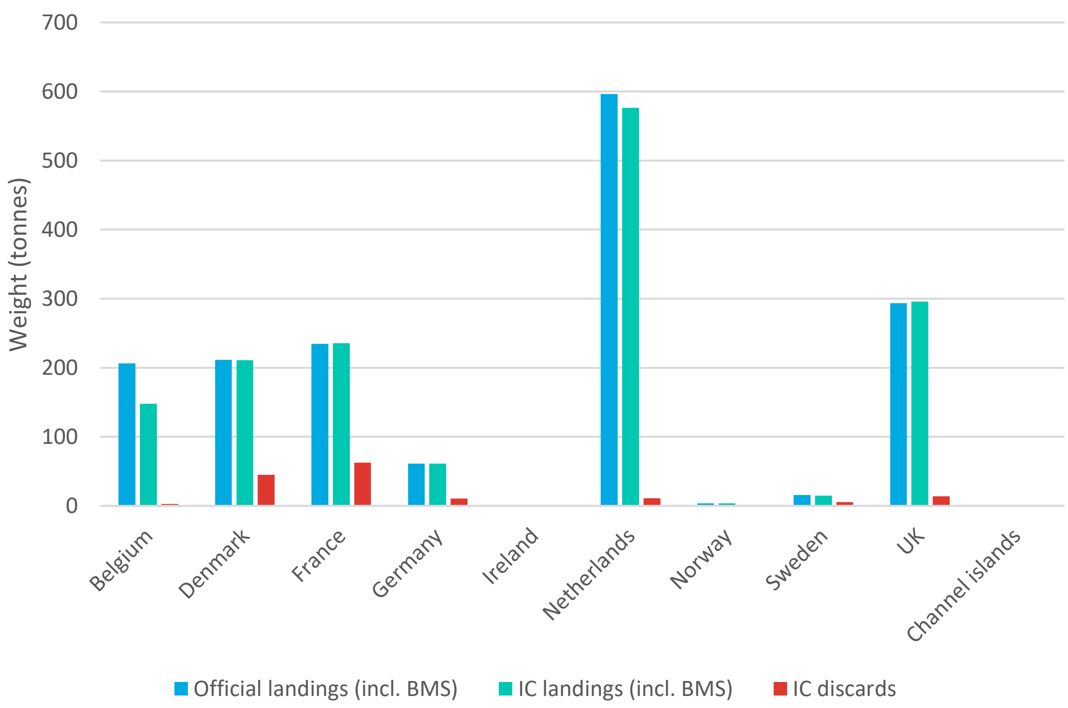

Figure 3.4: BLL 27.3a47de – Comparing ICES catch estimates (InterCatch, IC) to the official catch statistics by country for 2021.

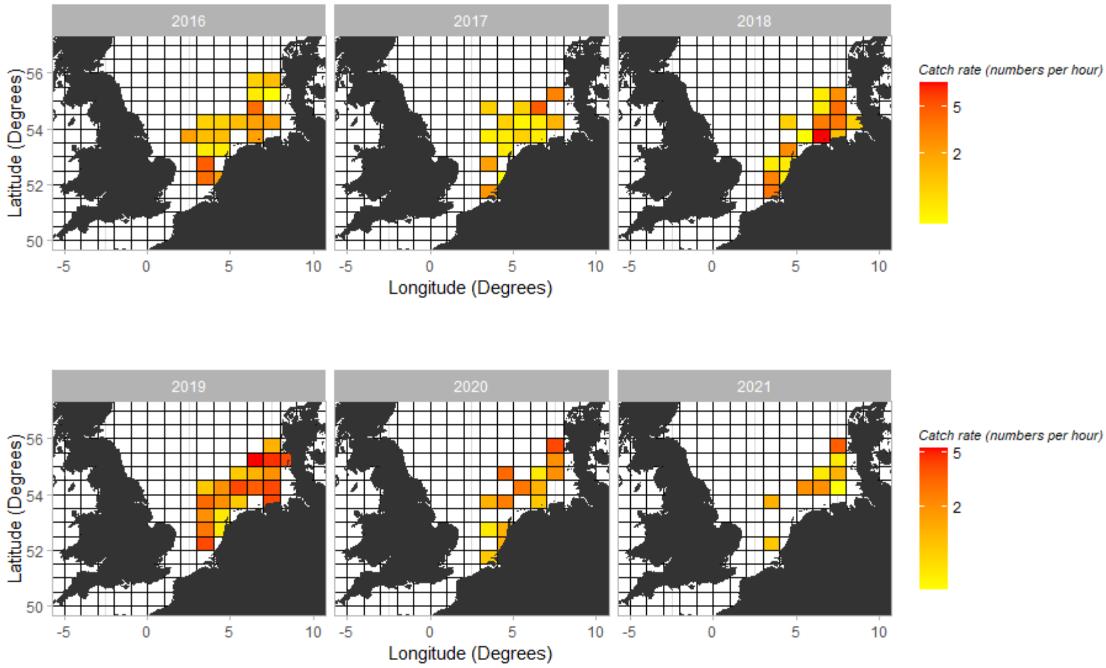

Figure 3.5: BLL 27.3a47de – Average numbers of brill caught per hour and rectangle by BTS_ISI_Q3 in the North Sea (27.4) for 2016-2021; note the slightly different scales for the different graphs.

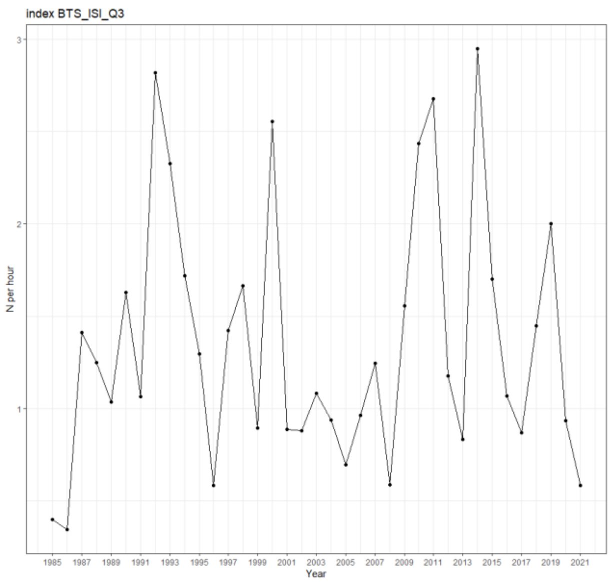

Figure 3.6: BLL 27.3a47de – Abundance index (numbers caught per hour) of brill for the BTS_ISI_Q3 in the North Sea (27.4) over the period 1985–2021.

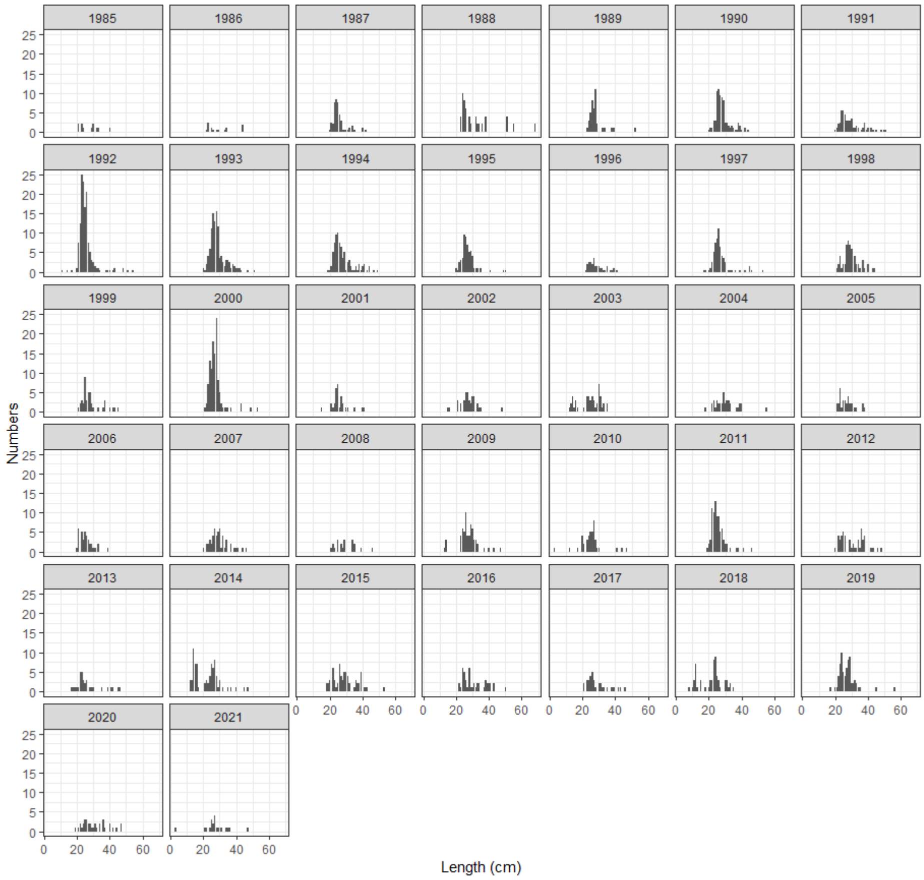

Figure 3.7: BLL 27.3a47de – Length distributions of brill in the North Sea (27.4) as documented in the BTS_ISI_Q3 (1985–2021).

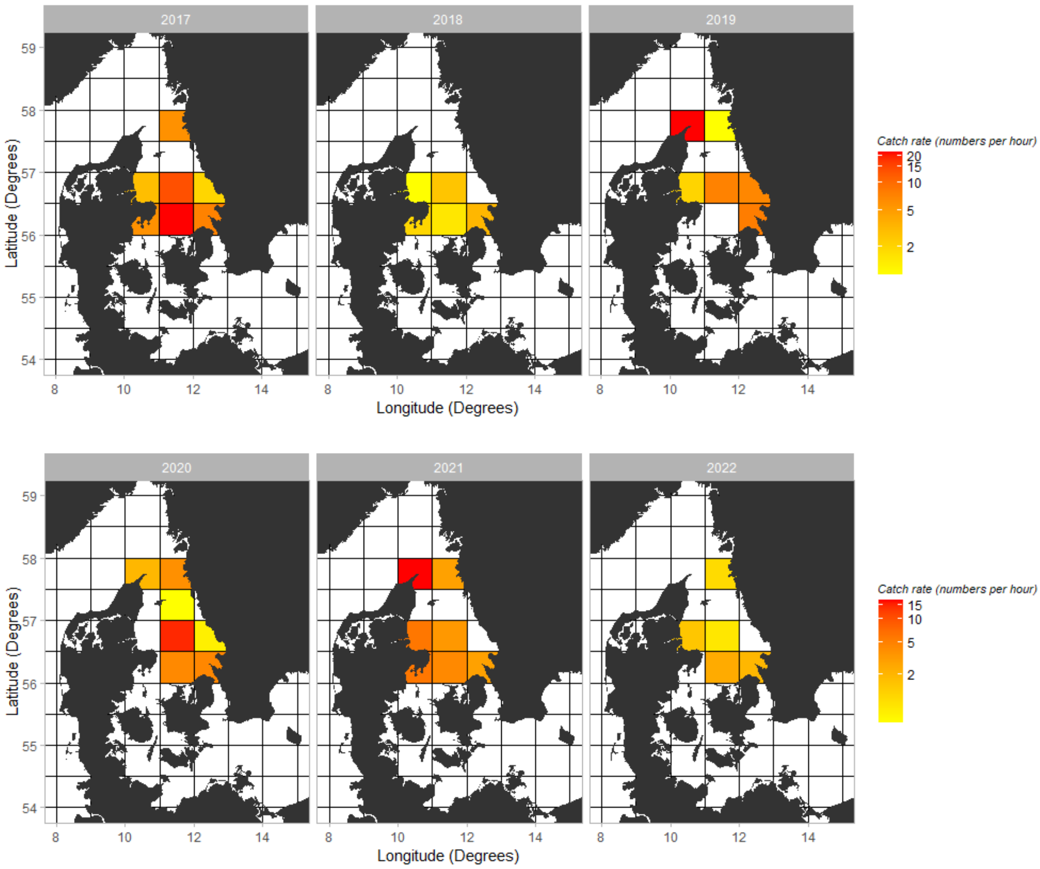

Figure 3.8: BLL 27.3a47de – Numbers of brill caught per hour and rectangle by BITS_HAF_Q1 in the Kattegat (27.3.a21) in 2017-2022.

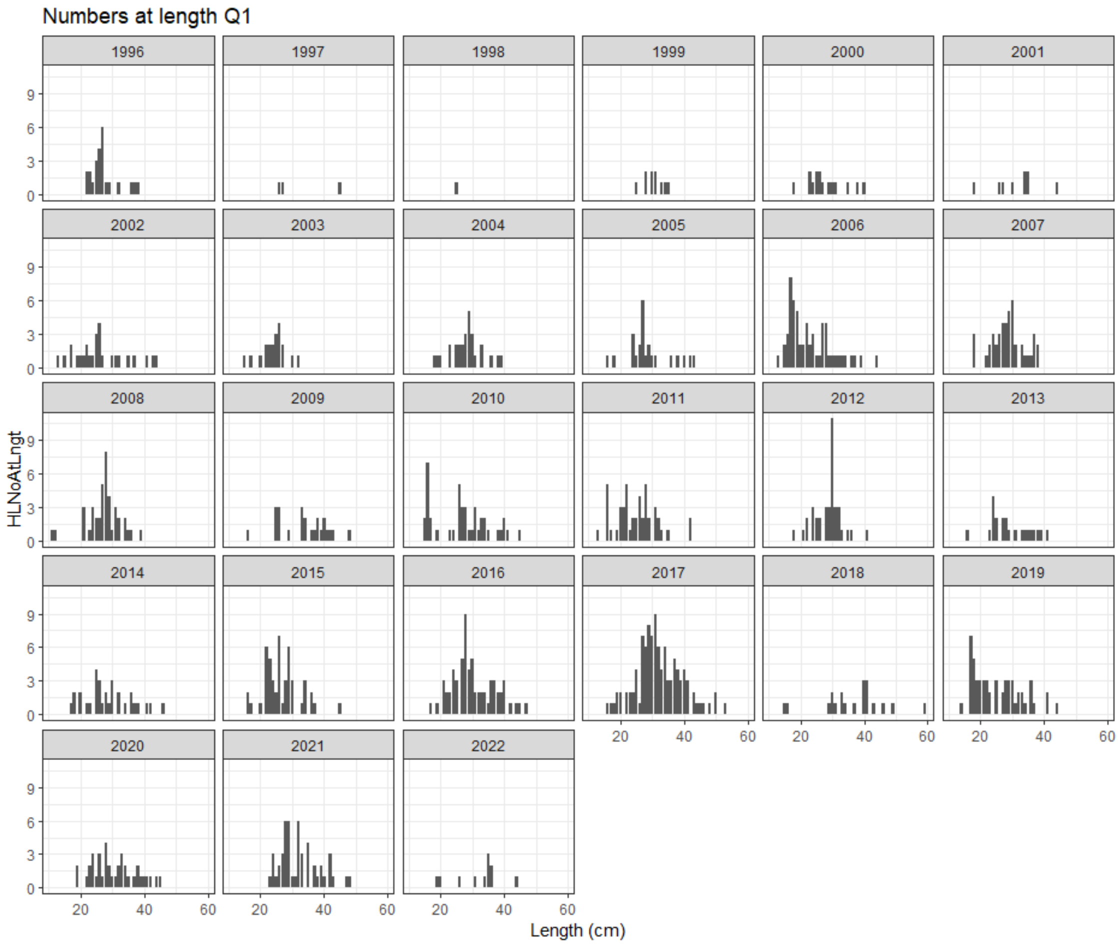

Figure 3.9: BLL 27.3a47de – Length distributions of brill in the Kattegat as documented in the BITS_HAF_Q1 (1996–2022).

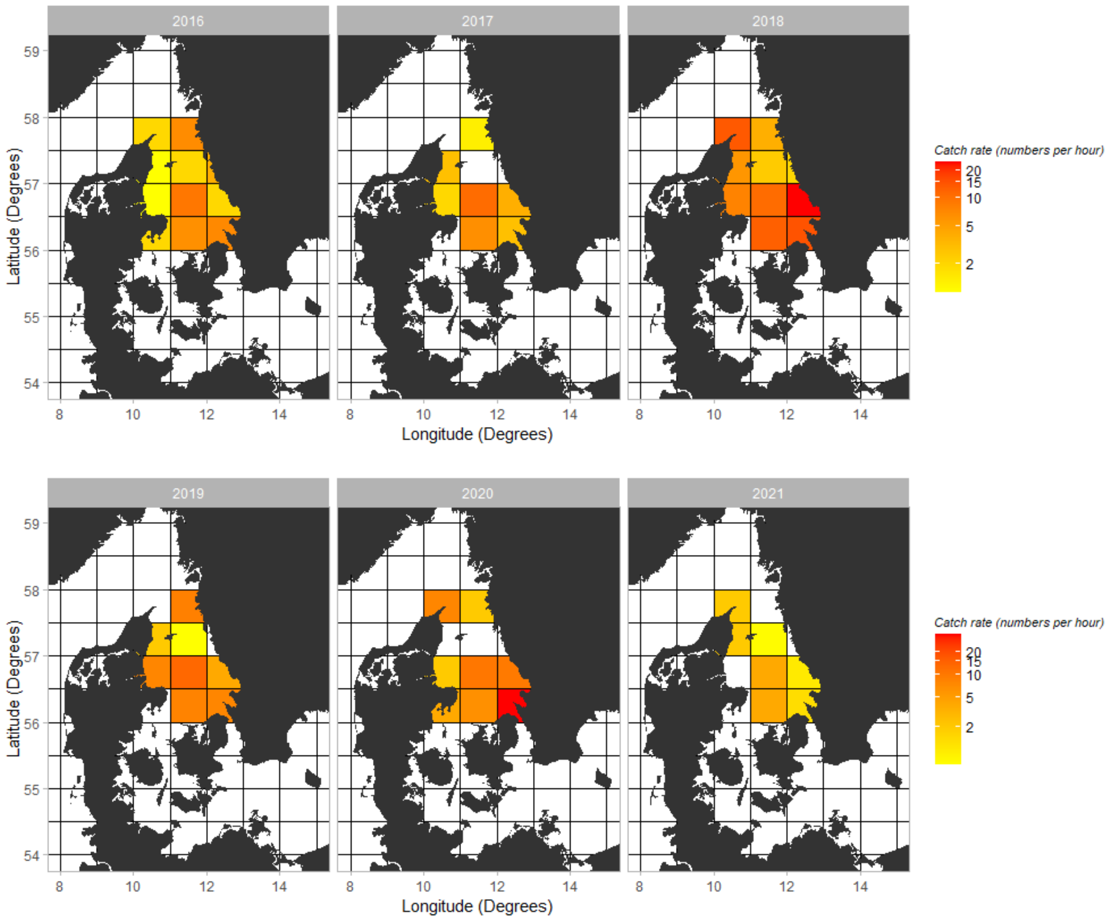

Figure 3.10: BLL 27.3a47de – Numbers of brill caught per hour and rectangle by BITS_HAF_Q4 in the Kattegat (27.3.a21) in 2016-2021; note the slightly different scales for the different graphs.

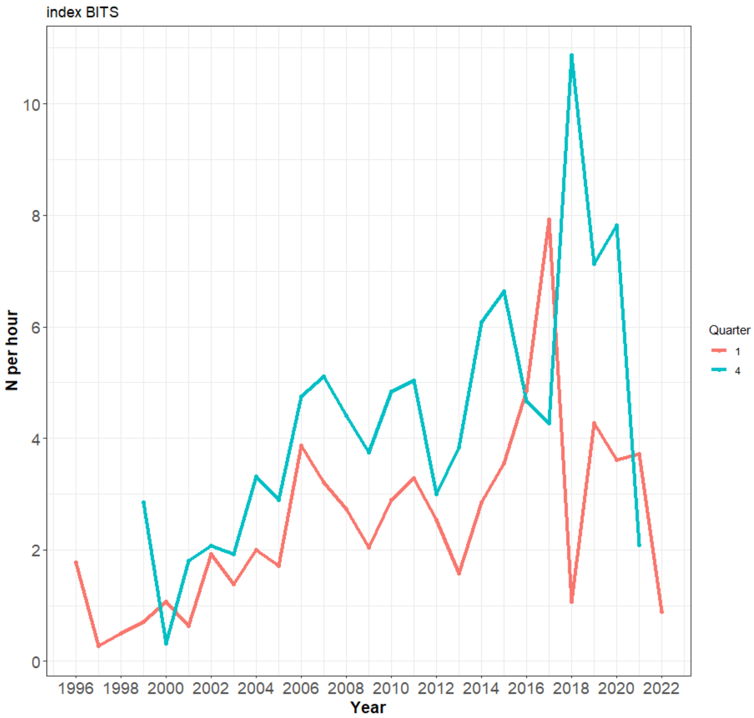

Figure 3.11: BLL 27.3a47de – Abundance indices (numbers caught per hour) of brill for both quarters (Q1 and Q4) of the BITS_HAF in the Kattegat over the period 1996–2022.

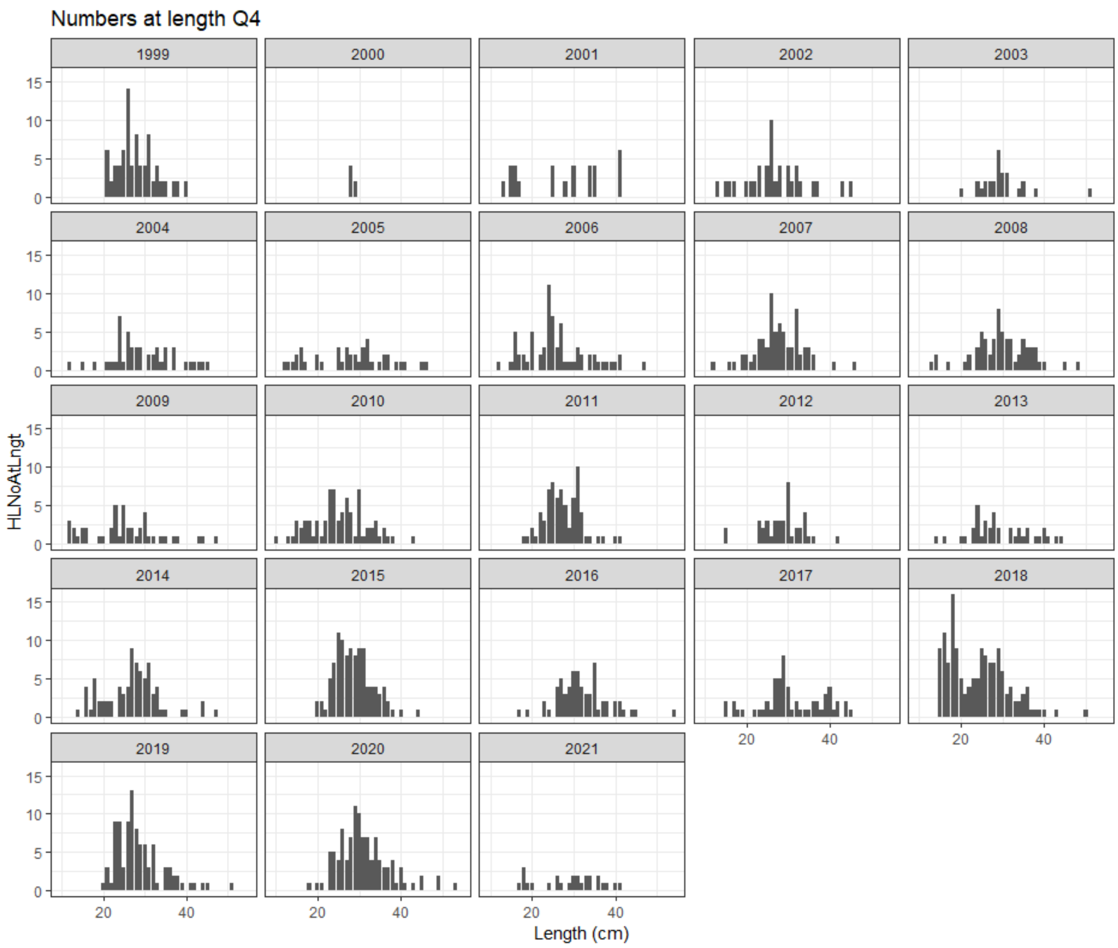

Figure 3.12: BLL 27.3a47de – Length distributions of brill in the Kattegat as documented in the BITS_HAF_Q4 (1996–2021).

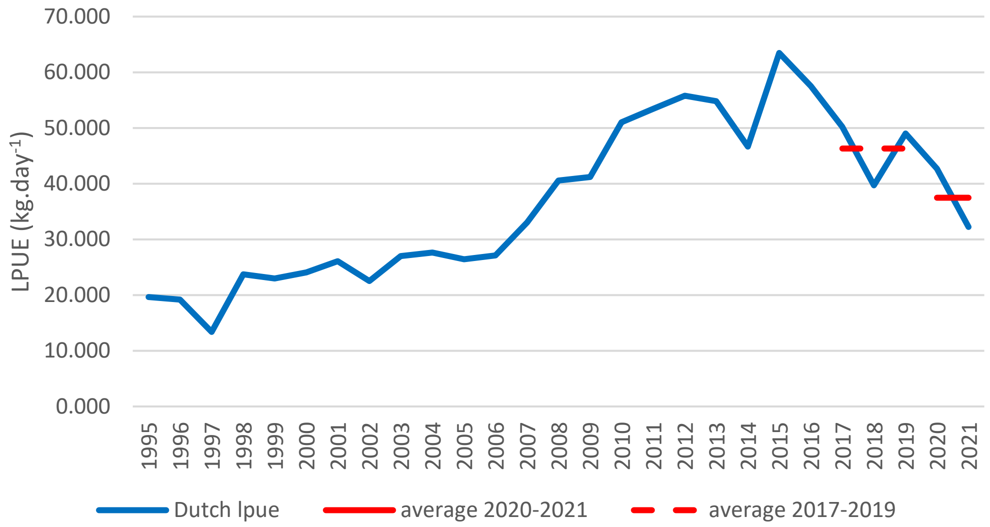

Figure 3.13: BLL 27.3a47de – Commercial LPUE (kg/day) of brill by the Dutch beam trawl fleet > 221 kW (standardized for engine power and corrected for targeting behaviour). The red lines are the averages of the last two (2020–2021) and the previous three (2017–2019) years.

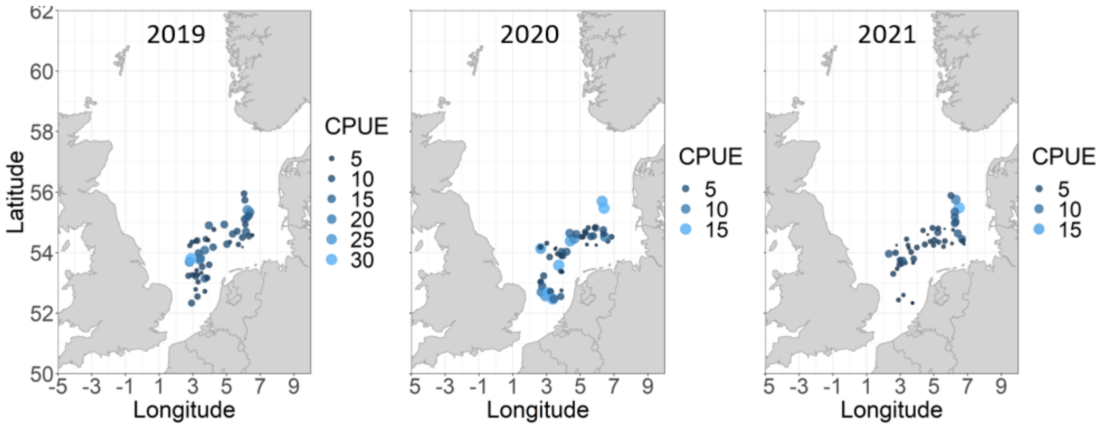

Figure 3.14: BLL 27.3a47de – Map showing the CPUE for brill in numbers per hour of the Dutch industry survey over the period 2019-2021.

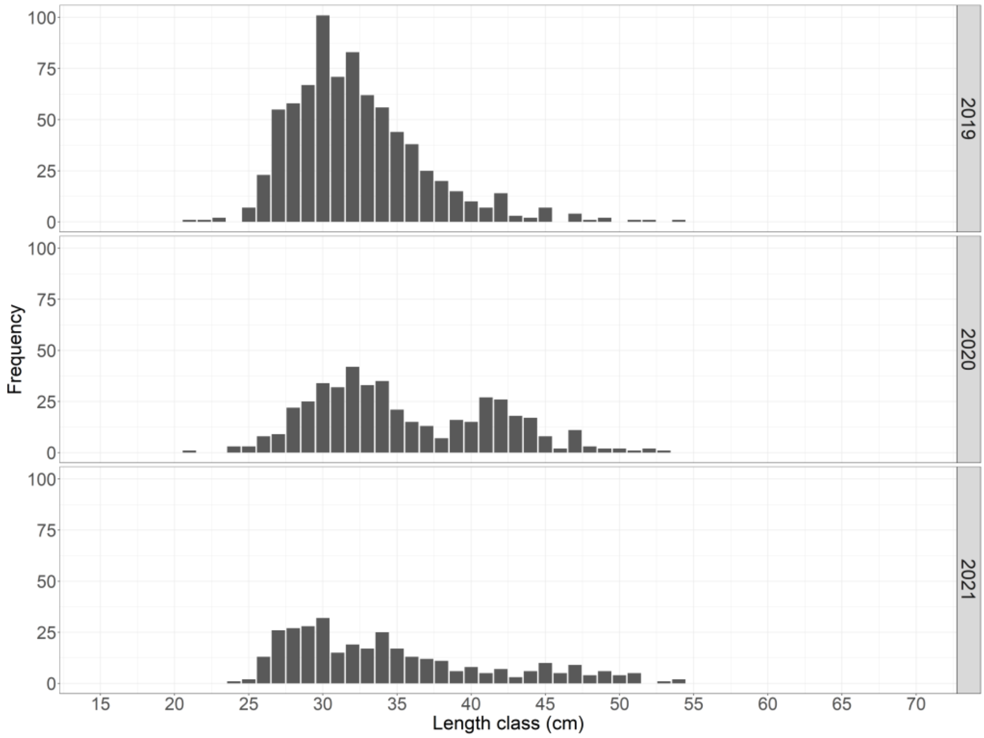

Figure 3.15: BLL 27.3a47de – Length distribution plot for brill as sampled during the Dutch industry survey (BSAS) in 2019-2021.

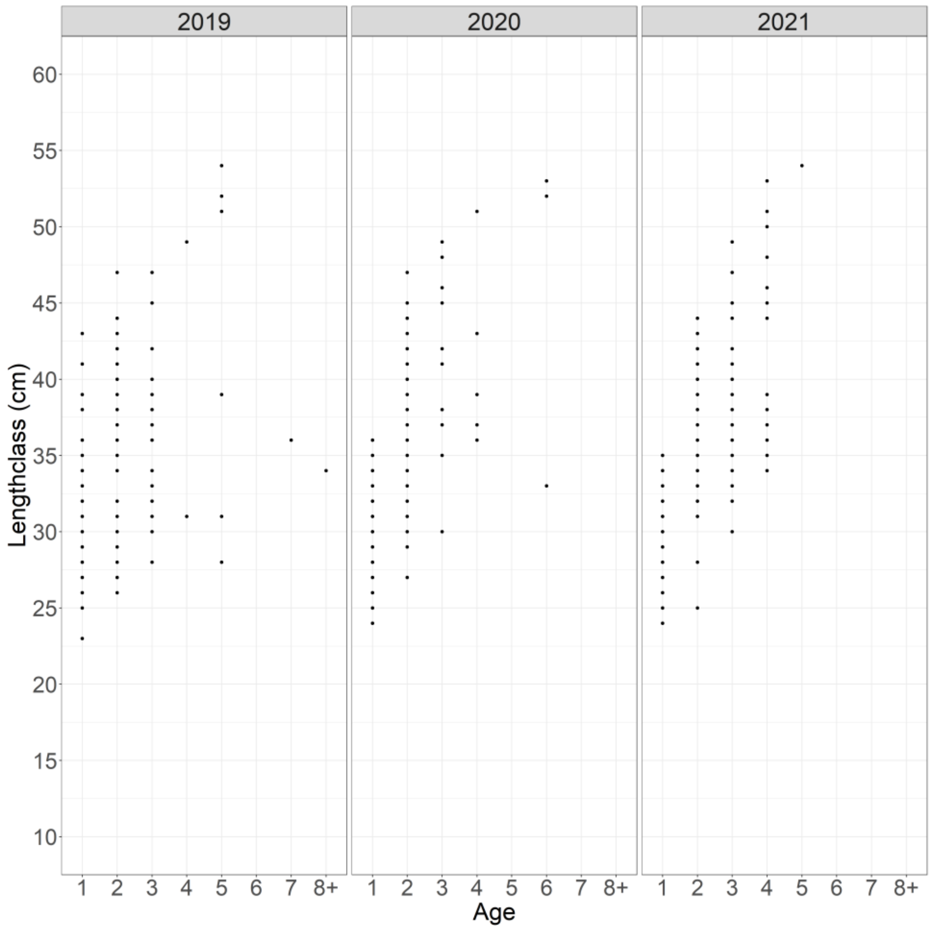

Figure 3.16: BLL 27.3a47de – Age length information for brill as sampled during the Dutch industry survey (BSAS) in 2019-2021.

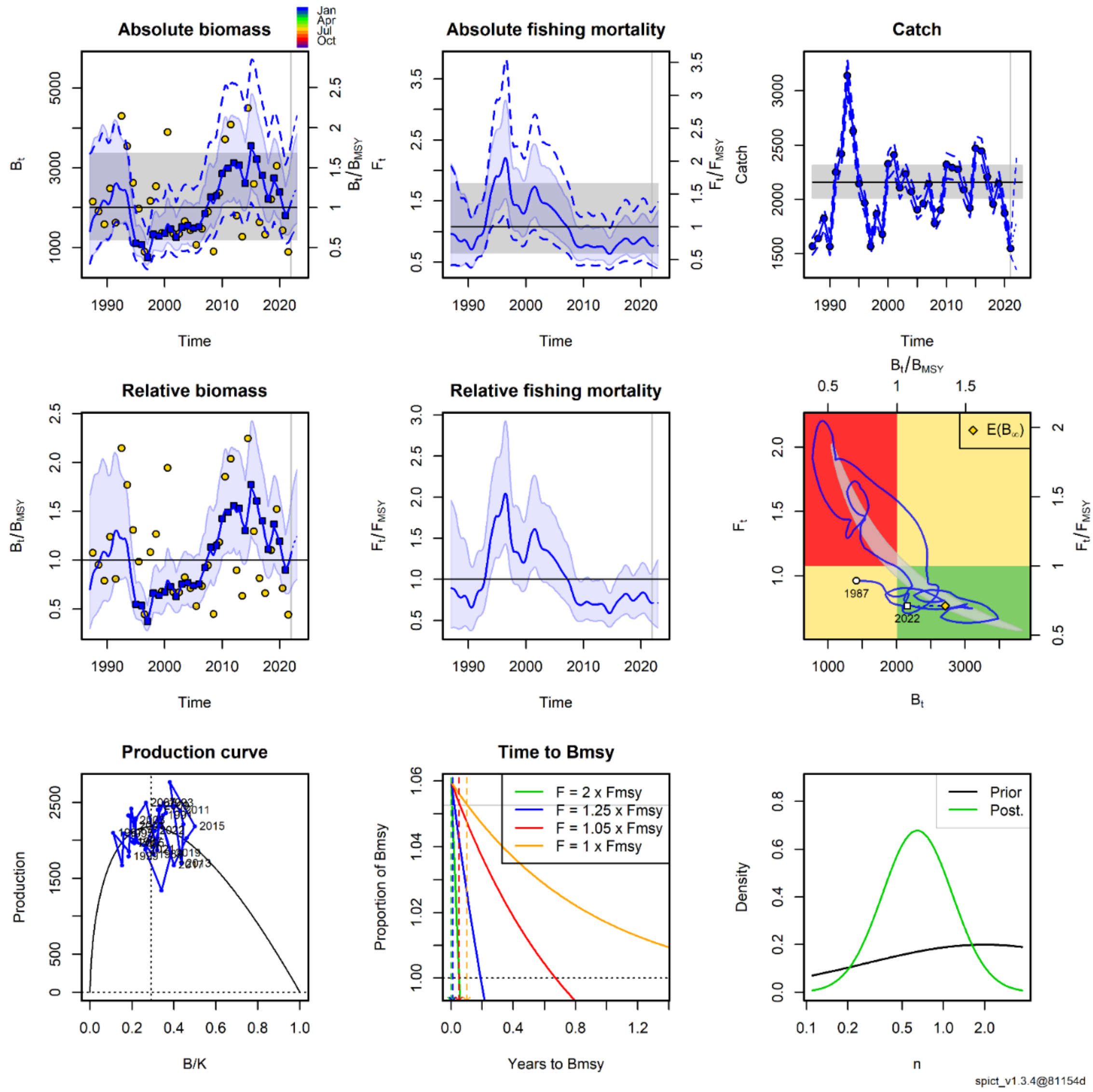

Figure 3.17: BLL 27.3a47de – SPiCT model results from WGNSSK 2022. Top row: absolute biomass, absolute F estimates, and fitted catch. Middle row: relative biomass and F, and a Kobe plot comparing biomass and F. The grey area in the Kobe plot represents the uncertainty in the relative biomass and F estimates. Bottom row: production curve, estimated time to B_{MSY}, and prior and posterior parameter distributions. The dashed lines are 95% CI bounds for absolute estimated values, shaded blue regions are 95% CIs for relative estimates, shaded grey regions are 95% CIs for estimated absolute reference points (horizontal lines).

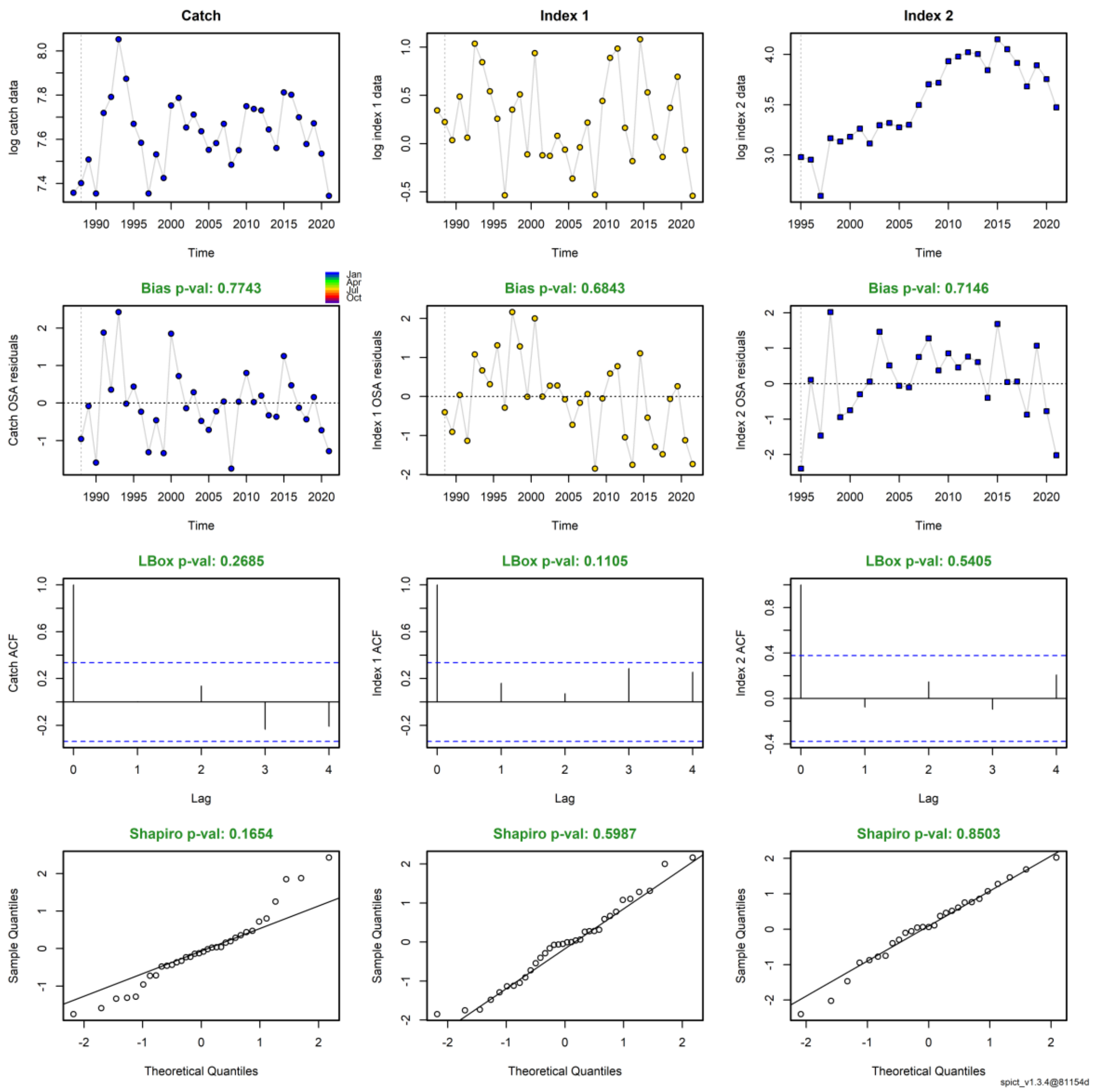

Figure 3.18: BLL 27.3a47de – SPiCT model diagnostics.

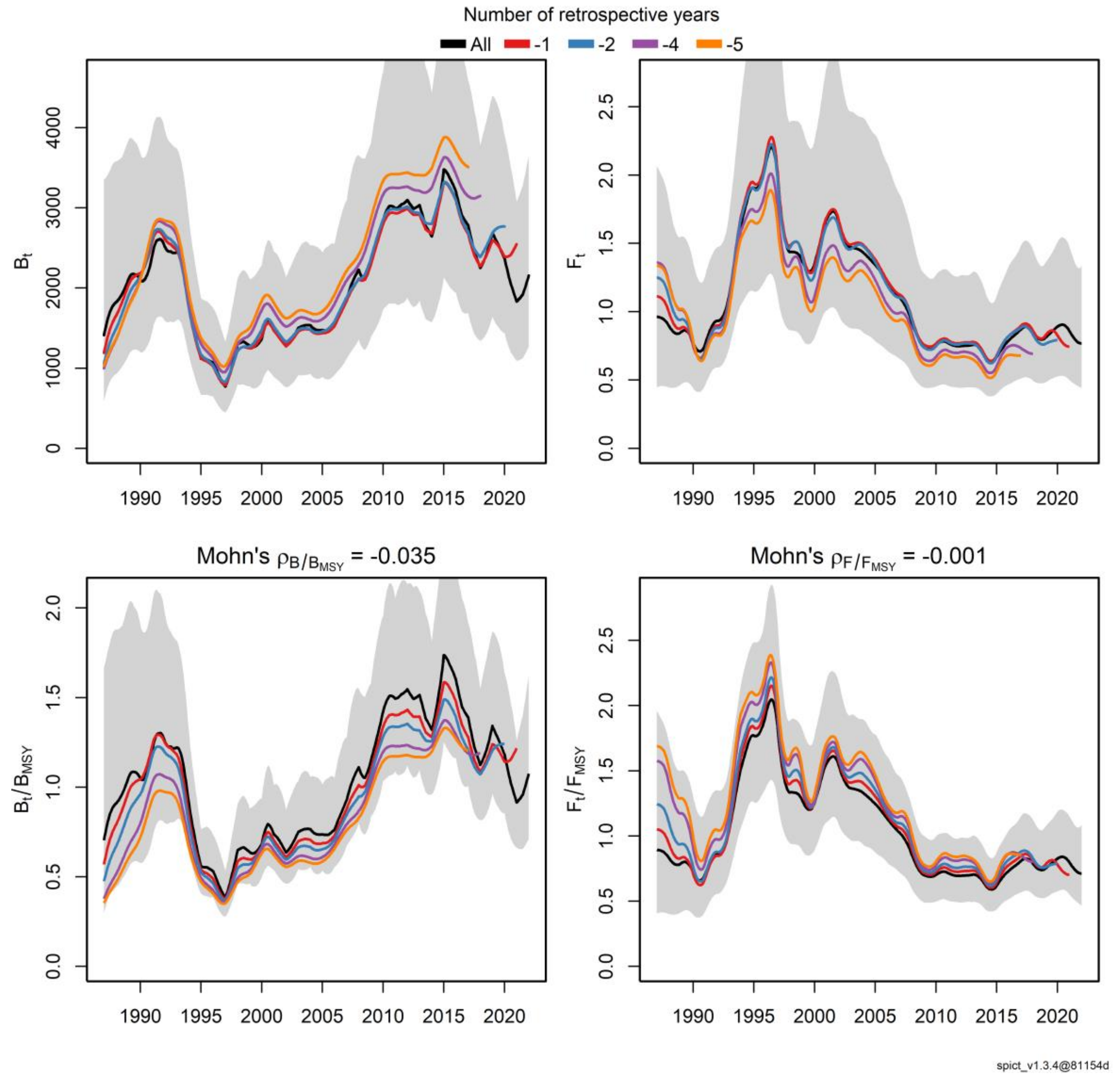

Figure 3.19: BLL 27.3a47de – Retrospective analysis of the SPiCT model from WGNSSK 2022. Top row: absolute biomass and absolute F; bottom row: relative biomass and relative F.

4 Cod (*Gadus morhua*) in Subarea 4, Division 7.d and Subdivision 20 (North Sea, Eastern English Channel, Skagerrak)

4.1 General

This assessment relates to the cod stock in the North Sea (Subarea 4), the Skagerrak (Subdivision 20), and the eastern Channel (Division 7.d). This assessment is presented as an update from last year.

A stock annex records more detail and references information on the stock definition, ecosystem aspects and the fisheries. This report section records only recent developments and new information presented to WGNSSK.

4.1.1 Stock definition

The North Sea stock consists of reproductively isolated populations of Viking and Dogger cod, with the Dogger population exhibiting spatial heterogeneity and extending to Division 6.a. A comprehensive summary of available information on stock definition can be found in ICES WKNSCodID (2020) and ICES WK6aCodID (2022).

4.1.2 Ecosystem aspects

The North Sea is characterised by episodic changes in productivity of key components of the ecosystem. Phytoplankton, zooplankton, demersal and pelagic fish have all exhibited such cycles in variability. Managers should expect long-term change and ensure that management plans have the potential to respond to new circumstances. For example, a regime shift occurred in the North Sea in the mid-1980s and evidence suggests another from around 1998, a time from which North Sea cod recruitment has been low. A summary of available information on ecosystem aspects is presented in the Stock Annex.

4.1.3 Fisheries

Cod are caught by virtually all the demersal gears in Subarea 4, Subdivision 20 (Skagerrak) and 7.d, including beam trawls, otter trawls, seine nets, gill nets, trammel nets and lines. Most of these gears take a mixture of species. In some of them, cod is considered a bycatch (for example in beam trawls targeting flatfish), and in others, the fisheries are directed mainly towards cod (for example, in large-meshed otter trawls and some fixed gear fisheries). The main gears landing North Sea cod are primarily TR1 (mainly operated by Scotland and Denmark), but also GN1 (mainly Denmark and Norway), TR2 and BT1. Cod are also an important target for marine recreational fisheries. A summary of information on cod fisheries and past and current technical measures used for the management of cod is presented in the Stock Annex.

4.1.4 Technical Conservation Measures

The recovery plan for cod (EC 1342/2008) triggered considerable improvements in selectivity and cod avoidance through incentives that were linked to the fishing effort regime and through national measures, such as the Scottish Conservation Credits Scheme. The Conservation Credits scheme was suspended on 20 November 2016 and the fishing effort regime discontinued in 2017 (EC 2094/2016). Further details of these measures are presented in the Stock Annex.

The expansion of the closed-circuit TV (CCTV) and FDF programmes in 2010–2016 in Scotland, Denmark, Germany, England and the Netherlands is expected to have contributed to a reduction of cod mortality. The cod specific FDF scheme terminated at the end of 2016. Further details are presented in the Stock Annex.

4.1.5 Management

Management of cod is by TAC and technical measures. The agreed TACs for Cod in Subarea 4, Division 7.d and Subdivision 20 (Skagerrak) over the last ten years were as follows:

TAC(000t)	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
20(Skagerrak)	3.8	4.0	4.2	4.8	5.7	8.0	4.2	2.1	1.9	1.9
2.a + 4	26.5	27.8	29.2	33.7	39.2	43.2	29.4	14.7	13.2	13.2
7.d	1.5	1.6	1.7	2.0	2.1	1.7	1.7	0.9	0.8	0.8

For 2013–2016, Council Regulations (EC) N°297/2013, N°432/2014, N°2015/104 and N°2016/72 allocated different amounts of Kw*days by Member State and area to different effort groups of vessels depending on gear and mesh size as stipulated by Council Regulation (EC) N°43/2009. The effort regime has now been discontinued, and the TACs for 2017–2022 are given in Council Regulations (EC) N°2017/127, N°2018/120, N°2019/124, N°2020/123, N°2021/1239 and N°2022/109 respectively. Since 2020, and in addition to TACs, remedial measures have been agreed by the EU, UK, and Norway to reduce the fishing pressure on cod in the North Sea. Details of these remedial measures are given in EC 2021/92 and EC 2022/109.

The EU landing obligation was implemented from 1 January 2017 for several gears, including otter trawlers with >100 mm mesh (TR1), beam trawlers with >120 mm mesh (BT1) and fixed gears. The EU landing obligation was fully implemented in the North Sea and Skagerrak from 1 January 2018 and in the eastern Channel from 1 January 2019, although a few exemptions exist. Council Regulation (EC) N°2019/2238 lists *de minimis* exemptions for cod caught in some bottom trawls targeting *Nephrops* or Northern prawn in Subdivision 20, mixed demersal fisheries using TR2 gears in Subarea 4 and beam trawls targeting brown shrimp in Divisions 4b-c. From 2022, the *de minimis* exemption for TR2 gears was discontinued in the UK waters of Divisions 4.a and 4.b and the exemption for brown shrimp beam trawls modified to limit discarding to a maximum of 5% of the total catch. Council Regulations (EC) N°2019/2238 and N°2019/2239 respectively detail survivability exemptions for bycatch in pots and fyke nets in Subarea 4 and Subdivision 20 and for species caught using pots, traps and creels in Division 7.d.

Demersal fisheries in the area are mixed fisheries, with many stocks exploited together in various combinations in the various fisheries. In these cases, management advice must consider both the state of individual stocks and their simultaneous exploitation in demersal fisheries. Stocks in the poorest condition, particularly those which suffer from reduced reproductive capacity, become the overriding concern for the management of mixed fisheries, where these stocks are exploited either as a targeted species or as bycatch.

Cod recovery and management plans

A Cod Recovery Plan which detailed the process of setting TACs for the North Sea cod was in place until 2008 (EC 423/2004). In December 2008, the European Commission and Norway agreed on a new cod management plan that aimed to be consistent with the precautionary approach and was intended to achieve sustainable fisheries and high yield. In addition to the EU–Norway agreement, the EU implemented effort restrictions, reducing KW-days available to EU vessels in the main métiers catching cod in direct proportion to reductions in fishing mortality until the long-term phase of the plan was reached (EC 1342/2008). A historical evaluation of the effectiveness of these plans (ICES WKROUNDMP, 2011; Kraak *et al.*, 2013) concluded that for North Sea cod, although there had been a gradual reduction in F and discards, the plans had not controlled F as envisaged.

In November 2016, the cod management plan was amended to discontinue the effort regime set out in EC 1342/2008 as it became an obstacle to the implementation of the landing obligation. Details of the amended cod management plan are given in EC 2016/2094.

In July 2018, the European Union agreed to a multiannual management plan for demersal fisheries in the North Sea (MAP). However, the plan was not adopted by Norway and the UK and is therefore not used as the basis of advice for this shared stock. Details of the plan are given in EC 2018/973.

In June 2018, EU-Norway requested an evaluation of multiple management strategies (ICES WKNSMSE, 2019); however, these are no longer consistent with the assessment and reference points following the benchmark in 2021.

Since 2015, advice has been given according to the ICES MSY approach.

4.2 Data available

4.2.1 Catch

Landings data from human consumption fisheries for recent years as officially reported to ICES together with those estimated by the WG are given for each area separately and combined in Table 4.1a.

The catch estimate for 2021 (uploads in weight) is 18 583 tonnes, and above the TAC of 15 911 tonnes. The catch is split as follows for the separate areas (tonnes):

	TAC	Landings	Discards	BMS*
20–Skagerrak	1893	2017	663	0
4	13246	12737	3127	2
7.d	772	37	<1	<1
Total	15911	14791	3790	2

*** BMS landings uploaded to InterCatch.**

Prior to the use of InterCatch for discard estimation, discard numbers-at-age were estimated for areas 4 and 7.d by applying the Scottish discard ogives to the international landings-at-age, and were based on observer sampling estimates for Subdivision 20–Skagerrak. Discard raising for 2002–2021 was performed in InterCatch, with the different nations providing information by area, quarter and métier. Sampling for discards and age compositions was poor in area 7.d in 2002–2003, and this necessitated combining areas 4 and 7.d in those years. The provision of discard information has vastly improved since the reform of the EU's data collection framework in

2008 (see http://datacollection.jrc.ec.europa.eu/) but was lower in 2020 and 2021 (57% of the landings in both years), likely due to the COVID-19 pandemic. All nations apart from Norway now provide discard information. Figure 4.1a plots reported landings and estimated discards (including BMS landings) used in the assessment. Discard ratio sampling coverage by area and season for 2021 is provided in Table 4.1b, along with the contributions to total landings, discards and BMS from each area prior to raising.

Norwegian discarding is illegal, so although this nation has accounted for 7–15% of cod landings over the period 2002–2021 (InterCatch data), it does not provide discard estimates. Nevertheless, the agreed procedure applied in InterCatch is that discards raising should include Norway (i.e., Norway will be allocated discards associated with landings in reported métiers). Furthermore, tagging and genetic studies have indicated that Norwegian coastal cod are different to North Sea cod and do not generally move into areas occupied by North Sea cod. Therefore, Norwegian coastal cod data have been removed from North Sea cod data by uploading only North Sea cod data into InterCatch for 2002 onwards, and by adjusting catches prior to 2002 to reflect the removal of Norwegian coastal cod data (an annual multiplicative adjustment of no more than 2.5% was made using Norwegian coastal cod data (see ICES WKNSEA, 2015, for more details).

For cod in 4, 20–Skagerrak and 7.d, ICES first raised concerns about the misreporting and non-reporting of landings in the early 1990s, particularly when TACs became intentionally restrictive for management purposes. The WG believes that under-reporting of landings may have been significant in 1998 because of the abundance in the population of the relatively strong 1996 year-class as 2-year-olds. The landed weight and input numbers at age data for 1998 were adjusted to include an estimated 3000 tonnes of under-reported catch. The 1998 catch estimates remain unchanged in the present assessment (apart from the adjustment for Norwegian coastal cod). The UK Buyers and Sellers legislation, introduced towards the end of 2005, is expected to have improved the accuracy of reported cod landings.

Since the WG has no basis to judge the overall extent of under-reported catch over time, it has no alternative but to use its best estimates of landings, which in general are in line with the officially reported landings.

Age compositions

Age compositions were provided by all nations apart from France for 2021 data. The sampling coverage for landings and discards age compositions for 2021 are reported in Table 4.1b.

Landings in numbers at age for age groups 1–11+ and 1963–2021 are given in Table 4.2a. These data form the basis for the catch at age analysis but do not include industrial fishery bycatches landed for reduction purposes prior to 2002 (values from 2002 onwards were entered into InterCatch for all relevant nations except Norway, and were included in the raising, although the numbers were very small). Bycatch estimates are available for the total Danish industrial fishery in Subdivision 20 and Subarea 4 (Table 4.1a). During the last five years, an average of 66% of the international landings in number were accounted for by juvenile cod aged 1–3; this average rises to 83% when considering landings and discards combined. In 2021, age 1 cod comprised 28% of the total catch by number, age 2, 38% and age 3, 19%.

Discard numbers-at-age (including BMS landings from 2016) are shown in Table 4.2b. The proportions of the estimated numbers discarded for ages 1–4 and the proportion of the estimated total discards by weight and number are shown in Figure 4.1b. Estimated proportion of total numbers caught that were discarded (Figure 4.1b) had decreased from a peak of 84% in 2006 to 36% in 2019 but increased to 54% in 2021. Historically, the proportion of numbers discarded at age 1 has fluctuated around 80% but was estimated at 92% in 2021. At ages 2 to 4 discard proportions increased to a maximum around 2006–10 but have subsequently declined to give 66%

for age 2, 14% for age 3 and 1% for age 4 cod in 2021. Note that these observations refer to numbers discarded, not weight.

Total catch numbers-at-age are shown in Table 4.2c. Landings, discards (including BMS landings) and total catch numbers at age are given by season in Table 4.2d for 2021. Reported landings, estimated discards (including BMS landings from 2016) and total catch (sum of landings and discards), given in tonnage, are shown in Table 4.3.

InterCatch

InterCatch was used for estimation of landings, discards (including BMS landings) and total catch at age and mean weight at age in 2021. Data co-ordinators from each nation were tasked to input data into InterCatch, disaggregated to quarter and métier. The data from Norway excluded Norwegian coastal cod. Allocations of discard ratios and age compositions for unsampled strata were then performed to obtain the data required for the assessment. The approach used for discard ratio allocations was to do it by area (20, 4 and 7.d), giving three broad categories. Annual discards were first matched to quarterly landings. Then, within each of these three categories, ignoring country and season, where métiers had some samples, these were pooled and allocated to unsampled records within that métier. At the end of this process, any remaining métiers were allocated an all samples pooled discard ratio for the given category.

The landings and discards imported in weight or raised for 2021 are as follows (tonnes):

Catch Category	Raised or Imported	CATON	Percentage
BMS landing	Imported	2	100
Discards	Imported	2509	66
Discards	Raised	1281	34
Landings	Imported	14791	100
Logbook Registered Discard	Imported	0	NA

A similar approach was used for allocating age compositions, except that there were six broad categories because discards (including BMS landings) were treated separately to landings. However, discard age compositions for Division 7.d had to be allocated from métiers in Subarea 4 as there was no discards age sampling in 7.d in 2021.

The landings and discards imported in weight or raised, with age distribution sampled or estimated for 2021 are as follows (tonnes):

Catch Category	Raised or Imported	Sampled or Estimated	CATON	Percentage
Logbook Registered Discard	Imported	Estimated	0	NA
Landings	Imported	Sampled	11582	78
Landings	Imported	Estimated	3209	22
Discards	Imported	Sampled	2364	62
Discards	Raised	Estimated	1281	34
Discards	Imported	Estimated	145	4
BMS landing	Imported	Sampled	0	NA
BMS landing	Imported	Estimated	2	100

InterCatch is discussed in Section 1.2, and all results are available on the WGNSSK SharePoint. Further work is ongoing, analysing the InterCatch data (cf. ICES WGMIXFISH meeting during 2022).

Recreational catches

Recreational catches were estimated for 2010–2020 from data provided by Belgium, Denmark, Germany, Sweden, Norway, the Netherlands, and UK, but are considered provisional and not included in the assessment due to length of time series and unknown age structure and uncertainty. Further details are provided in the stock annex and ICES WKNSEA (2021). Estimates of commercial and recreational removals along with the percentage of recreational removals and percentage of recreational removals derived from imputation are as follows:

Year	commercial removals (t)			Recreational removals (t)			% recr.	%imputed
	Landings	Discards	Total	Retained	Released	Total		
2010	36746	12488	49234	1759	432	2191	4.3	60
2011	31950	8745	40695	1610	517	2128	5.0	87
2012	32074	8689	40763	1392	516	1908	4.5	53
2013	30386	10324	40710	1588	299	1887	4.4	80
2014	34673	10666	45339	2271	583	2854	5.9	67
2015	37205	12562	49767	3586	490	4076	7.6	82
2016	38230	12315	50544	2597	443	3040	5.7	12
2017	37994	8731	46725	1976	463	2439	5.0	25
2018	40012	7824	47836	1844	320	2164	4.3	2
2019	32072	3607	35679	1533	332	1865	5.0	23
2020	19523	4701	24224	1455	226	1681	6.5	11
Mean	33715	9150	42865	1964	420	2385	5.3	46

4.2.2 Weight-at-age

Mean weight at age data for landings, discards (including BMS landings from 2016) and catch, are given in Tables 4.4a–c. Landings, discards and catch mean weights at age are given by season in Table 4.4d for 2021. Long-term trends in mean catch weights-at-age by catch component for ages 1–7 are plotted in Figure 4.2a, which indicates an overall decline from around 2010 for ages 3 and above. Ages 1 and 2 show little absolute variation over the long term.

Stock mean weights are derived from the NS–IBTS–Q1 survey data for ages 1–2 and from the Q1 catch data for ages 3+. Stock mean weights are given in Table 4.5a and plotted in Figure 4.2b.

4.2.3 Maturity and natural mortality

Values for proportion mature at age are derived from an area-weighted maturity age key constructed from NS–IBTS–Q1 data from 1978. The calculation is described in the Stock Annex. In 2022, biological sampling in the Viking 20 (Skagerrak) and Southern subareas was low (<5 fish at each age) and necessitated pooling with samples from the Viking 4a and Northwestern subareas respectively (see Figure 4.16c for subarea definitions). It was noted that some nations used the A–E format to report maturity since 2021, while others continue to use the 61–66 format; however, consequent revisions to the maturity ogive had little impact on the assessment. The time-varying maturity ogive used as input to the assessment is given in Table 4.5b and illustrated in Figure 4.2c.

Table 4.5c and Figure 4.2d show estimates of M based on multi-species considerations adopted for the assessment. Estimates of natural mortality are derived from multispecies analyses updated by the Working Group on Multi-Species Stock Assessment Methods (WGSAM) every three years in so-called "key runs" to account for improved knowledge of predation on cod by other species (mainly seals, harbour porpoises and gurnards) and cannibalism; the last update occurred in 2020 with the new key run (ICES WGSAM, 2020).

An ad-hoc adjustment is made to the M values of ages 3+ to mimic a 15% emigration out of the assessment area from 2011 (Table 4.5c and Figure 4.2d). Full details of this adjustment are given in the Stock Annex.

4.2.4 Catch, effort and research vessel data

Reliable, individual, disaggregated trip data were not available for the analysis of CPUE. Therefore, only survey and combined commercial landings and discard information are analysed within the assessment presented.

Two survey series are available for use within this assessment:

Quarter 1 international bottom-trawl survey (IBTS–Q1): ages 1–6+, covering the period 1976–2022. This multi-vessel survey covers the whole of the North Sea using fixed stations of at least two tows per rectangle with the GOV trawl.

Quarter 3 international bottom-trawl survey (IBTS–Q3): ages 0–6+, covering the period 1991–2021. This multi-vessel survey covers the whole of the North Sea using fixed stations of at least two tows per rectangle with the GOV trawl.

Maps showing the IBTS distribution of cod are presented in Figures 4.3a–b (ages 1–3+). The recent dominant effect of the size and distribution of 2005, 2009, 2013 and 2016 year-classes are apparent from these charts. Fish of older ages continued to decline until 2006 due to the very weak 2002- and 2004-year classes, but subsequently increased, especially in the north and west; however, the abundance of 3+ fish is still at a low level compared to historic levels. A combination of several major storms and mechanical issues with some vessels resulted in a reduction in the sampling coverage in the IBTS–Q1 survey in 2022. The maps for 2022 in Figure 4.3a are not therefore fully representative of the distribution of cod due to incomplete survey coverage, especially in the central and northern North Sea.

Standardised age-based survey indices for North Sea cod are calculated based on GAMs and Delta-distributions. The general methodology is described in Berg and Kristensen (2012) and Berg *et al*. (2014) and is implemented in Microsoft R Open 4.0.2 based on the DATRAS (http://rforge.net/DATRAS/) and surveyIndex packages. The Delta-GAM is fit to each survey separately. For the IBTS–Q1, the Delta-GAM is fit to ages 1–6+, with ages 1–5 retained and used in the assessment model. For the IBTS–Q3, the Delta-GAM is fit to ages 0–5+, with ages 1–4 retained and used as an index in the assessment. Because the first age in the assessment model is age 1, estimates of age 0 from the IBTS–Q3 indices are retained as a separate recruitment index forward shifted to 1st January the following year.

More details of the method used to produce the NS–IBTS Delta–GAM indices are provided in the stock annex and can be found in ICES WKNSEA (2021), as well as the above-mentioned publications. In summary, the final Delta–GAM models selected for NS–IBTS–Q1 and Q3 comprised a high resolution stationary spatial model with low resolution yearly independent deviations and included ship, year, depth, time of day and haul-duration effects. The NS–IBTS Delta–GAM indices and associated standard deviations used in the assessment are given in Table 4.6. The increased uncertainty from reduced coverage in the IBTS–Q1 survey in 2022 is reflected by higher standard deviations for that year (Table 4.6), which are subsequently carried through to the SAM assessment. Figures 4.3d-e compare the Q1 and Q3 NS–IBTS Delta–GAM indices to the corresponding NS–IBTS extended indices (calculated using the standard stratified mean methodology applied to an extended area; Figure 4.3c) and the Delta-GAM indices from the 2021 assessment (which have one-year fewer data; ICES WGNSSK 2021). Retrospective analyses with three peels give average Mohn's rho values of 0 and 0.01 across all ages for the IBTS–Q1 and IBTS–Q3 indices, respectively.

4.3 Data analyses

4.3.1 Assessment audit

The assessment audit for North Sea cod was completed and no significant issues found for the assessment itself. Additional checks on the forecast are carried out during the ICES WGMIXFISH meeting in 2022.

4.3.2 Exploratory survey-based analyses

Survey abundance indices are plotted in log-mean standardised form by year and cohort in Figure 4.4a for the IBTS–Q1 survey, together with log-abundance curves and associated negative gradients for the age range 2–4. Similar plots are shown for the IBTS–Q3 survey in Figure 4.4b. The log-mean standardised curves track cohort signals well (top right), although there is some loss of signal between the 2012 and 2013 cohorts associated with an apparent positive year effect in 2017 and disappearance of the strong 2013-year class from survey catches at older ages. The log abundance curves for each survey series have shown a sharp decrease in the most recent year(s) (bottom left) with a substantial decrease in the negative gradient for ages 2–4 following the 2017 year class (bottom right), likely due to the reductions in catches from 2019 onwards.

Figures 4.5a and b show within-survey consistency (in cohort strength) for the NS-IBTS Q1 and Q3 Delta–GAM survey indices, while Figures 4.5c and 4.5d show between survey consistencies (for each age) for the two surveys. These show generally good consistency, justifying their use for survey tuning.

The SURBAR survey analysis model was fitted to both the Q1 and Q3 NS–IBTS Delta-GAM survey indices (ages 1–5). The summary plots are presented in Figure 4.6a.

Biomass: Spawning stock biomass reached a peak in 2013 but subsequently declined rapidly. SSB has started to increase since 2020 due to a reduction in total mortality. A similar trend can also be seen in the time series for total stock biomass.

Total mortality: the SURBAR analysis indicates an overall gradual decline in total mortality until 2014, followed by a rapid increase peaking in 2018 and reaching the lowest value in the time-series by 2021.

Recruitment: the SURBAR analysis indicates that the recruiting year classes since 1996 have been relatively weak, but with stronger 1999-, 2005-, 2009-, 2013-, 2016- and 2019-year classes.

There are patterns in the residuals (Figure 4.6b), potentially because the SURBAR analysis does not reflect the underlying stock structure and connectivity with Division 6a. In recent years, residuals are positive for all ages in the NS-IBTS-Q1 in 2017 and negative for ages 2+ in the NS-IBTS-Q3 in 2017–2018 (Figure 4.6b).

4.3.3 Exploratory catch-at-age-based analyses

Catch-at-age matrix

The total catch-at-age matrix (Table 4.2c) is expressed as numbers at age, and proportions-at-age, standardised over time in Figure 4.7. It clearly shows the contribution of the 2005-, 2009-, 2013- and 2016-year classes to catches in recent years and indicates a relative increase in the number of older fish in the catches.

Catch curve cohort trends

The top panel of Figure 4.8 presents the log catch curve plot for the catch at age data. In recent years there has been a gradual decrease in the slope at the youngest ages–a sign of decreased mortality rates. The bottom panel plots the negative slope of a regression fitted to the ages 2–4, the age range used as the reference for mortality trends. Like equivalent plots for the survey indices, these gradients show a sharp decrease for the 2017 year class, likely due to the reductions in catches from 2019 onwards.

4.3.4 Final assessment

The final assessment used SAM (State-space Assessment Model; Nielsen and Berg, 2014) run with R *stockassessment* package version 0.11.0 in R version 4.1.0. The data used in the assessment are given in Tables 4.2 and 4.4–6, and the model configuration in Table 4.7a. Random walk processes are used to model recruitment and fishing mortality-at-age, where the random walks for fishing mortality are correlated among ages according to an AR(1) process. Correlations between ages in the IBTS surveys are modelled according to an AR(1) process that estimates a single parameter for the correlation between ages 1 and 2 and common correlation parameters between the older ages (Berg and Nielsen, 2016). Maturity is modelled as a Gaussian Markov Random Field (GMRF) process with cohort- and within year correlations. Model fitting diagnostics, parameter estimates, and associated correlation matrix are given in Table 4.7b.

Figure 4.9 shows summary plots of the final assessment in terms of population trends. Estimates of fishing mortality at age, stock numbers at age, catches at age and maturity at age are given in Tables 4.8–11 respectively, while a summary table for estimates of recruitment (age 1), TSB, SSB, catches and F_{bar} (2–4) are given in Table 4.12a (along with 95% confidence bounds), and estimates of landings, discards and catches are given in Table 4.12b (and can be compared to the corresponding data in Table 4.3). Mean fishing mortality split into landings and discards, using landings fraction, and split into ages is shown in Figure 4.10a and selectivity in F is shown in Figure 4.10b, while estimated maturity at age is shown in Figure 4.11. Estimated correlations between ages in the catch and survey indices are shown in Figure 4.12. These correlations reflect the couplings specified in the model configuration (Table 4.7a) assuming independence in the catch and correlation between ages in each of the IBTS surveys.

Residual plots are shown in Figures 4.13a-b, indicating no serious model misspecification, although residuals for the IBTS–Q1 are all positive in 2017 and all negative in 2018 while residuals for the IBTS–Q3 are all negative in 2017–2018. Retrospective plots for SSB, average fishing mortality, recruitment at age 1 and TSB are shown in Figure 4.14. Mohn's rho statistics based on a five-year peel are calculated as 0.101, 0.021, 0.221 and 0.130 for SSB, $F_{2\text{–}4}$, recruitment, and TSB respectively.

A comparison with last year's assessment (ICES WGNSSK, 2021) is provided in Figure 4.15a. Differences between the assessments are due to the addition of one year of catch and NS–IBTS Q1 and Q3 survey data, as well as slight revisions to the delta-GAM indices and maturity ogive. The addition of the new data results in a slight upscaling of SSB in recent years and a decrease in Mohn's rho (from 0.150 to 0.101). A check of diagnostics (likelihood, AIC and Mohn's rho for SSB) confirmed that inclusion of the ad-hoc adjustment on M still results in improved model performance (compared to a SAM run without this adjustment). A comparison with the SURBAR survey-based assessment is provided in Figure 4.15b and shows similar trends between models, although the larger recruitment predicted by SURBAR in 2020 is not realised in SAM.

4.4 Historic stock trends

The historic stock and fishery trends are presented in Figures 4.9–10 and Tables 4.12a–b.

Recruitment fluctuated at a relatively low level from 1998. The 1996-year class was the last large year class that contributed to the fishery, and subsequent year classes have been the lowest in the time series, but with stronger 1999-, 2005-, 2009-, 2013- and 2016-year classes.

Fishing mortality increased until the early 1980s, remained high until 2000 and declined to a low level in 2013. This decline in F subsequently reversed with F increasing rapidly to a smaller peak in 2018. F has since declined to its lowest level in 2021, following a series of reductions to the TACs and catches, and is now below all fishing mortality reference points.

SSB declined steadily during the 1970s and 1980s. There was a small increase in SSB following improved recruitment coupled with a slight dip in fishing mortality in the mid-1990s, but with low recruitment since 1998 and continued high mortality rates, SSB continued to decline to its lowest level in 2005. SSB subsequently increased with a decline in fishing mortality, reaching a peak in 2016, but has since declined rapidly. Despite a slight increase in 2022, the SSB remains below B_{lim}.

The North Sea cod stock consists of reproductively isolated populations of Viking cod and Dogger cod, with the Dogger cod population exhibiting spatial heterogeneity and extending to Division 6.a (ICES WKNSCodID, 2020; ICES WK6aCodID, 2022). These genetically different groups have different rates of maturity and growth. Trends in biomass and recruitment have been strongly correlated among subareas of the North Sea but have diverged in the last decade, with no apparent rebuilding in the South (Figures 4.16a-c). The low landings in 7.d (37 tonnes in 2021) and low biological sampling in the southern subregion in the NS-IBTS Q1 survey may indicate a collapse of the stock in this area. Official nominal landings from 2021 are low in both divisions 4.c (63 tonnes) and 7.d (28 tonnes).

Figure 4.17 indicates that the age structure in the population gradually improved (number of fish aged 5 and older in the population increased) with the decrease in fishing mortality from the early 2000s, but the trend reversed, with poorer survival to the older ages evident over the past 5-years. Although the number of 5+ fish in the population remains low, % survival to age 5 reached its highest level in 2022 following the recent reductions in F.

4.5 Recruitment estimates

Recruitment in the intermediate year (2022) was sampled from a normal distribution about the assessment estimate and is reported as the median of those samples. Estimates of recruitment for subsequent years were resampled from the 1997–2021-year classes, reflecting recent low levels of recruitment, but including the relatively stronger 1999-, 2005-, 2009-, 2013- and 2016-year classes.

4.6 MSY estimation

MSY estimation is performed with the EQSIM software (ICES WGMG, 2013), in accordance with the ICES guidelines. MSY estimation for North Sea cod was last performed during ICES WKNSEA (2021) based on a truncated recruitment time-series (1998–2020) and without the ad hoc adjustment on M. Details of the analysis are available in the expert group report (ICES WKNSEA, 2021).

A summary of the biological reference points (not including the advisory HCR in all but $F_{P.05}$) is provided in the following table.

Stock	
F_{MSY}	0.28
F_{MSY} lower	0.186
F_{MSY} upper	0.45
$F_{P.05}$ (5% risk to B_{lim}, with HCR included)	0.49
F_{MSY} upper precautionary	0.45*
MSY	51 541 t
Median SSB at F_{MSY}	163 738 t
Median SSB at F_{MSY} upper precautionary	92 668 t
Median SSB at F_{MSY} lower	247 255 t

*** Note that the FP0.5 value is 0.49 for an EQSIM run (with HCR included), so the F_{MSY} upper value is not constrained.**

4.7 Short-term forecasts

The May forecast

Forecasting takes the form of short-term stochastic projections. A total of 1000 samples are generated from the estimated distribution of survivors. These replicates are then simulated forward according to model and forecast assumptions (see table below), using the usual exponential decay equations, but also incorporating the stochastic survival process (using the estimated survival standard deviation) and subject to different catch-options scenarios.

The intermediate year assumption was taken as a 27% overshoot of the TAC, which is the average of the overshoots in 2020 and 2021 and results in an intermediate year F assumption of 0.21. A status quo F assumption, corresponding to the lowest F in the time series, was also considered and would have resulted in a 54% overshoot of the TAC.

Forecasts options are presented in Table 4.13. Forecast assumptions are as follows (note that the values that appear in the catch scenarios in Table 4.13 are medians from the distributions that result from the stochastic forecast):

Initial stock size	**Starting populations are simulated from the estimated distribution at the start of the intermediate year (including co-variances).**
Maturity	Forecasted according to the SAM GMRF process for maturity (Figure 4.11).
Natural mortality	Average of final three years of assessment data with M-adjustment.
F and M before spawning	Both taken as zero.
Weight at age in the catch	Average of final three years of assessment data.
Weight at age in the stock	Average of final three years of assessment data.
Exploitation pattern	Forecasted according to the SAM F processes (Figure 4.10b).
Intermediate year assumptions	Median total catch in the intermediate year assuming a 27% overshoot of the TAC in the intermediate year.
Stock recruitment model used	Recruitment for the intermediate year (the year the WG meets) is sampled from a normal distribution of the SAM estimate and reported as the median. Recruitment for the TAC year onwards is sampled, with replacement, from 1998 to the intermediate year.
Procedures used for splitting projected catches	The final year landing fractions-at-age are used in the forecast period.

The October forecast

Since the final SAM model includes two indices from the IBTS Q3, the assessment is subject to the AGCREFA protocol for reopening of advice in the autumn (ICES AGCREFA, 2008; ICES WKNSROP, 2020). The reopening protocol for North Sea cod is:

Re-run the delta-GAM index for Q3 including the new data from the autumn survey.
Conduct an RCT3 check on age 1 for year classes y-1 and y including information from the IBTS Q3 only.
If a reopening is triggered:

Rerun SAM with the updated Q3 indices;
Populate and re-run the forecast procedure with the resulting assessment estimates, using the SAM estimate of recruitment in the TAC year (y+1) rather than a resampled recruitment, as done in May.

The current May forecast

Several scenarios were considered as follows (note, $B_{trigger}$ = B_{pa} = 97 777 tonnes, and F_{MSY} = 0.28; see Section 4.9):

MSY approach: F_{bar} (2023) = F_{MSY}×min{1; SSB_{2023}/$B_{trigger}$}
$F_{MSY\ lower}$ with reduction: F_{bar} (2023) = $F_{MSY\ lower}$×min{1; SSB_{2023}/$B_{trigger}$}
Zero catch: F_{bar} (2023) = 0
F_{pa}: F_{bar} (2023) = F_{pa} = $F_{P.05}$ = 0.49
F_{lim}: F_{bar} (2023) = F_{lim} = 0.58
SSB (2024) = B_{lim}: F corresponding to SSB (2024) = B_{lim}
SSB (2024) = $B_{trigger}$ = B_{pa}: F corresponding to SSB (2024) = $B_{trigger}$ = B_{pa}
Lower TAC constraint: F_{bar} (2023) such that TAC (2023) = 0.8×TAC (2022)
Rollover TAC 15%: F_{bar} (2023) such that TAC (2023) = 0.85×TAC (2022)
Rollover TAC 10%: F_{bar} (2023) such that TAC (2023) = 0.9×TAC (2022)
Rollover TAC 5%: F_{bar} (2023) such that TAC (2023) = 0.95×TAC (2022)
Rollover TAC: F_{bar} (2023) such that TAC (2023) = TAC (2022)
Rollover TAC + 5%: F_{bar} (2023) such that TAC (2023) = 1.05×TAC (2022)
Rollover TAC + 10%: F_{bar} (2023) such that TAC (2023) = 1.1×TAC (2022)
Rollover TAC + 15%: F_{bar} (2023) such that TAC (2023) = 1.15×TAC (2022)
Upper TAC constraint: F_{bar} (2023) such that TAC (2023) = 1.2×TAC (2022)
Status quo – constant F: F_{bar} (2023) = F_{bar} (2022)
$F_{MSY\ lower}$: F_{bar} (2023) = $F_{FMY\ lower}$ = 0.186
F_{MSY}: F_{bar} (2023) = F_{FMY} = 0.28
$F_{MSY\ upper}$: F_{bar} (2023) = $F_{FMY\ upper}$ = 0.45

Forecasts for the SAM final run are given in Table 4.13.

4.8 Medium-term forecasts

Medium-term projections are not carried out for this stock.

4.9 Biological reference points

The reference points for cod in Subarea 4, Division 7.d and Subdivision 20 were estimated at ICES WKNSEA (2021). Biological reference points and their technical basis are as follows:

Framework	Reference point	Value	Technical basis	Source
MSY approach	MSY $B_{trigger}$	97 777 t	B_{pa}; in tonnes	ICES WKNSEA (2021)
	F_{MSY}	0.28	Stochastic simulations (EqSim) based on recruitment period 1998–2020	ICES WKNSEA (2021)
Precautionary approach	B_{lim}	69 841 t	B_{pa} / 1.4; in tonnes	ICES WKNSEA (2021)
	B_{pa}	97 777 t	Highest observed SSB (1998) based on the recruitment period 1998–2020 with 2019 as the last year of catch data; in tonnes.	ICES WKNSEA (2021)
	F_{lim}	0.58	The F that on average leads to B_{lim}	ICES WKNSEA (2021)
	F_{pa}	0.49	The F that provides a 95% probability for SSB to be above B_{lim} ($F_{P.05}$ with AR)	ICES WKNSEA (2021)

4.10 Quality of the assessment

The quality of the commercial landings and catch-at-age data for this stock deteriorated in the 1990s following reductions in the TAC without associated control of fishing effort. The WG considers the international landings figures from 1993–2005 to have inaccuracies but no longer estimates a catch multiplier in the SAM assessment to account for this (ICES WKNSEA, 2021).

The proportion of landings sampled for ages was lower in 2020 (75%) and 2021 (78%) than in 2019 (89%) likely due to the COVID-19 situation. Weights at age in the catch and selectivity patterns however did not exhibit unreasonable deviations from the previous years.

Stock identity remains an issue with this assessment, with multiple populations inhabiting the North Sea and extending to neighbouring areas (ICES WKNSCodID, 2020; ICES WK6aCodID, 2022). The 2021 benchmark introduced an ad hoc adjustment to account for emigration of North Sea cod to the West of Scotland area (ICES WKNSEA, 2021), which is currently not included in the assessment area.

The estimated CVs for observed catch at age 1, for the NS–IBTS–Q1, Q3 and Q3 recruitment indices at age 1 and the stock-recruitment relationship are all large: 60%, 228%, 234%, 241% and 79%, respectively. These large CVs suggest that these sources of information are somewhat ignored in the SAM recruitment estimation, which might therefore be more influenced by age 2 abundance estimates and model assumptions about F-at-age 1. The CV of the survival process is assumed to be the same for all non-recruiting ages (estimated at 12%) and this might have an impact on recruitment estimates (and, hence, age 1 catch and survey residuals) because it constrains the changes permitted between abundance at ages 1 and 2 of a cohort. The high correlation (0.96) estimated for the increments of log[F(y,a)] across ages suggests that the model might react slowly if different changes in selectivity start to happen for different ages.

A reduction of the plus group from 7+ to 6+ following the 2015 benchmark (ICES WKNSEA, 2015) introduced increasingly domed selection in the latter half of the time series that was not present in previous assessments; although there are reasons why such increasingly domed selection might occur, such as some evidence that larger cod inhabit less accessible rocky areas or simply move away from areas fishing vessels operate in, these reasons remain largely speculative.

There is general agreement across both models presented (SAM and SURBAR) of a recent sharp decline in total mortality, a corresponding increase in SSB (following a sharp decline from the mid-2010s), and stronger 2005-, 2009-, 2013- and 2016-year classes (Figure 4.15b). SURBAR estimates the 2019 year class to be stronger, although this is not so apparent in SAM.

4.11 Status of the stock

There has been a sharp decline in the status of the stock in the last few years. Although SSB has increased in the last year, it is still below B_{lim}.

Fishing mortality has declined from a peak in 2018 and is now below both the precautionary reference points, F_{lim} and F_{pa}, and the level that achieves the long-term objective of maximum yield, F_{MSY}.

Recruitment of 1-year old cod has varied considerably since the 1960s, but since 1998, average recruitment has been lower than any other time. The last larger recruitment observed during this period was the 2016-year class.

4.12 Management considerations

Cod has been fully under the EU landing obligation since 2018 in Subarea 4 and Subdivision 20, and since 2019 in Division 7d although there are some *de minimis* exemptions in Subarea 4 and Subdivision 20 (see Section 4.1.4). BMS landings of cod reported to ICES are currently negligible and much lower than the estimates of catches below MCRS (Minimum Conservation Reference Size) estimated by observer programmes.

It is uncertain whether if and to what extent, the discontinuation of the days-at-sea regulation in 2017, which was part of the cod recovery plan, has had an impact on the recent decline of the cod stock. Although F has reduced since 2018, catches have not been in line with ICES advice. The SSB remains below B_{lim}, with an increased risk of impaired recruitment (which remains low).

There is a need to reduce fishing induced mortality on North Sea cod, particularly for younger ages, to allow more fish to reach maturity and increase the probability of good recruitment. Discards currently contribute 20% of the total catch by weight and 54% of the catch by number with 92% of 1 year old, 66% of 2-year-old and 14% of 3-year-old cod being discarded.

Because the fishery is at present so dependent on incoming year classes, fishing mortalities on these year classes remain high. At the same time, the unbalanced age structure of the stock reduces its reproductive capacity even if a sufficient SSB were reached, as first-time spawners reproduce less successfully than older fish. Both factors are believed to have contributed to the reduction in recruitment of cod.

The North Sea cod stock consists of reproductively isolated populations of Viking cod and Dogger cod, with the Dogger cod population exhibiting spatial heterogeneity and extending to Division 6.a (ICES WKNSCodID, 2020, ICES WK6aCodID, 2022). Because these genetically different groups have different rates of maturity and growth, management measures that ensure sustainable exploitation of substocks may be needed in addition to management for the stock as a whole. In particular, the low landings in 7.d in 2021 (37 tonnes) and low biological sampling in the southern subregion in the NS-IBTS Q1 survey may indicate a collapse of the stock in this area. Official nominal landings from 2021 are low in both divisions 4.c (63 tonnes) and 7.d (28 tonnes).

Cod are taken by towed gears in mixed demersal fisheries, which include haddock, whiting, *Nephrops*, plaice, and sole. They are also taken in directed fisheries using fixed gears. It is important to consider both the species-specific assessments of these species for effective management, but also the broader mixed-fisheries context. This is not straightforward when stocks are managed via a series of single-species TACs that do not incorporate such mixed-stocks considerations. However, a reduction in effort on one stock may lead to a reduction or an increase in effort on another, and the implications of any change need to be considered carefully. The ICES WGMIXFISH Group monitors the consistency of the various single-species management plans under current effort schemes, to estimate the potential risks of quota over- and undershooting for the different stocks.

The catch scenarios assume that the TAC is overshot by 27% in 2022, which is the average of the overshoots in 2020 and 2021 (37% and 17% respectively). This implies a reduction in fishing mortality (from 0.26 to 0.21) and may be too optimistic given the increase in SSB and potential for non-compliance to the landing obligation caused by cod becoming a choke species in mixed fisheries. This assumption gives a lower F than assuming status quo (the lowest F in the time series), which would give a 54% overshoot of the TAC.

The forecasting procedure uses the assessment estimate of recruitment in 2022. This remains to be confirmed by the IBTS-Q3 survey and a reopening of the advice may be triggered in October.

4.13 Issues for future benchmarks

The stock was last benchmarked in 2021 and there are plans for another benchmark in 2023. Below is a list of issues that were either left unresolved from the last benchmark or have arisen during subsequent WGNSSK meetings. A scoring system has been developed to aid working groups in prioritising stocks to be put forward for benchmark (see Annex 5 for further details). The current scoring for this stock is:

1. Assessment quality	2. Opportunity to improve	3. Management importance	4. Perceived stock status	5. Time since last benchmark	Total Score
3	5	5	5	2	3.9

4.13.1 Data

Stock identity

Stock identity is an issue for this assessment, with multiple populations inhabiting the North Sea and extending to neighbouring areas (ICES WKNSCodID, 2020; ICES WK6aCodID, 2022). The ICES Workshop on Stock Identification of North Sea Cod (ICES WKNSCodID, 2020) recommended that stock assessments recognise and account for Viking and Dogger cod populations and consider accounting for phenotypic stocks within the Dogger cod population. However, the ability of the last benchmark to reflect the new paradigm of cod stock structure was limited by (1) the challenges of disaggregating historic fisheries data spatially; (2) unexplained differences between the spatially aggregated and disaggregated fisheries data; and (3) the decision to consider connectivity of cod between 6.aN and 4.aW in a future benchmark workshop (ICES WKNSEA, 2021). Trends in sub-stock biomass will continue to be monitored in the meantime. The ICES Workshop on Stock Identification of West of Scotland Sea Cod (ICES WK6aCodID, 2022) also concluded linkages between inshore and offshore populations of cod in Division 6.a to cod in Division 4.a and recommended to combine the North Sea and West of Scotland cod assessments.

Maturity

ICES WKNSEA (2015) raised concerns that accounting for the increase in maturity may give the impression that the spawning stock is in better condition than it is given the possibility of lower fecundity of younger age groups and the potential for a maternal age effect on survival, and recommended exploration of the significance of spawner age on reproductive potential.

Survey

Catchability issues and year effects have become apparent in the IBTS surveys, with reduced cohort consistency and lower than expected catch rates of older fish in recent years. There are also discrepancies between catch and survey data, with cohorts disappearing faster than expected in the scientific surveys compared to the catches. While there is some evidence to support emigration of North Sea cod to the West of Scotland, age reading issues may also contribute and should be investigated.

Recreational catches

Recreational catches are estimated to account for an average of 5% of the total removals of this stock but are not included in the assessment due to length of time series and unknown age structure and uncertainty (Section 4.2.1). Work on standardisation of recreational inputs should be given relevance for future consideration in the assessment.

4.13.2 Assessment

Following the recommendations of ICES WKNSCodID (2020) and ICES WK6aCodID (2022), spatial assessment approaches should be developed that (1) account for sub-stock structure, and (2) expand the stock area to include cod in Division 6.a. An extension of the SAM model, currently used for the single stock assessments, to a multi-stock model was presented and is currently under development.

4.13.3 Forecast

Walker (2020) explored the perception that short-term forecasts in a given year tend to be more optimistic than realised values in subsequent years; however, results of this analysis were largely driven by the retrospective pattern in the former assessment. Similar analyses could be conducted to gain a better idea of potential biases in the forecast procedure.

4.14 References

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Table 4.1a Nominal landings (in tonnes) of COD in Subarea 4, Division 7.d and Subdivision 20, as officially reported to ICES, and as used by the Working Group.

Sub-area IV

Country	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Belgium	2,616	1,482	1,627	1,722	1,309	1,008	894	946	666	653
Denmark	9,022	4,676	5,889	6,291	5,105	3,430	3,831	4,402	5,686	4,863
Faroe Islands	34	36	37	34	3	-	16	45	32	-
France	1,777	620	294	664	354	659	573	950	782	619
Germany	2,018	2,048	2,213	2,648	2,537	1,899	1,736	2,374	2,844	2,211
Greenland	.	.	.	35	23	17	17	11	-	-
Netherlands	4,707	2,305	1,726	1,660	1,585	1,523	1,896	2,649	2,657	1,928
Norway	5,217	4,417	3,223	2,900	2,749	3,057	4,128	4,234	4,495	4,898
Poland	39	35	-	-	-	1	2	3	-	2
Sweden	463	252	240	319	309	386	439	378	362	316
UK (E/W/NI)	3,112	2,213	1,890	1,270	1,491	1,587	1,546	2,383	2,553	2,169
UK (Scotland)	15,416	7,852	6,650	4,936	6,857	6,511	7,185	9,052	11,567	10,141
Others	-	-	-	-	786	-	-	-	-	-
Danish industrial by-catch *	105	22	17	21	11	23	1	72	12	<0.5
Norwegian industrial by-catch *	.	.	.	.	48	101	22	4	201	1
Total Nominal Catch	44,526	25,958	23,806	22,500	23,119	20,102	22,262	27,497	31,657	27,800
Unallocated landings	-2,333	-1,875	-1,277	356	-2,041	-1,046	-605	136	-677	-1,125
WG estimate of total landings	**42,193**	**24,083**	**22,529**	**22,855**	**21,078**	**19,056**	**21,657**	**27,634**	**30,980**	**26,675**
Agreed TAC	**49,300**	**27,300**	**27,300**	**27,300**	**23,205**	**19,957**	**22,152**	**28,798**	**33,552**	**26,842**

Division VIId

Country	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Belgium	51	54	47	51	80	84	154	73	57	56
Denmark	-	-	-	-	-	-	-	-	-	-
France	1,361	1,730	810	986	1,124	1,743	1,326	1,779	1,606	1,078
Netherlands	6	36	14	9	9	59	30	35	45	51
UK (E/W/NI)	145	121	103	184	267	174	144	133	127	125
UK (Scotland)	-	-	-	-	1	12	7	3	1	1
Total Nominal Catch	1,563	1,941	974	1,230	1,480	2,073	1,662	2,023	1,836	1,311
Unallocated landings	1,576	190	40	29	-2	74	-33	-135	-128	8
WG estimate of total landings	**3,139**	**2,131**	**1,014**	**1,259**	**1,479**	**2,147**	**1,629**	**1,887**	**1,708**	**1,319**
Agreed TAC								**1,678**	**1,955**	**1,564**

Division IIIa (Skagerrak)**

Country	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Denmark	5,525	3,067	3,038	3,019	2,513	2,246	2,553	3,024	3,286	3,118
Germany	83	49	99	86	84	67	52	55	56	60
Norway	645	825	856	759	628	681	779	440	375	421
Sweden	897	510	495	488	372	370	365	459	458	518
Others	-	27	24	21	373	385	13	2	26	-
Danish industrial by-catch *	20	5	4	2	3	2	7	2	10	<0.5
Total Nominal Catch	7,170	4,483	4,516	4,375	3,972	3,751	3,769	3,982	4,211	4,117
Unallocated landings	-316	-504	-602	-376	-715	-731	-376	-188	-154	-161
WG estimate of total landings	**6,854**	**3,979**	**3,914**	**3,998**	**3,258**	**3,020**	**3,393**	**3,794**	**4,057**	**3,956**
Agreed TAC	**7,100**	**3,900**	**3,900**	**3,900**	**3,315**	**2,851**	**3,165**	**4,114**	**4,793**	**3,835**

Sub-area IV, Divisions VIId and IIIa (Skagerrak) combined

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Total Nominal Catch	53,260	32,382	29,296	28,104	28,572	25,926	27,693	33,502	37,704	33,228
Unallocated landings	-1,074	-2,189	-1,839	9	-2,757	-1,703	-1,014	-187	-958	-1,277
WG estimate of total landings	**52,186**	**30,193**	**27,457**	**28,113**	**25,815**	**24,223**	**26,679**	**33,315**	**36,746**	**31,950**

** Skaggerak/Kattegat split derived from national statistics

* The Norwegian industrial bycatch are not included in the (WG estimate of) total landings

. Magnitude not available - Magnitude known to be nil <0.5 Magnitude less than half the unit used in the table n/a Not applicable

Division IV and IIIa (Skagerrak) landings not included in the assessment

Country	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Norwegian industrial by-catch	.	.	.	.	48	101	22	4	201	1
Total	**.**	**.**	**.**	**.**	**48**	**101**	**22**	**4**	**201**	**1**

Table 4.1a cont. Nominal landings (in tonnes) of COD in Subarea 4, Division 7.d and Subdivision 20, as officially reported to ICES, and as used by the Working Group.

Sub-area IV

Country	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Belgium	862	1,075	1,258	1,223	1,103	695	817	727	666	553
Denmark	4,803	4,536	5,457	6,026	6,713	6,119	5,493	4,967	3,064	2,021
Faroe Islands	-	-	-	-	-	-	-	<0.5	1	.
France	369	287	637	517	391	401	583	450	265	284
Germany	2,385	1,921	2,257	2,133	2,083	2,300	1,510	824	755	767
Greenland	-	-	-	-	2	1	-	-	.	.
Netherlands	1,955	1,344	1,242	1,403	1,365	653	515	719	590	618
Norway	4,601	4,080	4,600	5,404	5,627	5,521	5,539	4,509	2,330	1,659
Poland	-	-	-	-	-	-	-	-	.	.
Sweden	471	332	401	415	373	387	274	344	354	396
UK (E/W/NI)	1,629	2,129	2,962	.	.	.	.	.	.	.
UK (Scotland)	10,565	10,619	10,517	.	.	.	.	.	.	.
UK (combined)	n/a	n/a	n/a	14,889	16,603	18,523	21,265	15,621	9,061	6,416
Others	-	-	-	-	-	-	-	-	-	<0.5
Danish industrial by-catch	<0.5	2	24	<0.5	5	147	<0.5	2	11	5
Norwegian indust by-catch *	.	.	.	.	.	.	.	.	.	.
Total Nominal Catch	27,640	26,324	29,355	32,012	34,265	34,746	35,997	28,163	17,095	12,718
Unallocated landings	-1,013	-1,009	-805	-768	-1,230	-1,637	-1,553	395	97	19
BMS landings	-	-	-	-	-	1	8	41	32	8
WG estimate of total landings	**26,627**	**25,315**	**28,550**	**31,244**	**33,035**	**33,109**	**34,444**	**28,558**	**17,192**	**12,737**
Agreed TAC	**26,475**	**26,475**	**27,799**	**29,189**	**33,651**	**39,220**	**43,156**	**29,437**	**14,718**	**13,246**

Division VIId

Country	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Belgium	40	53	72	78	39	18	8	3	8	12
Denmark	-	-	-	-	-	-	-	-	.	.
France	885	768	1,270	1,142	279	92	35	16	10	5
Netherlands	40	38	50	52	40	22	10	3	2	1
UK (E/W/NI)	99	100	156	.	.	.	.	.	.	.
UK (Scotland)	-	-	-	.	.	.	.	.	.	.
UK (combined)	n/a	n/a	n/a	162	102	48	39	17	20	11
Others	-	-	-	-	-	<0.5	-	<0.5	-	-
Total Nominal Catch	1,064	959	1,548	1,434	459	180	92	38	40	28
Unallocated landings	56	-43	-112	-36	-38	-10	-8	-3	-8	9
BMS landings	-	-	-	-	-	-	-	-	<0.5	<0.5
WG estimate of total landings	**1,120**	**916**	**1,436**	**1,398**	**421**	**170**	**84**	**36**	**32**	**37**
Agreed TAC	**1,543**	**1,543**	**1,620**	**1,701**	**1,961**	**2,059**	**1,733**	**1,715**	**858**	**772**

Division IIIa (Skagerrak)**

Country	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Denmark	3,178	3,033	3,430	3,344	3,696	3,665	4,222	2,740	1,857	1,597
Germany	78	69	84	87	94	67	86	52	35	25
Norway	615	575	533	500	551	486	288	151	94	68
Sweden	520	529	570	571	641	557	670	355	223	238
Others	-	33	29	26	25	38	58	40	18	11
Danish industrial by-catch	1	1	5	5	<0.5	40	7	1	13	1
Total Nominal Catch	4,391	4,240	4,650	4,533	5,006	4,852	5,332	3,339	2,239	1,940
Unallocated landings	-64	-86	37	31	-232	-137	152	139	61	77
BMS landings	-	-	-	-	-	1	4	3	4	5
WG estimate of total landings	**4,327**	**4,154**	**4,687**	**4,563**	**4,774**	**4,715**	**5,484**	**3,478**	**2,299**	**2,017**
Agreed TAC	**3,783**	**3,783**	**3,972**	**4,171**	**4,807**	**5,744**	**7,995**	**4,205**	**2,103**	**1,893**

Sub-area IV, Divisions VIId and IIIa (Skagerrak) combined

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Total Nominal Catch	33,095	31,523	35,554	37,978	39,730	39,778	41,421	31,540	19,373	14,686
Unallocated landings	-1,022	-1,138	-881	-773	-1,500	-1,784	-1,409	532	150	105
BMS landings	.	.	.	.	.	2	12	44	36	13
WG estimate of total landings	**32,074**	**30,386**	**34,673**	**37,205**	**38,230**	**37,994**	**40,012**	**32,072**	**19,523**	**14,791**

*** WG estimates of total landings do not include BMS landings

** Skaggerak/Kattegat split derived from national statistics prior to 2016

* The Norwegian industrial by-catch are not included in the (WG estimate of) total landings

. Magnitude not available - Magnitude known to be nil <0.5 Magnitude less than half the unit used in the table n/a Not applicable

Division IV and IIIa (Skagerrak) landings not included in the assessment

Country	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Norwegian indust by-catch *	.	.	.	.	.	.	.	.	.	.
Total	**.**	**.**	**.**	**.**	**.**	**.**	**.**	**.**	**.**	**.**

Table 4.1b. Cod in Subarea 4, Division 7.d and Subdivision 20: Sampling coverage for discard ratio, landings age composition and discards age composition by area and season (quarter or annual, depending on data stratification) for 2021, calculated as the weight in each area–season–métier stratum covered by the relevant sampling, then summed over métiers and expressed as a proportion of the total for the area–season (note the country dimension is not used). Also provided is the contribution of landings, discards and BMS in each area (by weight) to the total for that catch category (before raising is conducted).

Discard ratio coverage

Area/Season	Q1	Q2	Q3	Q4	annual
27.4	18%	53%	65%	73%	13%
27.3.a.20	76%	54%	68%	76%	-
27.7.d	17%	23%	13%	67%	98%

Landings age composition coverage

Area/Season	Q1	Q2	Q3	Q4	annual
27.4	87%	60%	73%	90%	13%
27.3.a.20	98%	96%	93%	95%	-
27.7.d	-	-	-	-	98%

Discards age composition coverage

Area/Season	Q1	Q2	Q3	Q4	annual
27.4	30%	75%	95%	98%	100%
27.3.a.20	95%	87%	91%	98%	-
27.7.d	-	-	-	-	-

Contribution to total (before raising)

Area/Type	Landings	Discards	BMS
27.4	86%	81%	100%
27.3.a.20	14%	19%	0%
27.7.d	0%	0%	0%

Table 4.2a. Cod in Subarea 4, Division 7.d and Subdivision 20: Landings numbers at age (Thousands).

Landings numbers at age (thousands)

AGE/YEAR	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
1	3198	5004	15734	18133	10749	5800	2932	54219	44599	3813	25836	15484
2	42377	22373	51628	62202	70539	83416	22561	33747	154565	186744	31596	58624
3	6995	20003	17557	29695	32529	42373	31419	18395	17132	47885	54655	11347
4	3519	4285	9135	6153	11205	12330	13641	13272	6720	5653	14002	15745
5	2774	1908	2375	3362	3255	6046	4542	6266	7065	2713	2195	4601
6	1207	1809	946	1272	1964	1407	2881	1754	2686	3184	1103	956
7	81	596	655	475	884	866	585	956	888	1671	1055	436
8	489	117	297	368	353	307	420	208	455	609	487	393
9	13	93	51	125	137	150	147	185	227	388	79	330
10	6	11	75	56	40	111	46	97	77	112	57	80
+gp	0	4	8	83	17	24	77	40	93	17	161	188
TOTALNUM	60659	56203	98460	121923	131671	152829	79251	129139	234508	252789	131226	108183
TONSLAND	115873	125408	180127	220225	251707	286921	199753	224989	326451	352200	237851	213204
SOPCOF %	100	100	100	100	100	100	100	100	100	100	100	100

AGE/YEAR	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
1	33210	5695	75130	29593	34627	62394	20131	66220	25488	64358	8795	99841
2	46907	99779	50926	174912	91143	104356	187626	64755	128396	66026	117383	32308
3	18849	18481	25525	17178	44384	34938	34567	59907	21456	31087	18888	33973
4	4640	6707	4597	9396	4011	12274	8953	9487	11787	4238	7779	5791
5	7525	1732	2286	2989	3375	1958	4088	3447	2803	3415	1369	2981
6	2057	3056	833	1103	708	1269	779	2048	1246	1013	1257	602
7	447	920	1140	408	396	494	599	425	589	434	371	554
8	195	130	370	403	139	197	133	234	179	243	172	170
9	228	67	262	152	157	73	64	77	89	59	78	69
10	95	63	26	36	42	55	36	27	28	44	16	44
+gp	63	43	96	44	17	25	21	16	23	19	31	23
TOTALNUM	114215	136672	161191	236214	178997	218034	256998	206643	192083	170937	156139	176355
TONSLAND	204215	232994	208370	295645	268342	292656	333047	300723	256815	226904	213422	203242
SOPCOF %	100	100	100	100	101	100	100	99	100	100	100	101

AGE/YEAR	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
1	24816	21362	22072	11629	13288	27162	4688	15366	15486	4871	23443	1243
2	127774	55025	36084	53783	23145	31472	54171	24969	62650	36303	28793	80948
3	9761	43712	18056	11795	16554	8523	11134	20885	12753	23046	18390	16794
4	8689	3117	9791	4299	3267	4916	3126	3045	5223	3125	6409	5909
5	1528	2543	994	2445	1372	1041	1546	859	790	1834	1221	2379
6	1071	652	1028	307	1039	482	426	513	282	393	690	504
7	234	293	249	307	222	323	200	140	148	159	151	233
8	215	66	139	54	137	51	106	57	41	87	47	41
9	55	63	27	60	27	39	17	32	14	42	14	16
10	48	23	31	12	4	17	10	7	13	4	15	4
+gp	12	18	10	9	9	9	13	16	5	8	10	12
TOTALNUM	174203	126873	88481	84698	59065	74034	75437	65889	97405	69872	79183	108083
TONSLAND	215356	183223	138881	124144	101122	111932	119323	109279	134091	124598	122453	144603
SOPCOF %	100	100	100	99	100	99	99	99	98	100	100	100

AGE/YEAR	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
1	5831	8087	2164	4425	438	1470	1009	1286	776	338	519	1120
2	9549	22457	20309	8029	8893	3511	8175	4401	6334	3268	4833	5037
3	31624	6310	6044	13831	3552	5453	3036	4410	2264	4130	2839	4578
4	3959	6529	1114	2787	3072	1527	1714	969	1562	1146	2888	1582
5	1419	996	1053	395	397	939	479	520	398	706	596	1315
6	614	375	140	384	68	155	339	187	137	213	237	198
7	219	135	82	58	61	29	52	120	40	70	44	65
8	89	39	27	38	15	19	13	23	39	26	19	16
9	14	18	13	18	5	6	9	4	6	13	17	6
10	10	5	6	4	2	2	1	1	1	1	8	4
+gp	2	1	1	1	0	0	1	0	1	1	3	2
TOTALNUM	53329	44952	30953	29971	16505	13111	14830	11921	11558	9911	12003	13923
TONSLAND	94431	69586	48446	52187	30194	27457	28113	25815	24223	26679	33315	36746
SOPCOF %	100	100	100	98	99	99	100	101	100	99	100	100

AGE/YEAR	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
1	1099	665	683	2240	686	167	351	170	886	790	250
2	4540	2230	2688	4207	6384	2035	2240	6004	1856	2861	1398
3	4046	5367	3063	4376	4903	5644	3233	3599	6019	1675	1765
4	1408	1963	2592	1605	1933	3150	3495	2039	1097	1482	697
5	610	633	865	1286	745	1012	1660	1776	928	440	585
6	451	248	190	332	584	277	385	780	496	279	114
7	48	139	84	64	144	188	94	282	338	115	111
8	27	15	38	38	22	44	78	67	82	47	27
9	5	4	5	6	6	9	24	45	62	11	23
10	2	4	1	2	1	5	9	15	4	11	3
+gp	2	1	1	0	2	2	2	9	6	0	2
TOTALNUM	12237	11269	10208	14156	15411	12534	11571	14789	11774	7712	4975
TONSLAND	31950	32074	30386	34673	37205	38230	37994	40012	32072	19523	14791
SOPCOF %	100	100	100	100	100	100	101	100	99	101	101

Table 4.2b. Cod in Subarea 4, Division 7.d and Subdivision 20: Discard numbers at age (including BMS landings from 2016; Thousands).

Discards numbers at age (thousands)

AGE/YEAR	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
1	16150	8049	97921	108375	50214	31115	2502	52958	258920	38250	85915	124151
2	19902	6168	6599	22125	24736	22957	10279	8656	37224	59342	17387	15878
3	33	115	89	71	160	197	113	152	47	177	246	71
4	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0
+gp	0	0	0	0	0	0	0	0	0	0	0	0
TOTALNUM	36085	14332	104609	130570	75110	54268	12894	61766	296192	97768	103548	140100
TONSDISC	12186	4707	29104	37918	23320	17487	4792	17838	83968	33678	30038	39607
SOPCOF %	100	101	100	100	100	100	101	101	100	100	100	100

AGE/YEAR	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
1	136651	226781	472599	28908	581071	1185689	155732	181946	54949	537521	63301	563506
2	16214	83210	48009	78114	5270	17692	34307	8377	11130	12518	36573	5761
3	0	192	464	0	0	0	79	98	25	5	115	303
4	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0
+gp	0	0	0	0	0	0	0	0	0	0	0	0
TOTALNUM	152866	310182	521072	107022	586341	1203381	190118	190421	66103	550043	99989	569571
TONSDISC	36874	72474	139296	32432	162293	294455	57474	54047	21890	151003	31326	138529
SOPCOF %	100	100	100	100	100	100	101	100	102	100	100	100

AGE/YEAR	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
1	24634	15376	176920	33875	47473	102410	33433	320725	44756	14254	86109	15458
2	61948	17084	8685	48244	8383	9881	28538	16804	43434	23058	13701	90259
3	0	216	489	78	448	2	11	160	30	764	40	1500
4	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0
+gp	0	0	0	0	0	0	0	0	0	0	0	0
TOTALNUM	86583	32676	186094	82197	56304	112293	61983	337689	88220	38075	99851	107216
TONSDISC	27729	10655	61650	26770	18306	36244	21425	98358	31714	14061	33155	40089
SOPCOF %	100	101	100	100	101	100	100	100	100	100	100	100

AGE/YEAR	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
1	30962	37031	5460	26267	5696	20336	10213	26890	16171	10847	9608	9867
2	5630	5509	33094	13236	6082	8941	8303	35342	23047	9331	9055	9151
3	8280	0	753	3181	775	2007	1795	1965	2657	7591	2655	1254
4	0	0	0	17	55	122	149	51	481	223	650	65
5	0	0	0	0	0	6	66	4	52	14	50	30
6	0	0	0	0	0	0	12	1	24	11	17	0
7	0	0	0	0	0	0	0	1	0	0	9	0
8	0	0	0	0	0	0	0	0	2	0	0	0
9	0	0	0	0	0	0	2	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	2	0
+gp	0	0	0	0	0	0	0	0	0	0	0	0
TOTALNUM	44872	42540	39307	42702	12608	31413	20540	64253	42433	28017	22047	20366
TONSDISC	13916	13370	13523	11911	4081	8802	10087	12011	30450	25080	20965	12488
SOPCOF %	102	100	100	100	102	101	102	101	100	100	101	101

AGE/YEAR	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
1	3936	11149	6188	7756	3980	3067	9767	2771	4101	11163	2756
2	7851	5190	6055	6504	8935	4942	2814	9039	1614	4331	2675
3	925	1422	856	1434	1965	3110	1271	737	915	287	294
4	81	115	397	163	180	257	493	147	16	9	6
5	6	5	83	58	55	31	96	8	4	0	5
6	4	1	40	5	64	1	9	0	0	0	0
7	1	1	16	0	15	0	1	0	0	0	0
8	1	0	0	0	5	0	1	0	0	0	0
9	0	0	0	0	3	0	0	2	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0
+gp	0	0	0	0	0	0	0	0	0	0	0
TOTALNUM	12804	17884	13635	15921	15201	11409	14453	12704	6650	15791	5737
TONSDISC	8745	8689	10324	10666	12562	12315	8731	7824	3607	4701	3792
SOPCOF %	100	101	100	101	100	101	100	101	101	100	101

Table 4.2c. Cod in Subarea 4, Division 7.d and Subdivision 20: Catch numbers at age (Thousands).

Catch numbers at age (thousands)

AGE/YEAR	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
1	19347	13052	113655	126508	60962	36915	5434	107177	303519	42062	111751	139635
2	62280	28541	58227	84327	95275	106373	32840	42403	191789	246086	48983	74502
3	7028	20118	17646	29766	32689	42569	31532	18547	17179	48062	54901	11418
4	3519	4285	9135	6153	11205	12330	13641	13272	6720	5653	14002	15745
5	2774	1908	2375	3362	3255	6046	4542	6266	7065	2713	2195	4601
6	1207	1809	946	1272	1964	1407	2881	1754	2686	3184	1103	956
7	81	596	655	475	884	866	585	956	888	1671	1055	436
8	489	117	297	368	353	307	420	208	455	609	487	393
9	13	93	51	125	137	150	147	185	227	388	79	330
10	6	11	75	56	40	111	46	97	77	112	57	80
+gp	0	4	8	83	17	24	77	40	93	17	161	188
TOTALNUM	96744	70535	203069	252494	206780	207098	92145	190905	530700	350558	234774	248283
TONSLAND	128058	130116	209232	258143	275028	304408	204544	242827	410420	385878	267890	252811
SOPCOF %	100	100	100	100	100	100	100	100	100	100	100	100

AGE/YEAR	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
1	169862	232476	547729	58501	615698	1248084	175863	248166	80437	601879	72096	663347
2	63121	182989	98935	253025	96413	122048	221933	73132	139526	78543	153957	38069
3	18849	18672	25989	17178	44384	34938	34646	60005	21480	31092	19003	34277
4	4640	6707	4597	9396	4011	12274	8953	9487	11787	4238	7779	5791
5	7525	1732	2286	2989	3375	1958	4088	3447	2803	3415	1369	2981
6	2057	3056	833	1103	708	1269	779	2048	1246	1013	1257	602
7	447	920	1140	408	396	494	599	425	589	434	371	554
8	195	130	370	403	139	197	133	234	179	243	172	170
9	228	67	262	152	157	73	64	77	89	59	78	69
10	95	63	26	36	42	55	36	27	28	44	16	44
+gp	63	43	96	44	17	25	21	16	23	19	31	23
TOTALNUM	267081	446854	682263	343235	765338	1421415	447116	397064	258186	720980	256129	745925
TONSLAND	241089	305468	347666	328077	430635	587111	390521	354770	278705	377907	244748	341771
SOPCOF %	100	100	100	100	101	100	100	100	100	100	100	101

AGE/YEAR	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
1	49451	36738	198992	45504	60761	129572	38121	336092	60242	19124	109552	16701
2	189722	72109	44768	102027	31528	41353	82709	41773	106084	59360	42494	171206
3	9761	43929	18544	11873	17002	8525	11145	21045	12783	23809	18430	18293
4	8689	3117	9791	4299	3267	4916	3126	3045	5223	3125	6409	5909
5	1528	2543	994	2445	1372	1041	1546	859	790	1834	1221	2379
6	1071	652	1028	307	1039	482	426	513	282	393	690	504
7	234	293	249	307	222	323	200	140	148	159	151	233
8	215	66	139	54	137	51	106	57	41	87	47	41
9	55	63	27	60	27	39	17	32	14	42	14	16
10	48	23	31	12	4	17	10	7	13	4	15	4
+gp	12	18	10	9	9	9	13	16	5	8	10	12
TOTALNUM	260786	159550	274574	166895	115368	186327	137419	403578	185625	107947	179034	215299
TONSLAND	243085	193878	200531	150914	119428	148176	140748	207637	165805	138659	155608	184692
SOPCOF %	100	100	100	100	100	99	100	100	99	100	100	100

AGE/YEAR	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
1	36793	45118	7624	30692	6135	21807	11222	28177	16947	11185	10127	10987
2	15180	27965	53403	21265	14975	12452	16478	39743	29381	12599	13887	14188
3	39904	6310	6797	17012	4328	7460	4831	6375	4921	11721	5494	5831
4	3959	6529	1114	2805	3127	1650	1863	1020	2043	1369	3539	1646
5	1419	996	1053	395	397	944	546	524	451	720	646	1344
6	614	375	140	384	68	155	351	187	161	224	254	199
7	219	135	82	58	61	29	52	121	40	70	53	65
8	89	39	27	38	15	19	13	23	41	26	19	16
9	14	18	13	18	5	6	11	4	6	13	17	6
10	10	5	6	4	2	2	1	1	1	1	10	4
+gp	2	1	1	1	0	0	1	0	1	1	3	2
TOTALNUM	98201	87491	70260	72673	29113	44524	35370	76174	53992	37928	34050	34288
TONSLAND	108347	82956	61969	64098	34274	36259	38200	37826	54673	51759	54280	49234
SOPCOF %	101	100	100	99	100	99	100	101	100	100	100	100

AGE/YEAR	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
1	5035	11815	6871	9995	4666	3234	10118	2942	4986	11953	3007
2	12391	7420	8743	10711	15319	6977	5054	15043	3470	7192	4072
3	4970	6789	3919	5810	6869	8754	4504	4337	6935	1962	2059
4	1489	2077	2989	1768	2113	3408	3987	2186	1113	1492	703
5	616	638	949	1345	800	1044	1756	1784	932	440	590
6	455	249	229	337	648	279	395	780	496	279	114
7	49	139	100	64	159	188	95	282	338	115	111
8	28	15	38	38	27	44	79	67	82	47	27
9	5	4	5	6	9	9	24	47	62	11	23
10	2	4	2	2	1	5	9	15	4	11	3
+gp	2	1	1	0	2	2	2	9	6	0	2
TOTALNUM	25041	29153	23844	30076	30612	23942	26024	27493	18425	23503	10711
TONSLAND	40695	40763	40710	45339	49767	50544	46725	47836	35679	24224	18583
SOPCOF %	100	100	100	100	100	100	101	100	99	101	101

Table 4.2d. Cod in Subarea 4, Division 7.d and Subdivision 20: Landings, discards (including BMS landings) and catch numbers at age (Thousands) by season (quarter or annual, depending on data stratification) from InterCatch for 2021.

Landings numbers at age (thousands)

Age/Season	Q1	Q2	Q3	Q4	annual	TOTALNUM
1	21	24	69	126	11	251
2	324	170	379	510	15	1398
3	343	501	433	460	28	1765
4	164	176	175	172	10	697
5	167	168	151	91	9	586
6	24	42	18	29	2	115
7	19	37	38	15	2	111
8	3	10	10	4	0	27
9	3	8	7	4	0	22
10	0	1	1	0	0	2
+gp	0	2	0	0	0	2
TOTALNUM	1068	1139	1281	1411	77	4976

Discards numbers at age (including BMS landings; thousands)

Age/Season	Q1	Q2	Q3	Q4	annual	TOTALNUM
1	251	386	633	763	723	2756
2	456	638	509	470	602	2675
3	50	124	65	31	24	294
4	1	1	4	0	1	7
5	1	1	3	0	0	5
6	0	0	0	0	0	0
7	0	0	0	0	0	0
8	0	0	0	0	0	0
9	0	0	0	0	0	0
10	0	0	0	0	0	0
+gp	0	0	0	0	0	0
TOTALNUM	759	1150	1214	1264	1350	5737

Catch numbers at age (thousands)

Age/Season	Q1	Q2	Q3	Q4	annual	TOTALNUM
1	272	410	702	889	734	3007
2	780	809	888	979	617	4073
3	392	625	498	491	52	2058
4	165	177	179	172	11	704
5	168	169	154	91	9	591
6	24	42	18	29	2	115
7	19	37	38	15	2	111
8	3	10	10	4	0	27
9	3	8	7	4	0	22
10	0	1	1	0	0	2
+gp	0	2	0	0	0	2
TOTALNUM	1826	2290	2495	2674	1427	10712

Table 4.3. Cod in Subarea 4, Division 7.d and Subdivision 20: Reported landings, estimated discards (including BMS landings from 2016) and total catch (landings + discards) in tonnes. Note any differences in values between Table 4.3 and those given in the report and advice are due to SOP correction.

Year	Landings	Discards	Catch
1963	115893	12199	128092
1964	125393	4656	130049
1965	180120	28973	209092
1966	220197	37862	258059
1967	251687	23285	274972
1968	286948	17468	304417
1969	199746	4757	204503
1970	224993	17663	242656
1971	326492	84007	410498
1972	352161	33603	385764
1973	237874	29966	267840
1974	213215	39533	252748
1975	204249	36841	241089
1976	233007	72397	305404
1977	208318	139027	347345
1978	294640	32434	327074
1979	266019	162278	428297
1980	293753	294208	587962
1981	333616	57076	390691
1982	302365	54008	356372
1983	257634	21430	279065
1984	227070	151004	378074
1985	214354	31298	245651
1986	201279	138604	339883
1987	216041	27706	243747
1988	183202	10504	193706
1989	139578	61656	201233
1990	124835	26747	151582
1991	101442	18199	119641
1992	112740	36193	148932
1993	119947	21412	141358
1994	109915	98208	208123
1995	136397	31707	168104
1996	124721	14030	138751
1997	122434	33184	155618
1998	144637	40102	184740
1999	94108	13642	107749
2000	69567	13360	82927

Year	Landings	Discards	Catch
2001	48440	13519	61960
2002	53152	11901	65053
2003	30426	4007	34433
2004	27748	8721	36469
2005	28165	9932	38097
2006	25665	11923	37589
2007	24215	30422	54637
2008	26814	24984	51798
2009	33177	20846	54023
2010	36762	12341	49103
2011	31979	8711	40689
2012	32124	8638	40762
2013	30474	10289	40763
2014	34651	10538	45190
2015	37373	12537	49910
2016	38104	12203	50307
2017	37668	8702	46371
2018	40153	7744	47898
2019	32361	3555	35917
2020	19373	4700	24072
2021	14660	3744	18403

Table 4.4a. Cod in Subarea 4, Division 7.d and Subdivision 20: Landings weights at age (kg).

Landings weights at age (kg)

AGE/YEAR	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
1	0.538	0.496	0.581	0.579	0.590	0.640	0.544	0.626	0.579	0.616	0.559	0.594
2	1.004	0.863	0.965	0.994	1.035	0.973	0.921	0.961	0.941	0.836	0.869	1.039
3	2.657	2.377	2.304	2.442	2.404	2.223	2.133	2.041	2.193	2.086	1.919	2.217
4	4.491	4.528	4.512	4.169	3.153	4.094	3.852	4.001	4.258	3.968	3.776	4.156
5	6.794	6.447	7.274	7.027	6.803	5.341	5.715	6.131	6.528	6.011	5.488	6.174
6	9.409	8.520	9.498	9.599	9.610	8.020	6.722	7.945	8.646	8.246	7.453	8.333
7	11.562	10.606	11.898	11.766	12.033	8.581	9.262	9.953	10.356	9.766	9.019	9.889
8	11.942	10.758	12.041	11.968	12.481	10.162	9.749	10.131	11.219	10.228	9.810	10.791
9	13.383	12.340	13.053	14.060	13.589	10.720	10.384	11.919	12.881	11.875	11.077	12.175
10	13.756	12.540	14.441	14.746	14.271	12.497	12.743	12.554	13.147	12.530	12.359	12.425
+gp	0.000	18.000	15.667	15.672	19.016	11.595	11.175	14.367	15.544	14.350	12.886	13.731

AGE/YEAR	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
1	0.619	0.568	0.541	0.573	0.550	0.550	0.723	0.589	0.632	0.594	0.590	0.583
2	0.899	1.029	0.948	0.937	0.936	1.003	0.837	0.962	0.919	1.007	0.932	0.856
3	2.348	2.470	2.160	2.001	2.411	1.948	2.190	1.858	1.835	2.156	2.141	1.834
4	4.226	4.577	4.606	4.146	4.423	4.401	4.615	4.130	3.880	3.972	4.164	3.504
5	6.404	6.494	6.714	6.530	6.579	6.109	7.045	6.785	6.491	6.190	6.324	6.230
6	8.691	8.620	8.828	8.667	8.474	9.120	8.884	8.903	8.423	8.362	8.430	8.140
7	10.107	10.132	10.071	9.685	10.637	9.550	9.933	10.398	9.848	10.317	10.362	9.896
8	10.910	11.340	11.052	11.099	11.550	11.867	11.519	12.500	11.837	11.352	12.074	11.940
9	12.339	12.888	11.824	12.427	13.057	12.782	13.338	13.469	12.797	13.505	13.072	12.951
10	12.976	14.139	13.134	12.778	14.148	14.081	14.897	12.890	12.562	13.408	14.443	13.859
+gp	14.431	14.760	14.362	13.981	15.478	15.392	18.784	14.608	14.426	13.472	16.588	14.707

AGE/YEAR	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
1	0.635	0.585	0.673	0.737	0.670	0.699	0.699	0.677	0.721	0.699	0.656	0.542
2	0.976	0.881	1.052	0.976	1.078	1.146	1.065	1.075	1.021	1.117	0.960	0.922
3	1.955	1.982	1.846	2.176	2.038	2.546	2.479	2.201	2.210	2.147	2.120	1.724
4	3.650	3.187	3.585	3.791	3.971	4.223	4.551	4.471	4.293	4.034	3.821	3.495
5	6.052	5.992	5.273	5.931	6.082	6.247	6.540	7.167	7.220	6.637	6.228	5.387
6	8.307	7.914	7.921	7.890	8.033	8.483	8.094	8.436	8.980	8.494	8.394	7.563
7	10.243	9.764	9.724	10.235	9.545	10.101	9.641	9.537	10.282	9.729	9.979	9.628
8	11.461	12.127	11.212	10.923	10.948	10.482	10.734	10.323	11.743	11.080	11.424	10.643
9	12.447	14.242	12.586	12.803	13.481	11.849	12.329	12.223	13.107	12.264	12.300	11.499
10	18.691	17.787	15.557	15.525	13.171	13.904	13.443	14.247	12.052	12.756	12.761	13.085
+gp	16.604	16.477	14.695	23.234	14.989	15.794	13.961	12.523	13.954	11.304	13.416	14.921

AGE/YEAR	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
1	0.640	0.611	0.725	0.626	0.573	0.726	0.747	0.793	0.830	1.067	0.788	0.715
2	0.935	1.021	1.004	0.996	1.079	1.072	1.160	1.200	1.182	1.389	1.412	1.292
3	1.663	1.747	2.303	1.844	1.895	2.089	1.952	2.239	2.365	2.456	2.674	2.671
4	3.305	3.216	3.663	3.735	3.347	3.252	3.647	3.894	4.050	4.063	4.145	4.223
5	5.726	4.903	5.871	5.537	5.757	5.184	5.244	5.676	6.053	6.224	6.119	6.049
6	7.403	7.488	7.333	8.006	6.694	7.438	7.225	7.234	8.250	7.393	7.490	8.299
7	8.582	9.636	9.264	9.451	8.838	8.974	9.457	9.243	9.262	9.651	8.968	9.472
8	10.365	10.671	10.081	10.012	12.674	9.894	10.567	10.477	10.015	11.489	11.447	11.631
9	11.600	10.894	12.062	11.888	11.518	11.857	12.015	12.325	12.282	11.387	11.291	12.827
10	12.330	11.414	12.009	12.795	11.053	12.095	12.066	14.862	14.559	12.725	11.716	12.083
+gp	11.926	15.078	10.196	11.688	14.988	14.093	22.464	17.887	17.522	15.381	18.764	10.052

AGE/YEAR	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
1	0.862	0.938	0.883	0.699	0.596	0.800	0.753	0.607	0.764	0.759	0.741
2	1.328	1.369	1.240	1.213	1.206	1.315	1.119	1.065	1.119	1.358	1.330
3	2.525	2.354	2.461	2.390	2.291	2.342	2.379	1.943	2.136	1.925	2.536
4	4.596	4.175	4.164	4.180	4.112	3.862	3.906	3.838	3.707	3.809	3.902
5	6.481	6.391	6.187	5.678	5.935	5.744	5.393	5.633	5.505	5.424	5.351
6	7.843	8.115	8.347	7.435	6.920	7.342	6.897	6.829	7.188	6.729	7.046
7	9.681	9.092	9.817	9.191	8.775	7.928	8.906	7.683	7.764	8.964	7.642
8	9.629	11.799	9.486	9.180	9.622	8.717	8.664	8.867	9.684	8.671	10.961
9	10.845	12.548	11.364	11.469	10.654	10.367	9.586	8.481	6.788	11.459	11.340
10	14.436	11.436	10.935	16.456	13.838	11.926	17.579	8.972	11.466	16.458	21.935
+gp	12.421	20.644	29.764	34.656	30.079	19.623	20.519	23.381	21.796	14.596	10.706

Table 4.4b. Cod in Subarea 4, Division 7.d and Subdivision 20: Discard weights-at-age (includes BMS landings from 2016; kg).

Discards weights at age (kg)

AGE/YEAF	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
1	0.270	0.270	0.269	0.269	0.269	0.269	0.268	0.268	0.268	0.268	0.268	0.268
2	0.393	0.393	0.392	0.392	0.392	0.392	0.392	0.392	0.392	0.392	0.392	0.392
3	0.505	0.508	0.506	0.509	0.506	0.505	0.504	0.505	0.508	0.507	0.507	0.508
4	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
+gp	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

AGE/YEAF	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
1	0.227	0.189	0.255	0.287	0.276	0.242	0.279	0.274	0.297	0.270	0.276	0.242
2	0.359	0.354	0.382	0.309	0.361	0.411	0.396	0.489	0.458	0.469	0.376	0.365
3	0.000	0.412	0.376	0.000	0.000	0.000	0.517	0.593	0.534	0.509	0.652	0.437
4	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
+gp	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

AGE/YEAF	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
1	0.237	0.300	0.326	0.260	0.315	0.314	0.274	0.287	0.316	0.342	0.313	0.358
2	0.353	0.339	0.431	0.371	0.366	0.408	0.429	0.362	0.404	0.380	0.453	0.375
3	0.000	0.463	0.484	0.526	0.395	2.309	0.705	0.483	0.553	0.515	0.616	0.481
4	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
+gp	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

AGE/YEAF	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
1	0.257	0.298	0.232	0.243	0.262	0.236	0.302	0.224	0.288	0.404	0.385	0.292
2	0.389	0.422	0.361	0.314	0.345	0.270	0.565	0.116	0.814	0.735	0.984	0.785
3	0.422	0.000	0.406	0.413	0.498	0.686	0.814	0.827	1.690	1.699	2.013	1.533
4	0.000	0.000	0.000	2.205	0.528	0.864	2.223	2.557	3.949	3.002	3.485	3.137
5	0.000	0.000	0.000	0.000	0.000	3.852	4.255	4.208	6.609	5.311	6.565	5.323
6	0.000	0.000	0.000	0.000	0.000	11.300	6.509	5.437	10.198	9.341	8.521	8.369
7	0.000	0.000	0.000	0.000	0.000	0.000	0.000	11.048	5.900	5.128	13.464	6.728
8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	15.906	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000	0.000	0.000	8.100	0.000	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	12.014	0.000
+gp	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

AGE/YEAF	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
1	0.277	0.234	0.334	0.311	0.326	0.364	0.231	0.281	0.328	0.220	0.293
2	0.677	0.556	0.796	0.742	0.759	0.939	0.771	0.607	0.557	0.456	0.905
3	2.057	1.867	1.493	1.772	1.617	1.767	1.881	1.410	1.382	0.842	1.573
4	4.099	3.803	3.375	3.128	3.158	3.092	3.002	2.662	2.286	2.578	5.195
5	5.576	6.456	4.048	3.826	3.983	4.687	3.629	3.560	2.641	0.000	4.239
6	6.071	8.579	8.419	4.642	5.303	5.439	5.172	0.000	0.000	0.000	0.000
7	8.264	9.733	7.086	4.423	6.940	0.000	5.313	0.000	0.000	0.000	0.000
8	6.213	0.000	0.000	0.000	8.390	0.000	4.577	0.000	0.000	0.000	0.000
9	11.617	0.000	0.000	0.000	4.087	0.000	0.000	9.790	0.000	0.000	0.000
10	0.000	16.370	16.370	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
+gp	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table 4.4c. Cod in Subarea 4, Division 7.d and Subdivision 20: Catch weights at age (kg).

Catch weights at age (kg)

AGE/YEAF	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
1	0.314	0.357	0.312	0.313	0.326	0.327	0.417	0.449	0.314	0.300	0.335	0.304
2	0.809	0.761	0.900	0.836	0.868	0.848	0.755	0.845	0.834	0.729	0.700	0.901
3	2.647	2.366	2.295	2.437	2.395	2.215	2.127	2.028	2.188	2.080	1.913	2.206
4	4.491	4.528	4.512	4.169	3.153	4.094	3.852	4.001	4.258	3.968	3.776	4.156
5	6.794	6.447	7.274	7.027	6.803	5.341	5.715	6.131	6.528	6.011	5.488	6.174
6	9.409	8.520	9.498	9.599	9.610	8.020	6.722	7.945	8.646	8.246	7.453	8.333
7	11.562	10.606	11.898	11.766	12.033	8.581	9.262	9.953	10.356	9.766	9.019	9.889
8	11.942	10.758	12.041	11.968	12.481	10.162	9.749	10.131	11.219	10.228	9.810	10.791
9	13.383	12.340	13.053	14.060	13.589	10.720	10.384	11.919	12.881	11.875	11.077	12.175
10	13.756	12.540	14.441	14.746	14.271	12.497	12.743	12.554	13.147	12.530	12.359	12.425
+gp	0.000	18.000	15.667	15.672	19.016	11.595	11.175	14.367	15.544	14.350	12.886	13.731

AGE/YEAF	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
1	0.304	0.198	0.294	0.432	0.291	0.257	0.330	0.358	0.403	0.305	0.314	0.293
2	0.760	0.722	0.673	0.743	0.905	0.917	0.769	0.908	0.882	0.921	0.800	0.782
3	2.348	2.449	2.128	2.001	2.411	1.948	2.186	1.856	1.834	2.156	2.132	1.822
4	4.226	4.577	4.606	4.146	4.423	4.401	4.615	4.130	3.880	3.972	4.164	3.504
5	6.404	6.494	6.714	6.530	6.579	6.109	7.045	6.785	6.491	6.190	6.324	6.230
6	8.691	8.620	8.828	8.667	8.474	9.120	8.884	8.903	8.423	8.362	8.430	8.140
7	10.107	10.132	10.071	9.685	10.637	9.550	9.933	10.398	9.848	10.317	10.362	9.896
8	10.910	11.340	11.052	11.099	11.550	11.867	11.519	12.500	11.837	11.352	12.074	11.940
9	12.339	12.888	11.824	12.427	13.057	12.782	13.338	13.469	12.797	13.505	13.072	12.951
10	12.976	14.139	13.134	12.778	14.148	14.081	14.897	12.890	12.562	13.408	14.443	13.859
+gp	14.431	14.760	14.362	13.981	15.478	15.392	18.784	14.608	14.426	13.472	16.588	14.707

AGE/YEAF	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
1	0.437	0.466	0.364	0.382	0.393	0.395	0.326	0.305	0.420	0.433	0.386	0.372
2	0.773	0.753	0.932	0.690	0.889	0.970	0.846	0.788	0.768	0.831	0.797	0.634
3	1.955	1.975	1.810	2.165	1.995	2.546	2.477	2.188	2.206	2.095	2.117	1.622
4	3.650	3.187	3.585	3.791	3.971	4.223	4.551	4.471	4.293	4.034	3.821	3.495
5	6.052	5.992	5.273	5.931	6.082	6.247	6.540	7.167	7.220	6.637	6.228	5.387
6	8.307	7.914	7.921	7.890	8.033	8.483	8.094	8.436	8.980	8.494	8.394	7.563
7	10.243	9.764	9.724	10.235	9.545	10.101	9.641	9.537	10.282	9.729	9.979	9.628
8	11.461	12.127	11.212	10.923	10.948	10.482	10.734	10.323	11.743	11.080	11.424	10.643
9	12.447	14.242	12.586	12.803	13.481	11.849	12.329	12.223	13.107	12.264	12.300	11.499
10	18.691	17.787	15.557	15.525	13.171	13.904	13.443	14.247	12.052	12.756	12.761	13.085
+gp	16.604	16.477	14.695	23.234	14.989	15.794	13.961	12.523	13.954	11.304	13.416	14.921

AGE/YEAF	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
1	0.318	0.354	0.372	0.298	0.285	0.269	0.342	0.250	0.313	0.424	0.406	0.335
2	0.732	0.903	0.606	0.572	0.781	0.496	0.860	0.236	0.893	0.904	1.133	0.965
3	1.405	1.747	2.093	1.576	1.645	1.712	1.529	1.804	2.001	1.966	2.355	2.426
4	3.305	3.216	3.663	3.726	3.298	3.075	3.533	3.828	4.026	3.890	4.023	4.180
5	5.726	4.903	5.871	5.537	5.757	5.175	5.124	5.665	6.117	6.207	6.154	6.033
6	7.403	7.488	7.333	8.006	6.694	7.449	7.201	7.229	8.543	7.491	7.560	8.299
7	8.582	9.636	9.264	9.451	8.838	8.974	9.457	9.262	9.255	9.644	9.733	9.472
8	10.365	10.671	10.081	10.012	12.674	9.894	10.567	10.477	10.293	11.489	11.447	11.631
9	11.600	10.894	12.062	11.888	11.518	11.857	11.384	12.325	12.282	11.387	11.291	12.827
10	12.330	11.414	12.009	12.795	11.053	12.095	12.066	14.862	14.559	12.725	11.786	12.083
+gp	11.926	15.078	10.196	11.688	14.988	14.093	22.464	17.887	17.522	15.381	18.764	10.052

AGE/YEAF	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
1	0.405	0.274	0.388	0.398	0.366	0.387	0.249	0.300	0.405	0.256	0.330
2	0.915	0.800	0.932	0.927	0.945	1.049	0.925	0.790	0.857	0.815	1.051
3	2.438	2.252	2.249	2.237	2.098	2.138	2.238	1.853	2.036	1.766	2.398
4	4.569	4.154	4.060	4.083	4.031	3.803	3.794	3.759	3.687	3.802	3.914
5	6.472	6.392	5.999	5.598	5.802	5.712	5.296	5.624	5.493	5.424	5.342
6	7.829	8.117	8.360	7.392	6.761	7.332	6.857	6.829	7.188	6.729	7.046
7	9.656	9.095	9.385	9.190	8.602	7.928	8.850	7.683	7.764	8.964	7.642
8	9.461	11.799	9.486	9.180	9.410	8.717	8.618	8.867	9.684	8.671	10.961
9	10.853	12.548	11.364	11.469	8.663	10.367	9.586	8.546	6.788	11.459	11.340
10	14.436	11.754	11.680	16.456	13.838	11.926	17.579	8.972	11.466	16.458	21.935
+gp	12.421	20.644	29.764	34.656	30.079	19.623	20.519	23.381	21.796	14.596	10.706

Table 4.4d. Cod in Subarea 4, Division 7.d and Subdivision 20: Landings, discards (including BMS landings) and catch weights at age (kg) by season (quarter or annual, depending on data stratification) from InterCatch for 2021 (note, any differences in the +gp values between Tables 4.4a–c and Table 4.4d are due to rounding error alone).

Landings weights at age

Age/Season	Q1	Q2	Q3	Q4	annual	total
1	0.74	0.737	0.786	0.705	0.904	0.741
2	0.95	1.291	1.471	1.47	1.629	1.33
3	2.009	2.104	2.853	3.076	2.927	2.536
4	3.314	3.715	4.299	4.231	4.193	3.902
5	4.598	5.348	5.636	6.26	5.412	5.351
6	6.655	6.705	7.88	7.365	7.056	7.046
7	7.946	7.706	6.918	8.989	7.595	7.642
8	10.235	9.117	12.398	12.181	10.963	10.961
9	10.965	10.684	12.14	11.58	11.242	11.34
10	18.316	19.012	25.306	26.841	23.37	21.935
+gp	10.803	10.644	11.049	10.881	10.575	10.706

Discards weights at age (including BMS landings; kg)

Age/Season	Q1	Q2	Q3	Q4	annual	total
1	0.249	0.258	0.261	0.33	0.315	0.293
2	0.744	0.767	0.933	1.04	1.043	0.905
3	1.361	0.847	2.214	1.698	3.871	1.573
4	5.102	5.111	5.079	5.141	6.299	5.195
5	4.239	4.239	4.274	4.02	4.239	4.239
6	0	0	0	0	0	0
7	0	0	0	0	0	0
8	0	0	0	0	0	0
9	0	0	0	0	0	0
10	0	0	0	0	0	0
+gp	0	0	0	0	0	0

Catch weights at age (kg)

Age/Season	Q1	Q2	Q3	Q4	annual	total
1	0.287	0.286	0.312	0.383	0.324	0.33
2	0.83	0.877	1.163	1.264	1.057	1.051
3	1.927	1.854	2.769	2.99	3.363	2.398
4	3.325	3.722	4.315	4.233	4.303	3.914
5	4.596	5.344	5.611	6.249	5.402	5.342
6	6.655	6.705	7.88	7.365	7.056	7.046
7	7.946	7.706	6.918	8.989	7.595	7.642
8	10.235	9.117	12.398	12.181	10.963	10.961
9	10.965	10.684	12.14	11.58	11.242	11.34
10	18.316	19.012	25.306	26.841	23.37	21.935
+gp	10.803	10.644	11.049	10.881	10.575	10.706

Table 4.5a. Cod in Subarea 4, Division 7.d and Subdivision 20: Stock weights at age (kg). Values for 2022 are derived from NS–IBTS–Q1 survey data for ages 1–2 and taken as a three-year average for ages 3+.

Year	1	2	3	4	5	6+
1963	0.060	0.533	2.278	3.996	6.117	9.590
1964	0.068	0.501	2.036	4.029	5.805	8.651
1965	0.060	0.593	1.975	4.014	6.549	10.379
1966	0.060	0.550	2.097	3.709	6.327	10.367
1967	0.062	0.572	2.061	2.805	6.125	10.159
1968	0.063	0.558	1.906	3.643	4.809	8.302
1969	0.080	0.497	1.830	3.427	5.146	7.184
1970	0.086	0.556	1.745	3.560	5.520	8.618
1971	0.060	0.549	1.883	3.788	5.877	9.120
1972	0.057	0.480	1.790	3.530	5.412	8.682
1973	0.064	0.461	1.646	3.360	4.941	8.476
1974	0.058	0.593	1.898	3.698	5.559	9.658
1975	0.058	0.500	2.020	3.760	5.766	8.975
1976	0.038	0.475	2.107	4.072	5.847	8.626
1977	0.056	0.443	1.831	4.098	6.045	9.694
1978	0.083	0.489	1.722	3.689	5.879	9.224
1979	0.056	0.596	2.075	3.935	5.923	9.562
1980	0.049	0.604	1.676	3.916	5.500	9.230
1981	0.063	0.506	1.881	4.106	6.343	9.389
1982	0.068	0.598	1.597	3.675	6.109	8.979
1983	0.077	0.581	1.578	3.452	5.844	8.837
1984	0.058	0.606	1.855	3.534	5.573	9.043
1985	0.060	0.527	1.835	3.705	5.694	8.906
1986	0.056	0.515	1.568	3.118	5.609	9.278
1987	0.084	0.509	1.682	3.248	5.449	8.957
1988	0.089	0.496	1.699	2.836	5.395	8.824
1989	0.070	0.614	1.558	3.190	4.748	8.273
1990	0.073	0.454	1.863	3.373	5.340	9.287
1991	0.075	0.585	1.717	3.533	5.476	8.125
1992	0.076	0.639	2.191	3.757	5.624	8.942
1993	0.062	0.557	2.131	4.049	5.888	8.603
1994	0.058	0.519	1.883	3.978	6.453	8.487
1995	0.080	0.506	1.898	3.820	6.501	9.268
1996	0.083	0.547	1.803	3.589	5.976	8.830
1997	0.074	0.525	1.822	3.400	5.607	8.388
1998	0.071	0.417	1.396	3.110	4.850	8.000
1999	0.061	0.482	1.209	2.941	5.155	7.567
2000	0.068	0.595	1.503	2.861	4.414	7.832
2001	0.071	0.399	1.801	3.259	5.286	8.067
2002	0.057	0.289	1.467	3.448	4.922	7.749
2003	0.058	0.431	1.565	3.037	5.256	7.706
2004	0.056	0.242	1.427	2.762	4.705	7.474
2005	0.060	0.445	1.324	2.946	4.528	7.084
2006	0.058	0.498	1.484	3.379	5.046	7.833

Year	1	2	3	4	5	6+
2007	0.072	0.436	1.689	3.465	5.527	8.276
2008	0.083	0.681	1.889	3.546	5.404	7.404
2009	0.056	0.734	1.908	3.663	5.525	8.076
2010	0.073	0.569	2.188	3.852	5.539	8.897
2011	0.062	0.479	2.094	4.238	5.841	7.547
2012	0.062	0.621	1.910	3.673	5.923	8.107
2013	0.068	0.466	1.889	3.774	5.707	8.283
2014	0.064	0.540	1.873	3.516	5.211	7.420
2015	0.068	0.587	1.756	3.406	4.973	6.787
2016	0.071	0.553	1.712	3.253	5.143	7.215
2017	0.057	0.551	1.818	3.229	4.689	7.933
2018	0.059	0.460	1.682	3.276	5.173	6.909
2019	0.056	0.421	1.682	3.410	4.707	7.408
2020	0.059	0.457	1.712	3.351	5.030	7.424
2021	0.078	0.444	1.927	3.325	4.596	8.007
2022	0.095	0.441	1.774	3.362	4.778	7.802

Table 4.5b. Cod in Subarea 4, Division 7.d and Subdivision 20: Proportion mature by age-group.

	1	2	3	4	5	6+
1978	0.016	0.098	0.148	0.483	0.683	1.000
1979	0.000	0.047	0.217	0.524	0.615	1.000
1980	0.003	0.068	0.119	0.255	0.619	1.000
1981	0.003	0.035	0.168	0.412	0.506	1.000
1982	0.000	0.036	0.120	0.434	0.553	1.000
1983	0.000	0.035	0.174	0.392	0.761	1.000
1984	0.006	0.031	0.254	0.436	0.673	1.000
1985	0.000	0.026	0.158	0.508	0.685	1.000
1986	0.001	0.100	0.151	0.313	0.581	1.000
1987	0.000	0.028	0.258	0.537	0.815	1.000
1988	0.003	0.047	0.176	0.445	0.528	1.000
1989	0.232	0.179	0.272	0.529	0.770	1.000
1990	0.004	0.088	0.255	0.432	0.707	1.000
1991	0.000	0.068	0.322	0.445	0.745	1.000
1992	0.000	0.190	0.460	0.827	0.678	1.000
1993	0.000	0.075	0.356	0.618	0.747	1.000
1994	0.000	0.146	0.470	0.783	0.897	1.000
1995	0.004	0.042	0.342	0.733	0.874	1.000
1996	0.000	0.159	0.462	0.825	0.880	1.000
1997	0.000	0.191	0.590	0.659	0.792	1.000
1998	0.023	0.120	0.530	0.816	0.948	1.000
1999	0.014	0.385	0.467	0.709	0.981	1.000
2000	0.009	0.250	0.670	0.825	0.879	1.000
2001	0.016	0.189	0.454	0.777	0.974	1.000
2002	0.012	0.345	0.553	0.865	1.000	1.000
2003	0.000	0.198	0.455	0.705	0.961	1.000
2004	0.000	0.224	0.788	0.761	0.869	1.000
2005	0.005	0.218	0.626	0.843	0.928	1.000

	1	2	3	4	5	6+
2006	0.012	0.224	0.495	0.792	0.844	1.000
2007	0.017	0.188	0.594	0.823	0.979	1.000
2008	0.034	0.385	0.725	0.825	0.946	1.000
2009	0.016	0.246	0.696	0.870	0.918	1.000
2010	0.008	0.182	0.710	0.826	0.963	1.000
2011	0.082	0.157	0.731	0.898	0.985	1.000
2012	0.004	0.250	0.523	0.803	0.949	1.000
2013	0.018	0.096	0.474	0.855	0.900	1.000
2014	0.017	0.150	0.511	0.882	0.951	1.000
2015	0.018	0.279	0.441	0.786	0.865	1.000
2016	0.033	0.144	0.290	0.688	0.817	1.000
2017	0.013	0.144	0.496	0.747	0.859	1.000
2018	0.000	0.145	0.441	0.761	0.978	1.000
2019	0.000	0.312	0.607	0.779	0.971	1.000
2020	0.010	0.168	0.684	0.862	0.917	1.000
2021	0.033	0.164	0.381	0.624	0.860	1.000
2022	0.071	0.185	0.248	0.587	0.927	1.000

Table 4.5c. Cod in Subarea 4, Division 7.d and Subdivision 20: Natural mortality by age-group (left). The values on the right show the final Ms after application of the ad-hoc adjustment to mimic emigration of older cod to 6.a.

	1	2	3	4	5	6+	
1963	1.176	0.711	0.216	0.2	0.2	0.2	
1964	1.176	0.711	0.216	0.2	0.2	0.2	
1965	1.176	0.711	0.216	0.2	0.2	0.2	
1966	1.176	0.711	0.216	0.2	0.2	0.2	
1967	1.176	0.711	0.216	0.2	0.2	0.2	
1968	1.176	0.711	0.216	0.2	0.2	0.2	
1969	1.176	0.711	0.216	0.2	0.2	0.2	
1970	1.176	0.711	0.216	0.2	0.2	0.2	
1971	1.176	0.711	0.216	0.2	0.2	0.2	
1972	1.176	0.711	0.216	0.2	0.2	0.2	
1973	1.176	0.711	0.216	0.2	0.2	0.2	
1974	1.176	0.711	0.216	0.2	0.2	0.2	
1975	1.185	0.706	0.218	0.2	0.2	0.2	
1976	1.195	0.701	0.221	0.2	0.2	0.2	
1977	1.204	0.697	0.223	0.2	0.2	0.2	
1978	1.213	0.694	0.226	0.2	0.2	0.2	
1979	1.220	0.693	0.228	0.2	0.2	0.2	
1980	1.226	0.694	0.231	0.2	0.2	0.2	
1981	1.228	0.696	0.233	0.2	0.2	0.2	
1982	1.228	0.700	0.235	0.2	0.2	0.2	
1983	1.223	0.705	0.237	0.2	0.2	0.2	
1984	1.216	0.709	0.240	0.2	0.2	0.2	
1985	1.207	0.715	0.242	0.2	0.2	0.2	
1986	1.197	0.721	0.244	0.2	0.2	0.2	
1987	1.186	0.728	0.246	0.2	0.2	0.2	
1988	1.176	0.736	0.249	0.2	0.2	0.2	
1989	1.167	0.745	0.251	0.2	0.2	0.2	
1990	1.158	0.754	0.253	0.2	0.2	0.2	

	1	2	3	4	5	6+				
1991	1.151	0.763	0.256	0.2	0.2	0.2				
1992	1.144	0.771	0.259	0.2	0.2	0.2				
1993	1.139	0.779	0.263	0.2	0.2	0.2				
1994	1.135	0.787	0.268	0.2	0.2	0.2				
1995	1.131	0.796	0.275	0.2	0.2	0.2				
1996	1.128	0.806	0.283	0.2	0.2	0.2				
1997	1.124	0.818	0.293	0.2	0.2	0.2				
1998	1.122	0.833	0.305	0.2	0.2	0.2				
1999	1.121	0.849	0.317	0.2	0.2	0.2				
2000	1.121	0.866	0.330	0.2	0.2	0.2				
2001	1.125	0.886	0.343	0.2	0.2	0.2				
2002	1.133	0.906	0.355	0.2	0.2	0.2				
2003	1.144	0.926	0.365	0.2	0.2	0.2				
2004	1.157	0.945	0.371	0.2	0.2	0.2				
2005	1.170	0.961	0.374	0.2	0.2	0.2				
2006	1.183	0.973	0.373	0.2	0.2	0.2				
2007	1.194	0.981	0.368	0.2	0.2	0.2				
2008	1.202	0.984	0.362	0.2	0.2	0.2				
2009	1.209	0.985	0.354	0.2	0.2	0.2				
2010	1.213	0.982	0.346	0.2	0.2	0.2	3	4	5	6+
2011	1.215	0.978	0.339	0.2	0.2	0.2	0.501	0.364	0.363	0.363
2012	1.215	0.972	0.332	0.2	0.2	0.2	0.495	0.364	0.363	0.363
2013	1.212	0.965	0.327	0.2	0.2	0.2	0.489	0.363	0.363	0.363
2014	1.208	0.958	0.322	0.2	0.2	0.2	0.485	0.362	0.363	0.363
2015	1.201	0.951	0.318	0.2	0.2	0.2	0.481	0.362	0.363	0.363
2016	1.192	0.943	0.314	0.2	0.2	0.2	0.476	0.362	0.363	0.363
2017	1.181	0.935	0.310	0.2	0.2	0.2	0.472	0.361	0.363	0.363
2018	1.168	0.928	0.305	0.2	0.2	0.2	0.468	0.361	0.363	0.363
2019	1.154	0.920	0.301	0.2	0.2	0.2	0.463	0.361	0.363	0.363
2020*	1.154	0.920	0.301	0.2	0.2	0.2	0.463	0.361	0.363	0.363
2021*	1.154	0.920	0.301	0.2	0.2	0.2	0.463	0.361	0.363	0.363

***A new key run was performed in 2020 with data up to 2019 (ICES WGSAM 2020), so the 2020–2021 M–values are assumed equal to 2019.**

Table 4.6. Cod in Subarea 4, Division 7.d and Subdivision 20: Survey tuning indices and standard deviations for IBTS–Q1 and Q3 (NS–IBTS Delta–GAM indices). A third index for recruits is derived from the IBTS–Q3 index. Data used in the assessment are highlighted in bold font.

IBTS_Q1_gam							Standard deviations					
1983	2022											
1	1	0	0.25									
1	5						1	2	3	4	5	6
1	**2647.70**	**9142.12**	**1517.97**	**829.28**	**300.71**	369.83	**0.167**	**0.158**	**0.170**	**0.149**	**0.151**	0.151
1	**6819.36**	**3335.76**	**1501.79**	**342.72**	**291.30**	202.05	**0.146**	**0.144**	**0.138**	**0.142**	**0.133**	0.171
1	**374.53**	**8659.20**	**1501.30**	**756.14**	**178.25**	223.47	**0.188**	**0.133**	**0.144**	**0.155**	**0.158**	0.163
1	**7156.79**	**1750.00**	**2272.28**	**816.11**	**335.35**	230.70	**0.134**	**0.146**	**0.128**	**0.137**	**0.130**	0.144
1	**3364.39**	**9775.52**	**429.17**	**518.60**	**154.78**	175.30	**0.147**	**0.136**	**0.120**	**0.133**	**0.138**	0.146
1	**2452.81**	**2606.87**	**2216.68**	**221.01**	**244.19**	212.42	**0.217**	**0.135**	**0.133**	**0.173**	**0.135**	0.155
1	**4928.74**	**2352.39**	**1753.58**	**826.34**	**121.93**	216.70	**0.149**	**0.151**	**0.142**	**0.129**	**0.123**	0.152
1	**1091.41**	**5155.33**	**777.67**	**325.35**	**276.65**	141.15	**0.183**	**0.153**	**0.136**	**0.135**	**0.129**	0.159
1	**1242.00**	**1928.63**	**1395.52**	**328.72**	**151.90**	213.55	**0.189**	**0.154**	**0.137**	**0.134**	**0.126**	0.147
1	**4929.61**	**1992.22**	**488.52**	**359.33**	**86.23**	113.46	**0.157**	**0.140**	**0.137**	**0.151**	**0.145**	0.169
1	**2407.42**	**6390.93**	**740.34**	**263.57**	**154.95**	76.30	**0.204**	**0.137**	**0.121**	**0.129**	**0.135**	0.170
1	**4031.29**	**1367.69**	**1086.42**	**356.32**	**150.14**	115.28	**0.151**	**0.124**	**0.137**	**0.146**	**0.134**	0.171
1	**3588.70**	**7549.91**	**1249.74**	**458.06**	**134.42**	80.51	**0.174**	**0.135**	**0.128**	**0.139**	**0.135**	0.174
1	**1227.36**	**3965.02**	**1656.55**	**307.34**	**191.55**	87.29	**0.193**	**0.142**	**0.121**	**0.118**	**0.124**	0.170
1	**7536.14**	**2184.12**	**807.77**	**382.98**	**123.91**	98.85	**0.128**	**0.138**	**0.125**	**0.136**	**0.149**	0.161
1	**478.76**	**7899.53**	**848.82**	**378.06**	**192.60**	113.88	**0.207**	**0.129**	**0.118**	**0.118**	**0.112**	0.154
1	**1059.78**	**411.54**	**2465.94**	**360.47**	**157.38**	121.60	**0.217**	**0.157**	**0.105**	**0.120**	**0.119**	0.167
1	**1575.36**	**2017.61**	**388.15**	**704.20**	**118.28**	144.18	**0.157**	**0.167**	**0.132**	**0.116**	**0.129**	0.145
1	**839.06**	**2805.55**	**605.35**	**127.08**	**91.24**	65.51	**0.229**	**0.126**	**0.121**	**0.120**	**0.132**	0.158
1	**2193.19**	**1134.86**	**1322.59**	**219.55**	**47.05**	61.44	**0.211**	**0.144**	**0.130**	**0.131**	**0.139**	0.184
1	**192.42**	**1208.82**	**422.35**	**369.07**	**134.78**	58.50	**0.256**	**0.140**	**0.115**	**0.122**	**0.138**	0.172
1	**2327.30**	**741.80**	**584.71**	**127.18**	**140.58**	73.43	**0.249**	**0.136**	**0.122**	**0.144**	**0.146**	0.168
1	**714.62**	**1139.52**	**311.06**	**250.18**	**54.30**	90.18	**0.197**	**0.162**	**0.136**	**0.132**	**0.148**	0.175
1	**2439.72**	**586.83**	**428.85**	**105.16**	**64.40**	86.39	**0.182**	**0.163**	**0.140**	**0.160**	**0.159**	0.191
1	**951.74**	**2170.74**	**484.81**	**168.58**	**61.45**	71.17	**0.221**	**0.149**	**0.134**	**0.157**	**0.193**	0.210
1	**936.92**	**609.02**	**869.71**	**181.31**	**123.90**	45.75	**0.191**	**0.145**	**0.145**	**0.135**	**0.126**	0.179
1	**602.78**	**897.52**	**391.53**	**322.84**	**81.80**	78.72	**0.232**	**0.142**	**0.126**	**0.154**	**0.147**	0.168
1	**1560.44**	**1285.00**	**551.70**	**171.66**	**135.05**	64.66	**0.171**	**0.136**	**0.132**	**0.144**	**0.140**	0.183
1	**473.26**	**1968.17**	**554.46**	**233.54**	**111.96**	100.05	**0.251**	**0.137**	**0.148**	**0.154**	**0.147**	0.166
1	**1242.61**	**937.37**	**1713.64**	**480.33**	**146.98**	65.05	**0.285**	**0.130**	**0.160**	**0.165**	**0.139**	0.163
1	**843.46**	**1216.49**	**584.58**	**537.85**	**264.76**	88.75	**0.197**	**0.189**	**0.140**	**0.145**	**0.125**	0.153
1	**1067.97**	**1364.40**	**604.39**	**288.72**	**288.94**	96.12	**0.160**	**0.176**	**0.181**	**0.179**	**0.176**	0.220
1	**704.68**	**2534.79**	**1133.94**	**371.17**	**111.43**	95.32	**0.187**	**0.138**	**0.151**	**0.145**	**0.139**	0.174
1	**362.68**	**801.53**	**1577.93**	**588.58**	**229.12**	133.51	**0.211**	**0.158**	**0.148**	**0.151**	**0.123**	0.150
1	**2950.84**	**661.30**	**1005.56**	**942.84**	**437.83**	150.27	**0.139**	**0.146**	**0.165**	**0.145**	**0.130**	0.172
1	**211.59**	**2059.72**	**455.95**	**306.86**	**191.98**	175.00	**0.222**	**0.141**	**0.169**	**0.182**	**0.154**	0.172
1	**492.43**	**327.99**	**713.87**	**103.86**	**75.85**	58.74	**0.199**	**0.147**	**0.151**	**0.170**	**0.186**	0.241
1	**1694.17**	**764.85**	**204.87**	**246.84**	**49.08**	40.74	**0.228**	**0.174**	**0.158**	**0.165**	**0.171**	0.236
1	**738.40**	**1974.39**	**792.83**	**203.62**	**103.77**	84.72	**0.189**	**0.150**	**0.145**	**0.152**	**0.154**	0.179
1	**780.42**	**879.02**	**1386.72**	**435.37**	**97.58**	85.59	**0.216**	**0.198**	**0.207**	**0.207**	**0.244**	0.293
IBTS_Q3_gam												
1992	2021											
1	1	0.50	0.75									
1	4						1	2	3	4	5	
1	**11991.41**	**1623.65**	**451.92**	**194.50**	140.96		**0.114**	**0.157**	**0.141**	**0.138**	0.210	
1	**2449.54**	**3211.82**	**487.34**	**145.57**	153.12		**0.126**	**0.151**	**0.174**	**0.174**	0.231	
1	**14270.83**	**1917.62**	**795.70**	**146.88**	101.82		**0.120**	**0.130**	**0.144**	**0.182**	0.212	
1	**7006.85**	**4842.94**	**656.27**	**239.05**	80.36		**0.129**	**0.125**	**0.158**	**0.150**	0.229	
1	**3244.97**	**1962.63**	**625.11**	**170.73**	129.37		**0.137**	**0.162**	**0.143**	**0.156**	0.203	
1	**23444.80**	**2571.52**	**589.98**	**190.84**	115.72		**0.153**	**0.191**	**0.233**	**0.280**	0.305	
1	**706.02**	**7036.04**	**529.51**	**133.38**	127.60		**0.174**	**0.135**	**0.151**	**0.177**	0.209	
1	**3041.90**	**454.69**	**1197.04**	**116.58**	49.23		**0.172**	**0.152**	**0.124**	**0.140**	0.231	
1	**4717.82**	**929.80**	**89.21**	**231.82**	60.50		**0.262**	**0.265**	**0.200**	**0.227**	0.258	
1	**1307.51**	**1625.94**	**282.72**	**56.56**	94.23		**0.194**	**0.138**	**0.135**	**0.175**	0.238	
1	**3635.81**	**776.56**	**590.35**	**188.49**	63.69		**0.196**	**0.156**	**0.128**	**0.143**	0.191	
1	**551.51**	**949.50**	**187.51**	**165.28**	171.37		**0.157**	**0.153**	**0.152**	**0.185**	0.212	
1	**3060.62**	**590.74**	**374.23**	**73.98**	81.55		**0.202**	**0.145**	**0.162**	**0.194**	0.208	
1	**992.98**	**720.20**	**189.75**	**91.50**	65.46		**0.189**	**0.159**	**0.142**	**0.150**	0.197	
1	**3767.81**	**633.88**	**464.62**	**84.83**	37.70		**0.148**	**0.159**	**0.175**	**0.170**	0.222	
1	**1664.79**	**2214.58**	**371.34**	**144.29**	121.65		**0.184**	**0.168**	**0.161**	**0.161**	0.199	
1	**1915.95**	**824.54**	**848.07**	**174.75**	109.56		**0.184**	**0.155**	**0.148**	**0.145**	0.173	
1	**1640.58**	**688.72**	**223.86**	**218.27**	86.05		**0.207**	**0.163**	**0.184**	**0.209**	0.235	
1	**1974.58**	**1308.32**	**409.13**	**135.70**	100.90		**0.130**	**0.131**	**0.137**	**0.132**	0.162	
1	**847.44**	**2416.17**	**1049.02**	**293.57**	191.61		**0.159**	**0.131**	**0.187**	**0.158**	0.177	
1	**1661.50**	**783.81**	**1006.19**	**310.27**	113.52		**0.171**	**0.144**	**0.137**	**0.133**	0.169	
1	**1568.09**	**851.90**	**386.08**	**420.01**	185.43		**0.152**	**0.168**	**0.144**	**0.145**	0.170	
1	**1918.24**	**1207.63**	**529.39**	**218.96**	280.36		**0.133**	**0.141**	**0.150**	**0.130**	0.154	
1	**967.90**	**2157.41**	**857.63**	**350.52**	251.95		**0.160**	**0.130**	**0.134**	**0.128**	0.158	
1	**695.79**	**813.07**	**1092.74**	**593.65**	260.36		**0.174**	**0.137**	**0.127**	**0.123**	0.139	
1	**3708.25**	**475.46**	**387.09**	**372.88**	277.08		**0.122**	**0.147**	**0.166**	**0.134**	0.158	
1	**511.54**	**1566.57**	**276.54**	**182.79**	207.46		**0.154**	**0.139**	**0.125**	**0.161**	0.182	
1	**1254.04**	**340.98**	**444.85**	**92.56**	114.38		**0.139**	**0.150**	**0.146**	**0.156**	0.202	
1	**2240.48**	**889.07**	**138.13**	**169.23**	99.40		**0.167**	**0.131**	**0.163**	**0.170**	0.201	
1	**1078.78**	**1783.38**	**540.47**	**139.56**	126.96		**0.132**	**0.141**	**0.144**	**0.154**	0.169	

Table 4.6 condt. Cod in Subarea 4, Division 7.d and Subdivision 20: Survey tuning indices and standard deviations for IBTS–Q1 and Q3 (NS–IBTS Delta–GAM indices). A third index for recruits is derived from the IBTS–Q3 index. Data used in the assessment are highlighted in bold font.

IBTS_Q3_gam_age0_y+1				
1993	2022			
1	1	0	0	
1	1			1
1	**5764.75**			**0.261**
1	**5390.86**			**0.299**
1	**11616.42**			**0.266**
1	**5959.34**			**0.299**
1	**14996.27**			**0.282**
1	**144.01**			**0.419**
1	**8365.78**			**0.393**
1	**1975.54**			**0.350**
1	**1047.14**			**0.861**
1	**8678.15**			**0.463**
1	**305.90**			**0.574**
1	**3791.24**			**0.461**
1	**1749.10**			**0.617**
1	**2985.72**			**0.309**
1	**2219.64**			**0.446**
1	**4869.90**			**0.455**
1	**655.49**			**0.527**
1	**946.94**			**0.467**
1	**135.28**			**0.509**
1	**6392.98**			**0.663**
1	**540.45**			**0.605**
1	**279.67**			**0.523**
1	**413.56**			**0.447**
1	**23.96**			**0.724**
1	**3193.38**			**0.262**
1	**226.90**			**0.594**
1	**169.71**			**0.533**
1	**2050.57**			**0.450**
1	**763.56**			**0.363**
1	**1405.04**			**0.617**

Table 4.7a. Cod in Subarea 4, Division 7.d and Subdivision 20: SAM final run model specification.

```
# Configuration saved: Thu Apr 22 17:54:35 2021
#
# Where a matrix is specified rows corresponds to fleets and columns to ages.
# Same number indicates same parameter used
# Numbers (integers) starts from zero and must be consecutive
# Negative numbers indicate that the parameter is not included in the model
#
$minAge
# The minimium age class in the assessment
 1

$maxAge
# The maximum age class in the assessment
 6

$maxAgePlusGroup
# Is last age group considered a plus group for each fleet (1 yes, or 0 no).
 1 0 0 0

$keyLogFsta
# Coupling of the fishing mortality states processes for each age (normally only
# the first row (= fleet) is used).
# Sequential numbers indicate that the fishing mortality is estimated individually
# for those ages; if the same number is used for two or more ages, F is bound for
# those ages (assumed to be the same). Binding fully selected ages will result in a
# flat selection pattern for those ages.
   0   1   2   3   4   5
  -1  -1  -1  -1  -1  -1
  -1  -1  -1  -1  -1  -1
  -1  -1  -1  -1  -1  -1

$corFlag
# Correlation of fishing mortality across ages (0 independent, 1 compound symmetry,
# 2 AR(1), 3 separable AR(1).
# 0: independent means there is no correlation between F across age
# 1: compound symmetry means that all ages are equally correlated;
# 2: AR(1) first order autoregressive - similar ages are more highly correlated than
# ages that are further apart, so similar ages have similar F patterns over time.
# if the estimated correlation is high, then the F pattern over time for each age
# varies in a similar way. E.g if almost one, then they are parallel (like a
# separable model) and if almost zero then they are independent.
# 3: Separable AR - Included for historic reasons . . .  more later
 2

$keyLogFpar
# Coupling of the survey catchability parameters (nomally first row is
# not used, as that is covered by fishing mortality).
  -1  -1  -1  -1  -1  -1
   0   1   2   3   4  -1
   5   6   7   8  -1  -1
   9  -1  -1  -1  -1  -1

$keyQpow
# Density dependent catchability power parameters (if any).
  -1  -1  -1  -1  -1  -1
  -1  -1  -1  -1  -1  -1
  -1  -1  -1  -1  -1  -1
  -1  -1  -1  -1  -1  -1

$keyVarF
```

```
# Coupling of process variance parameters for log(F)-process (Fishing mortality
# normally applies to the first (fishing) fleet; therefore only first row is used)
   0   1   1   1   1   2
  -1  -1  -1  -1  -1  -1
  -1  -1  -1  -1  -1  -1
  -1  -1  -1  -1  -1  -1

$keyVarLogN
# Coupling of the recruitment and survival process variance parameters for the
# log(N)-process at the different ages. It is advisable to have at least the first age
# class (recruitment) separate, because recruitment is a different process than
# survival.
 0 1 1 1 1 1

$keyVarObs
# Coupling of the variance parameters for the observations.
# First row refers to the coupling of the variance parameters for the catch data
# observations by age
# Second and further rows refers to coupling of the variance parameters for the
# index data observations by age
   0   1   2   2   2   2
   3   4   4   4   4  -1
   5   6   6   6  -1  -1
   7  -1  -1  -1  -1  -1

$obsCorStruct
# Covariance structure for each fleet ("ID" independent, "AR" AR(1), or "US" for unstruc-
tured). | Possible values are: "ID" "AR" "US"
 "ID" "AR" "AR" "ID"

$keyCorObs
# Coupling of correlation parameters can only be specified if the AR(1) structure is
chosen above.
# NA's indicate where correlation parameters can be specified (-1 where they cannot).
#V1 V2 V3 V4 V5
  NA  NA  NA  NA  NA
   0   1   1   1  -1
   2   3   3  -1  -1
  -1  -1  -1  -1  -1

$stockRecruitmentModelCode
# Stock recruitment code (0 for plain random walk, 1 for Ricker, 2 for Beverton-Holt, and
3 piece-wise constant).
 0

$noScaledYears
# Number of years where catch scaling is applied.
 0

$keyScaledYears
# A vector of the years where catch scaling is applied.


$keyParScaledYA
# A matrix specifying the couplings of scale parameters (nrow = no scaled years, ncols =
no ages).

$fbarRange
# lowest and higest age included in Fbar
 2 4
```

```
$keyBiomassTreat
# To be defined only if a biomass survey is used (0 SSB index, 1 catch index, 2 FSB index,
3 total catch, 4 total landings and 5 TSB index).
 -1 -1 -1 -1

$obsLikelihoodFlag
# Option for observational likelihood | Possible values are: "LN" "ALN"
 "LN" "LN" "LN" "LN"

$fixVarToWeight
# If weight attribute is supplied for observations this option sets the treatment (0
relative weight, 1 fix variance to weight).
 0

$fracMixF
# The fraction of t(3) distribution used in logF increment distribution
 0

$fracMixN
# The fraction of t(3) distribution used in logN increment distribution
 0

$fracMixObs
# A vector with same length as number of fleets, where each element is the fraction of
t(3) distribution used in the distribution of that fleet
 0 0 0 0

$constRecBreaks
# Vector of break years between which recruitment is at constant level. The break year
is included in the left interval. (This option is only used in combination with stock-
recruitment code 3)


$predVarObsLink
# Coupling of parameters used in a prediction-variance link for observations.
  -1  -1  -1  -1  -1  -1
  -1  -1  -1  -1  -1  NA
  -1  -1  -1  -1  NA  NA
  NA  NA  NA  NA  NA  NA

$stockWeightModel
# Integer code describing the treatment of stock weights in the model (0 use as known, 1
use as observations to inform stock weight process (GMRF with cohort and within year
correlations))
 0

$keyStockWeightMean
# Coupling of stock-weight process mean parameters (not used if stockWeightModel==0)
 NA NA NA NA NA NA

$keyStockWeightObsVar
# Coupling of stock-weight observation variance parameters (not used if stockWeight-
Model==0)
 NA NA NA NA NA NA

$catchWeightModel
# Integer code describing the treatment of catch weights in the model (0 use as known, 1
use as observations to inform catch weight process (GMRF with cohort and within year
correlations))
 0
```

```
$keyCatchWeightMean
# Coupling of catch-weight process mean parameters (not used if catchWeightModel==0)
 NA NA NA NA NA NA

$keyCatchWeightObsVar
# Coupling of catch-weight observation variance parameters (not used if catchWeight-
Model==0)
 NA NA NA NA NA NA

$matureModel
# Integer code describing the treatment of proportion mature in the model (0 use as known,
1 use as observations to inform proportion mature process (GMRF with cohort and within
year correlations on logit(proportion mature)))
 1

$keyMatureMean
# Coupling of mature process mean parameters (not used if matureModel==0)
 0 1 2 3 4 5

$mortalityModel
# Integer code describing the treatment of natural mortality in the model (0 use as known,
1 use as observations to inform natural mortality process (GMRF with cohort and within
year correlations))
 0

$keyMortalityMean
#
 NA NA NA NA NA NA

$keyMortalityObsVar
# Coupling of natural mortality observation variance parameters (not used if mortali-
tyModel==0)
 NA NA NA NA NA NA

$keyXtraSd
# An integer matrix with 4 columns (fleet year age coupling), which allows additional
uncertainty to be estimated for the specified observations
```

Table 4.7b. Cod in Subarea 4, Division 7.d and Subdivision 20: SAM final run model fitting diagnostics, parameter estimates and correlation matrix.

Model fitting		
log(L)	#par	AIC
674.584	38	-1273.17

	value	std.dev	logFpar_0	logFpar_1	logFpar_2	logFpar_3	logFpar_4	logFpar_5	logFpar_6	logFpar_7	logFpar_8	logFpar_9	logSdLogF	logSdLogF	logSdLogF	logSdLogN	logSdLogN	logSdLogO	logSdLogO	logSdLogO	logSdLogO	logSdLogO	logSdLogO	logSdLogO	logSdLogO	transfIRAR	transfIRAR	transfIRAR	transfIRAR	itrans_rho	logPhiMO_	logPhiMO_	logSdProcl	meanLogit	meanLogit	meanLogit	meanLogit	meanLogit	meanLogit	logSdMO_
logFpar_0	-5.29	0.07	1																																					
logFpar_1	-3.71	0.05	0.15	1																																				
logFpar_2	-3.07	0.04	0.06	0.49	1																																			
logFpar_3	-2.84	0.05	0.06	0.28	0.54	1																																		
logFpar_4	-2.68	0.06	0.07	0.19	0.34	0.61	1																																	
logFpar_5	-3.99	0.07	0.17	0.16	0.08	0.08	0.09	1																																
logFpar_6	-3.18	0.05	0.13	0.23	0.15	0.15	0.18	0.32	1																															
logFpar_7	-2.91	0.05	0.09	0.15	0.23	0.24	0.3	0.18	0.54	1																														
logFpar_8	-2.79	0.07	0.08	0.14	0.22	0.36	0.45	0.14	0.35	0.61	1																													
logFpar_9	-4.95	0.18	0.08	0.06	0.03	0.03	0.03	0.09	0.06	0.04	0.04	1																												
logSdLogF	-1.68	0.2	-0.03	0.01	0	0	0.01	-0.02	0	0.01	0.02	-0.01	1																											
logSdLogF	-1.97	0.12	-0.02	-0.04	-0.04	-0.03	-0.02	-0.03	-0.06	-0.04	-0.03	-0.01	0.49	1																										
logSdLogF	-1.7	0.18	-0.03	-0.06	-0.09	-0.15	-0.23	-0.05	-0.09	-0.15	-0.23	-0.02	0.14	0.3	1																									
logSdLogN	-0.24	0.11	-0.04	0	-0.01	-0.01	-0.01	-0.01	0	-0.02	-0.02	-0.02	0	0	-0.01	1																								
logSdLogN	-2.12	0.11	-0.03	0.01	0	-0.01	0.01	-0.01	0.02	-0.03	-0.04	-0.02	-0.02	-0.02	-0.03	0.25	1																							
logSdLogO	-0.52	0.11	0	-0.01	0	-0.01	-0.01	-0.01	0	-0.01	-0.01	-0.01	-0.08	-0.02	0.01	-0.08	-0.08	1																						
logSdLogO	-1.43	0.13	-0.02	-0.04	0	0	-0.01	-0.02	-0.01	0	-0.01	-0.01	-0.02	-0.02	0.01	-0.02	-0.06	0.04	1																					
logSdLogO	-2.66	0.2	0	-0.01	-0.02	-0.04	-0.07	0	-0.02	-0.04	-0.04	0	-0.07	-0.15	-0.02	-0.05	-0.32	0.05	0.01	1																				
logSdLogO	0.82	0.13	0.03	0.01	0.01	0.01	0.01	0.04	0.02	0.02	0.02	0.03	0.01	0	0	-0.15	-0.18	0.03	0	0.05	1																			
logSdLogO	0.61	0.07	0.02	0.03	0.02	0.02	0.02	0.01	0.02	0.03	0.03	0.01	-0.01	-0.05	0.01	-0.07	-0.09	0.02	-0.01	-0.05	0.04	1																		
logSdLogO	0.85	0.16	0.04	-0.01	-0.01	-0.01	-0.03	0.02	-0.02	-0.01	-0.02	0.02	0.02	0.01	0.02	-0.19	-0.27	0.06	-0.01	0.07	0.16	0.06	1																	
logSdLogO	0.47	0.1	0.04	0.07	0.08	0.1	0.14	0.06	0.11	0.14	0.17	0.02	0	-0.05	-0.06	-0.04	-0.04	0	-0.03	-0.11	0.02	0.08	0.03	1																
logSdLogO	0.88	0.13	0.01	0	-0.01	-0.01	-0.01	0	-0.01	-0.01	-0.01	0.01	0	0.01	0.01	-0.04	-0.07	0	-0.01	0.02	0.05	0.01	0.07	0	1															
transfIRAR	3.39	1059.42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1														
transfIRAR	0.04	0.24	0	-0.01	-0.02	0	0.01	-0.01	-0.02	0	0	0	0.04	0.05	0	-0.03	-0.04	0	0.01	-0.08	0.01	-0.47	0.03	0.01	0.01	0	1													
transfIRAR	0.86	0.76	0.02	0.01	0.03	0.04	0.06	-0.03	-0.02	0.03	0.05	0	0.02	-0.01	-0.02	-0.11	-0.09	0	-0.03	-0.03	0.06	0.06	-0.07	0.01	0.02	0	0.05	1												
transfIRAR	0.04	0.32	-0.02	-0.03	-0.04	-0.04	-0.06	-0.03	-0.07	-0.08	-0.08	0	0.02	0.05	0.03	-0.01	-0.02	0	-0.02	-0.09	0	-0.01	0.03	-0.44	0.02	0	0.06	0.02	1											
itrans_rho	1.91	0.23	-0.01	0	-0.01	-0.02	-0.01	-0.01	0.01	-0.03	-0.03	-0.01	0.16	0.31	0.14	0.01	0.1	0.13	0.06	0.13	-0.02	0.02	-0.01	-0.02	-0.01	0	0	-0.02	-0.03	1										
logPhiMO_	6.44	1.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1									
logPhiMO_	5.48	1.76	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.62	1								
logSdProcl	2.32	0.68	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.94	0.79	1							
meanLogit	-4.85	0.55	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-0.02	-0.08	-0.05	1						
meanLogit	-1.99	0.52	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-0.04	-0.05	-0.05	0.92	1					
meanLogit	-0.53	0.51	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-0.05	-0.02	-0.05	0.91	0.96	1				
meanLogit	0.65	0.51	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-0.05	-0.02	-0.04	0.89	0.95	0.97	1			
meanLogit	1.72	0.52	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-0.03	-0.04	-0.03	0.87	0.93	0.95	0.96	1		
meanLogit	5.88	0.56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-0.09	0.03	-0.03	0.75	0.84	0.87	0.89	0.9	1	
logSdMO_	-3.47	0.15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-0.13	-0.14	-0.04	-0.14	-0.02	0	0.01	0.03	0.24	1

Table 4.8. Cod in Subarea 4, Division 7.d and Subdivision 20: SAM final run estimated fishing mortality at age.

Year/Age	1	2	3	4	5	6+	Fbar 2-4
1963	0.091	0.439	0.504	0.458	0.455	0.431	0.467
1964	0.102	0.481	0.561	0.506	0.5	0.486	0.516
1965	0.119	0.535	0.624	0.551	0.535	0.522	0.57
1966	0.122	0.546	0.63	0.547	0.533	0.525	0.574
1967	0.135	0.588	0.677	0.588	0.581	0.588	0.618
1968	0.147	0.627	0.717	0.623	0.613	0.621	0.656
1969	0.136	0.588	0.664	0.578	0.575	0.574	0.61
1970	0.155	0.638	0.701	0.596	0.583	0.568	0.645
1971	0.196	0.754	0.805	0.674	0.651	0.647	0.744
1972	0.231	0.842	0.877	0.731	0.707	0.723	0.817
1973	0.231	0.829	0.839	0.696	0.668	0.664	0.788
1974	0.224	0.797	0.787	0.652	0.633	0.626	0.745
1975	0.256	0.872	0.852	0.701	0.68	0.679	0.808
1976	0.29	0.951	0.916	0.736	0.712	0.715	0.868
1977	0.273	0.899	0.864	0.689	0.681	0.687	0.817
1978	0.313	0.998	0.986	0.788	0.778	0.808	0.924
1979	0.277	0.897	0.9	0.711	0.688	0.686	0.836
1980	0.31	0.979	1	0.791	0.749	0.765	0.923
1981	0.307	0.976	1.013	0.804	0.747	0.77	0.931
1982	0.348	1.085	1.154	0.926	0.85	0.915	1.055
1983	0.334	1.056	1.13	0.917	0.833	0.893	1.034
1984	0.303	0.98	1.048	0.865	0.786	0.836	0.964
1985	0.28	0.928	0.995	0.837	0.755	0.797	0.92
1986	0.3	0.989	1.079	0.929	0.835	0.911	0.999
1987	0.281	0.951	1.048	0.916	0.818	0.894	0.972
1988	0.283	0.964	1.078	0.946	0.837	0.917	0.996
1989	0.288	0.981	1.104	0.983	0.872	0.968	1.023
1990	0.259	0.91	1.021	0.915	0.809	0.878	0.949
1991	0.246	0.879	1.005	0.922	0.828	0.908	0.936
1992	0.23	0.84	0.975	0.907	0.814	0.879	0.907
1993	0.245	0.892	1.061	0.978	0.875	0.957	0.977
1994	0.228	0.849	1.041	0.946	0.841	0.904	0.946
1995	0.2	0.778	0.975	0.874	0.776	0.806	0.876
1996	0.195	0.775	1.014	0.921	0.844	0.905	0.903
1997	0.19	0.764	1.042	0.972	0.901	0.972	0.926
1998	0.23	0.895	1.266	1.203	1.117	1.259	1.121
1999	0.226	0.886	1.298	1.255	1.178	1.336	1.146
2000	0.225	0.886	1.315	1.291	1.217	1.371	1.164
2001	0.156	0.663	0.978	0.964	0.911	0.931	0.868
2002	0.199	0.8	1.201	1.178	1.099	1.161	1.06
2003	0.13	0.571	0.856	0.828	0.765	0.713	0.752
2004	0.142	0.609	0.919	0.872	0.808	0.747	0.8
2005	0.148	0.627	0.947	0.886	0.838	0.772	0.82
2006	0.13	0.564	0.844	0.78	0.758	0.676	0.729

Year/Age	1	2	3	4	5	6+	Fbar 2-4
2007	0.115	0.507	0.773	0.715	0.7	0.596	0.665
2008	0.107	0.48	0.749	0.693	0.7	0.598	0.641
2009	0.102	0.459	0.73	0.683	0.695	0.58	0.624
2010	0.081	0.379	0.611	0.578	0.593	0.466	0.523
2011	0.058	0.29	0.469	0.454	0.478	0.355	0.404
2012	0.052	0.264	0.431	0.421	0.446	0.32	0.372
2013	0.051	0.259	0.429	0.418	0.441	0.309	0.369
2014	0.052	0.261	0.438	0.426	0.449	0.311	0.375
2015	0.052	0.262	0.445	0.437	0.474	0.336	0.381
2016	0.052	0.259	0.443	0.433	0.468	0.323	0.378
2017	0.059	0.287	0.498	0.487	0.526	0.37	0.424
2018	0.08	0.361	0.637	0.619	0.68	0.515	0.539
2019	0.071	0.329	0.584	0.576	0.651	0.489	0.496
2020	0.049	0.245	0.43	0.431	0.497	0.345	0.369
2021	0.031	0.169	0.295	0.307	0.363	0.234	0.257

Table 4.9. Cod in Subarea 4, Division 7.d and Subdivision 20: SAM final run estimated population numbers at age (start of year; thousands).

Year/Age	1	2	3	4	5	6+	Total
1963	449510	177520	20532	10400	8317	5618	671897
1964	735687	126113	52107	11554	5270	7329	938060
1965	979639	216059	40283	22885	6189	5723	1270779
1966	1194064	262933	67633	16406	9440	6252	1556729
1967	1014952	322900	72671	28531	7942	8086	1455082
1968	506013	279578	89714	28541	14186	6934	924966
1969	438652	133613	73103	34134	11413	9952	700867
1970	1467939	123199	38936	32466	15417	8521	1686478
1971	1946869	398934	33492	14906	15929	10431	2420560
1972	481796	505450	90169	12037	5906	12194	1107553
1973	696540	114892	105889	29662	4918	6856	958756
1974	691555	170231	23926	36532	10979	5410	938634
1975	1185976	164792	37028	9626	16298	6893	1420612
1976	804738	286167	34037	13531	3783	9397	1151652
1977	1983363	172246	51566	10844	5079	5761	2228859
1978	1189443	455580	30989	18632	5510	4239	1704393
1979	1484327	266847	81317	8957	7274	3303	1852025
1980	2352815	316272	59331	24644	3949	4337	2761347
1981	942610	497684	59620	17624	8754	3297	1529589
1982	1471793	195268	93328	17056	6536	5006	1788988
1983	834246	312181	34021	21209	5480	3973	1211111
1984	1495910	179823	52377	8197	6747	3437	1746491
1985	372120	326021	33774	14928	2837	3821	753501
1986	1809813	86824	57655	10427	5561	2624	1972903
1987	707296	418382	16452	15330	3066	2955	1163481
1988	473232	163307	71835	5365	4917	2046	720702

Year/Age	1	2	3	4	5	6+	Total
1989	841461	109004	31141	16958	1836	2546	1002947
1990	339387	191460	20353	7789	4989	1406	565385
1991	398750	82127	31192	5922	2601	2531	523123
1992	959675	98779	15986	8649	1982	1732	1086803
1993	436956	223985	19228	5268	2853	1348	689637
1994	1068662	108944	36210	5412	1667	1392	1222288
1995	687254	254315	22863	9443	1705	1022	976603
1996	477313	169440	42137	6119	3410	1198	699617
1997	1536169	132765	32021	11240	2189	1614	1715998
1998	146708	411721	28006	8811	3743	1228	600218
1999	312329	39073	63530	6034	2213	1359	424538
2000	452206	79558	8906	10344	1492	830	553335
2001	182378	124706	13330	1988	1937	495	324836
2002	260328	50824	27407	4187	636	782	344165
2003	120773	63773	9067	5809	903	335	200660
2004	241673	37154	14371	2916	1934	447	298496
2005	188651	62262	8669	3591	1017	879	265068
2006	419451	51597	13449	2210	1087	724	488519
2007	187496	112145	10946	4120	958	643	316308
2008	212742	48018	25419	3246	1584	771	291781
2009	237406	56414	11853	7870	1374	902	315819
2010	306690	67117	14144	4043	3247	889	396129
2011	143469	90392	17101	4963	1888	2070	259884
2012	222444	42306	25686	6986	2094	1774	301290
2013	250277	61232	13743	10178	3180	1685	340295
2014	314562	74394	19227	5796	4515	2061	420554
2015	147637	99425	24266	7332	2438	3302	284400
2016	104054	43151	30539	11210	3283	2333	194571
2017	318892	30427	14315	11700	5148	2388	382871
2018	71266	81473	10303	5608	4327	3442	176419
2019	136603	20500	18959	3078	2190	2963	184293
2020	228698	40992	6533	5350	1272	1935	284779
2021	132685	65956	11232	3018	2263	1564	216717
2022	167384	39801	22927	5471	1518	1957	239058

Table 4.10. Cod in Subarea 4, Division 7.d and Subdivision 20: SAM final run estimated catches at age (thousands).

Year/Age	1	2	3	4	5	6+
1963	23124	46266	7378	3493	2776	1797
1964	42412	35422	20317	4195	1896	2578
1965	65125	66121	17007	8869	2345	2127
1966	81770	81678	28751	6321	3565	2333
1967	76250	106234	32544	11615	3203	3290
1968	41322	96642	41828	12116	5951	2937
1969	33331	43966	32294	13721	4568	3977
1970	125640	43151	17876	13340	6229	3380

Year/Age	1	2	3	4	5	6+
1971	207676	157879	16891	6701	6980	4554
1972	59638	216040	48093	5728	2744	5757
1973	86408	48566	54902	13637	2195	3048
1974	83526	70016	11894	16035	4717	2304
1975	160710	72255	19371	4448	7372	3114
1976	121684	133116	18621	6469	1766	4402
1977	282458	77353	27165	4949	2299	2623
1978	190758	219284	17704	9326	2735	2157
1979	213002	119869	43859	4178	3318	1503
1980	373141	150357	34123	12367	1910	2129
1981	147920	235833	34538	8942	4225	1624
1982	257922	98767	58211	9477	3439	2761
1983	141096	155039	20953	11711	2845	2159
1984	232703	85036	30870	4362	3371	1789
1985	54168	148562	19284	7771	1380	1928
1986	281506	41134	34503	5803	2892	1444
1987	104304	192816	9671	8457	1574	1606
1988	70533	75692	42890	3019	2562	1130
1989	127752	50920	18827	9768	982	1454
1990	47038	84854	11751	4292	2542	756
1991	52837	35460	17822	3280	1346	1389
1992	119745	41216	8957	4738	1014	931
1993	57916	97069	11311	3023	1529	764
1994	132814	45546	21026	3041	872	762
1995	75876	99663	12726	5047	845	519
1996	51610	65955	23938	3379	1787	656
1997	162054	50937	18420	6409	1196	924
1998	18537	175374	17881	5673	2324	813
1999	38822	16429	40894	3969	1415	928
2000	55984	33257	5746	6902	971	573
2001	15991	42033	7236	1125	1065	276
2002	28591	19511	16691	2660	391	496
2003	8856	18886	4482	2986	443	157
2004	19166	11481	7417	1551	985	216
2005	15472	19548	4557	1931	530	434
2006	30393	14869	6565	1094	530	326
2007	11984	29602	5045	1922	442	264
2008	12730	12106	11492	1484	731	318
2009	13456	13691	5284	3562	631	363
2010	13860	13908	5564	1621	1330	303
2011	4683	14835	5133	1538	610	525
2012	6549	6419	7222	2039	640	411
2013	7235	9152	3860	2954	963	379
2014	9238	11216	5502	1707	1388	467
2015	4398	15093	7038	2207	783	799
2016	3082	6500	8848	3352	1044	546

Year/Age	1	2	3	4	5	6+
2017	10856	5042	4566	3840	1794	626
2018	3253	16529	3973	2212	1827	1181
2019	5626	3853	6864	1150	896	975
2020	6570	5932	1859	1593	424	478
2021	2390	6776	2325	676	584	275

Table 4.11. Cod in Subarea 4, Division 7.d and Subdivision 20: SAM final run estimated maturity at age.

Year/Age	1	2	3	4	5	6+
1963	0.004	0.067	0.237	0.502	0.747	0.995
1964	0.004	0.067	0.236	0.502	0.747	0.995
1965	0.004	0.067	0.236	0.501	0.747	0.995
1966	0.004	0.066	0.235	0.5	0.746	0.995
1967	0.004	0.066	0.234	0.499	0.746	0.995
1968	0.004	0.066	0.233	0.498	0.745	0.995
1969	0.004	0.065	0.232	0.497	0.744	0.995
1970	0.004	0.065	0.23	0.495	0.743	0.995
1971	0.004	0.064	0.228	0.493	0.741	0.995
1972	0.004	0.063	0.226	0.49	0.74	0.995
1973	0.004	0.062	0.223	0.487	0.738	0.995
1974	0.004	0.062	0.22	0.482	0.736	0.995
1975	0.004	0.061	0.216	0.476	0.733	0.995
1976	0.004	0.061	0.211	0.469	0.729	0.995
1977	0.004	0.062	0.204	0.46	0.719	0.995
1978	0.004	0.066	0.191	0.458	0.696	0.995
1979	0.004	0.062	0.193	0.445	0.666	0.995
1980	0.004	0.061	0.175	0.364	0.647	0.995
1981	0.004	0.057	0.181	0.399	0.608	0.994
1982	0.004	0.057	0.174	0.421	0.633	0.994
1983	0.004	0.057	0.192	0.416	0.7	0.994
1984	0.004	0.057	0.211	0.436	0.691	0.995
1985	0.005	0.06	0.193	0.454	0.691	0.995
1986	0.005	0.071	0.199	0.414	0.677	0.995
1987	0.006	0.07	0.23	0.47	0.724	0.995
1988	0.007	0.083	0.228	0.472	0.677	0.995
1989	0.008	0.108	0.263	0.497	0.729	0.995
1990	0.008	0.11	0.29	0.49	0.732	0.995
1991	0.006	0.113	0.342	0.533	0.744	0.995
1992	0.006	0.127	0.396	0.675	0.75	0.996
1993	0.006	0.116	0.394	0.667	0.797	0.996
1994	0.006	0.122	0.422	0.716	0.846	0.996
1995	0.008	0.114	0.405	0.723	0.86	0.997
1996	0.008	0.149	0.45	0.746	0.868	0.997
1997	0.009	0.17	0.514	0.73	0.871	0.997
1998	0.014	0.18	0.515	0.773	0.904	0.998
1999	0.017	0.252	0.518	0.769	0.923	0.998

Year/Age	1	2	3	4	5	6+
2000	0.017	0.24	0.581	0.804	0.922	0.998
2001	0.017	0.231	0.531	0.816	0.945	0.998
2002	0.015	0.259	0.542	0.815	0.967	0.999
2003	0.011	0.234	0.544	0.775	0.942	0.999
2004	0.011	0.224	0.641	0.782	0.917	0.999
2005	0.015	0.22	0.599	0.808	0.912	0.998
2006	0.018	0.233	0.558	0.806	0.909	0.998
2007	0.021	0.248	0.596	0.811	0.926	0.998
2008	0.022	0.299	0.652	0.821	0.924	0.998
2009	0.021	0.269	0.662	0.839	0.924	0.998
2010	0.019	0.235	0.661	0.839	0.932	0.998
2011	0.019	0.213	0.64	0.845	0.937	0.998
2012	0.017	0.215	0.557	0.821	0.928	0.998
2013	0.017	0.176	0.514	0.817	0.915	0.998
2014	0.017	0.184	0.494	0.807	0.912	0.998
2015	0.016	0.205	0.454	0.766	0.893	0.998
2016	0.015	0.184	0.414	0.731	0.88	0.998
2017	0.013	0.18	0.472	0.742	0.888	0.998
2018	0.01	0.186	0.484	0.756	0.915	0.998
2019	0.01	0.209	0.542	0.765	0.916	0.998
2020	0.012	0.177	0.547	0.775	0.902	0.998
2021	0.014	0.169	0.429	0.706	0.889	0.998
2022	0.014	0.176	0.369	0.666	0.888	0.998

Table 4.12a. Cod in Subarea 4, Division 7.d and Subdivision 20: SAM final run estimated stock and management metrics, together with the lower and upper bounds of the pointwise 95% confidence intervals. Estimated recruitment, total stock biomass (TSB), spawning stock biomass (SSB), catches and average fishing mortality for ages 2 to 4 (Fbar 2–4).

	Recruits age 1 ('000)	Low	High	TSB (tonnes)	Low	High	SSB (tonnes)	Low	High	Catches (tonnes)	Low	High	Fbar 2-4	Low	High
1963	449510	325101	621528	314632	261652	378339	130008	80123	210952	117162	103474	132659	0.467	0.399	0.547
1964	735687	533113	1015236	360042	307700	421287	138781	86103	223690	145258	130807	161305	0.516	0.447	0.595
1965	979639	713234	1345551	457846	397012	528002	162934	101151	262454	199190	176808	224405	0.57	0.495	0.657
1966	1194064	869685	1639431	543430	475595	620940	182729	115173	289910	240928	214362	270787	0.574	0.501	0.658
1967	1014952	738586	1394730	608427	534342	692784	205473	132789	317943	288959	256522	325498	0.618	0.542	0.704
1968	506013	367655	696439	588496	523045	662137	210091	133952	329509	295242	266191	327462	0.656	0.574	0.749
1969	438652	316771	607428	482413	426581	545552	208384	139837	310530	225224	206812	245275	0.61	0.536	0.695
1970	1467939	1066185	2021080	536642	472893	608985	214001	150312	304676	251528	220468	286965	0.645	0.57	0.731
1971	1946869	1408511	2690997	644257	568117	730600	220706	162944	298945	352092	301053	411784	0.744	0.661	0.838
1972	481796	348298	666463	611979	542561	690280	201709	147688	275491	367636	319517	423001	0.817	0.726	0.918
1973	696540	504163	962323	453952	412384	499711	166664	117319	236765	258622	234428	285312	0.788	0.7	0.887
1974	691555	499679	957112	434984	391706	483043	178440	132020	241181	233796	208219	262514	0.745	0.661	0.841
1975	1185976	850247	1654271	418254	375863	465425	169172	133119	214989	245009	213499	281170	0.808	0.72	0.907
1976	804738	573430	1129349	396521	353652	444587	146145	116870	182752	247539	213725	286702	0.868	0.772	0.975
1977	1983363	1421056	2768175	413248	366716	465684	122551	98023	153217	257825	213262	311699	0.817	0.728	0.918
1978	1189443	851594	1661327	514729	451821	586397	118196	97571	143180	358339	295262	434890	0.924	0.826	1.034
1979	1484327	1062769	2073102	520239	467966	578350	118544	97678	143867	331690	284104	387248	0.836	0.746	0.937
1980	2352815	1677992	3299025	564300	501411	635076	118534	98637	142443	387219	321703	466077	0.923	0.828	1.029
1981	942610	673564	1319123	582484	517564	655547	128350	107964	152586	392815	333207	463086	0.931	0.836	1.037
1982	1471793	1066848	2030445	514108	464893	568532	129373	109814	152415	379092	323402	444372	1.055	0.952	1.17
1983	834246	620756	1121160	439635	393588	491070	108640	92702	127319	316220	269927	370452	1.034	0.933	1.146
1984	1495910	1122105	1994241	391119	354007	432121	96538	82101	113514	271176	232156	316754	0.964	0.87	1.07
1985	372120	271958	509170	361530	324360	402960	92457	78670	108660	236364	204932	272618	0.92	0.829	1.021

	Recruits age 1 ('000)	Low	High	TSB (tonnes)	Low	High	SSB (tonnes)	Low	High	Catches (tonnes)	Low	High	Fbar 2-4	Low	High
1986	1809813	1362158	2404583	324547	292024	360692	80509	68495	94631	229944	193276	273570	0.999	0.903	1.106
1987	707296	532364	939709	392695	346029	445655	83473	70841	98358	269187	226615	319757	0.972	0.878	1.076
1988	473232	350351	639213	305014	278914	333556	77979	65104	93401	210106	185636	237801	0.996	0.9	1.102
1989	841461	628081	1127334	257840	233703	284471	74678	64068	87044	181062	155844	210360	1.023	0.925	1.131
1990	339387	252975	455316	215674	194788	238798	66148	56924	76867	140690	122436	161667	0.949	0.854	1.054
1991	398750	300185	529679	187322	171103	205078	66167	57128	76638	121151	107061	137095	0.936	0.844	1.037
1992	959675	736133	1251100	229735	206151	256017	68067	59316	78109	145253	122834	171765	0.907	0.82	1.004
1993	436956	337912	565029	242717	217778	270512	69955	60060	81480	159741	137751	185241	0.977	0.883	1.081
1994	1068662	825589	1383301	231136	210053	254336	72371	62439	83883	149157	129089	172345	0.946	0.855	1.046
1995	687254	531867	888039	283824	255168	315700	77783	67219	90006	169352	145449	197183	0.876	0.788	0.973
1996	477313	367507	619927	261123	238333	286092	92947	80541	107266	158954	140243	180162	0.903	0.815	1.001
1997	1536169	1186489	1988906	305417	272803	341931	95003	83757	107759	182384	154173	215757	0.926	0.839	1.022
1998	146708	109958	195739	276788	245383	312213	98655	83956	115927	186372	160499	216415	1.121	1.023	1.229
1999	312329	236898	411779	154071	142818	166211	79256	69143	90848	110543	100461	121637	1.146	1.048	1.253
2000	452206	347432	588577	133984	120797	148611	56024	49448	63474	91636	79406	105750	1.164	1.06	1.279
2001	182378	138995	239303	107460	97117	118904	43396	37419	50327	59300	52060	67548	0.868	0.783	0.963
2002	260328	197737	342733	93471	85924	101682	46672	40774	53423	62284	55955	69330	1.06	0.956	1.175
2003	120773	91684	159090	73619	66921	80987	34951	30466	40097	38361	34153	43086	0.752	0.668	0.846
2004	241673	183692	317956	63631	57884	69949	33284	29319	37784	35149	31762	38898	0.8	0.715	0.895
2005	188651	143154	248608	71984	64761	80012	32115	27791	37112	41965	36892	47735	0.82	0.734	0.916
2006	419451	323844	543286	88552	79022	99231	34250	29287	40055	32836	29007	37172	0.729	0.647	0.823
2007	187496	143673	244686	105791	94327	118649	45228	38452	53199	53128	46367	60873	0.665	0.586	0.754
2008	212742	163554	276724	124130	111790	137831	64552	55333	75308	51924	46984	57384	0.641	0.561	0.731
2009	237406	180887	311584	121084	107669	136172	64841	55343	75970	54719	49278	60760	0.624	0.539	0.722
2010	306690	237775	395578	132898	116513	151588	67558	56417	80900	49057	44339	54276	0.523	0.446	0.613

	Recruits age 1 ('000)	Low	High	TSB (tonnes)	Low	High	SSB (tonnes)	Low	High	Catches (tonnes)	Low	High	Fbar 2-4	Low	High
2011	143469	108955	188917	135650	116440	158030	76022	61739	93610	43236	39165	47732	0.404	0.346	0.472
2012	222444	169085	292642	141509	121702	164539	80146	64855	99042	39330	36280	42637	0.372	0.318	0.436
2013	250277	191475	327137	142052	121944	165476	80573	65220	99539	41143	37700	44899	0.369	0.316	0.431
2014	314562	243508	406349	155555	134777	179537	78684	63763	97096	44820	40858	49166	0.375	0.323	0.435
2015	147637	113640	191806	170572	148148	196390	83779	67662	103735	49896	45475	54747	0.381	0.331	0.439
2016	104054	79620	135986	153707	133852	176507	84453	68778	103700	49892	46206	53873	0.378	0.328	0.436
2017	318892	243442	417726	141930	123333	163331	83907	68839	102274	46493	43152	50093	0.424	0.37	0.486
2018	71266	54500	93189	123486	106516	143160	73492	59881	90197	48683	44508	53250	0.539	0.468	0.621
2019	136603	104449	178656	90970	76544	108114	58536	46192	74179	36194	33469	39141	0.496	0.424	0.582
2020	228698	168068	311200	82202	68426	98752	43590	33451	56801	21898	19933	24058	0.369	0.307	0.443
2021	132685	90228	195120	94260	77238	115034	43189	32567	57277	21505	18956	24396	0.257	0.205	0.323
2022	167384	73733	379983	115085	89474	148026	52241	38721	70482						

Table 4.12b. Cod in Subarea 4, Division 7.d and Subdivision 20: SAM final run estimated landings, discards (including BMS landings from 2016) and catch (=landings + discards). Landings and discards are derived by applying the landing fraction from landings and discards data to the SAM estimate of catch.

Year	Landings	Discards	Catch
1963	106122	11039	117167
1964	135133	10129	145256
1965	181140	18074	199200
1966	213701	27279	240928
1967	261142	27787	288963
1968	277574	17643	295240
1969	215678	9566	225223
1970	231375	20165	251525
1971	292584	59514	352085
1972	332560	35046	367639
1973	233926	24686	258622
1974	208026	25790	233790
1975	208964	36012	245013
1976	203640	43942	247541
1977	181249	76668	257822
1978	310334	47971	358340
1979	273872	57847	331683
1980	292656	94744	387224
1981	341727	51023	392810
1982	321681	57402	379090
1983	281964	34304	316222
1984	208635	62470	271174
1985	209896	26472	236364
1986	169733	60277	229943
1987	234541	34539	269189
1988	195003	15033	210108
1989	139573	41525	181058
1990	116651	24031	140692
1991	104476	16640	121152
1992	111458	33741	145248
1993	131422	28294	159742
1994	106061	43084	149160
1995	135088	34315	169355
1996	135638	23286	158955
1997	135088	47334	182387
1998	144778	41518	186366
1999	96210	14347	110541
2000	75185	16458	91637
2001	46888	12386	59296
2002	51198	11084	62280
2003	33124	5228	38363
2004	27211	7941	35153

Year	Landings	Discards	Catch
2005	30067	11905	41967
2006	22959	9876	32836
2007	23913	29216	53123
2008	26811	25123	51929
2009	32967	21742	54715
2010	36197	12867	49060
2011	33488	9755	43237
2012	32079	7249	39328
2013	30545	10603	41140
2014	34382	10438	44819
2015	37461	12432	49890
2016	38011	11880	49895
2017	37643	8851	46488
2018	40390	8289	48685
2019	32387	3815	36195
2020	18661	3234	21898
2021	16257	5244	21501

Table 4.13. Cod in Subarea 4, Division 7.d and Subdivision 20: Catch scenarios based on the SAM assessment and assuming a 27% overshoot of the TAC in the intermediate year. Units are tonnes (SSB, landings, discards and catch) or thousands (recruitment).

Forecast assumptions

Variable	Value
Fbar(2022)	0.208
SSB(2023)	69023
R(2022)	169492
R(2023)	212742
Catch(2022)	20207
Landings(2022)	17064
Discards(2022)	3143

Catch scenarios

Basis	Catch (2023)	Landings (2023)	Discards (2023)	F_{total} (2023)	$F_{landings}$ (2023)	$F_{discards}$ (2023)	SSB (2024)	% SSB change	% TAC change	% advice change	Risk
MSY approach	22946	19500	3446	0.198	0.157	0.041	84197	22	44	61	0.169
$F_{MSY\ lower}$ x SSB(2023) / $B_{trigger}$	15752	13439	2313	0.131	0.104	0.027	90115	31	-1.00	10.3	0.095
F=0	0	0	0	0.00	0.00	0.00	103498	50	-100	-100	0.0160
F_{pa}	49839	41862	7977	0.49	0.39	0.101	62613	-9.3	210	250	0.68
F_{lim}	56773	47488	9285	0.58	0.46	0.119	57552	-16.6	260	300	0.80
SSB(2024)=B_{lim}	40682	34292	6390	0.38	0.30	0.078	69841	1.19	156	185	0.50
SSB(2024)=$B_{trigger}$=B_{pa}	6647	5678	969	0.053	0.042	0.0110	97775	42	-58	-53	0.039
TAC(2022)-20%	12729	10866	1863	0.105	0.083	0.022	92686	34	-20.0	-10.8	0.074
TAC(2022)-15%	13524	11537	1987	0.112	0.089	0.023	92031	33	-15.0	-5.3	0.080
TAC(2022)-10%	14320	12215	2105	0.119	0.094	0.025	91286	32	-10.0	0.31	0.084
TAC(2022)-5%	15115	12893	2222	0.126	0.100	0.026	90638	31	-5.0	5.9	0.089
Constant TAC	15911	13573	2338	0.133	0.105	0.028	89985	30	0.00	11.5	0.096
TAC(2022)+5%	16707	14248	2459	0.140	0.111	0.029	89323	29	5.0	17.0	0.107
TAC(2022)+10%	17502	14922	2580	0.147	0.117	0.030	88622	28	10.0	23	0.113
TAC(2022)+15%	18298	15597	2701	0.154	0.123	0.031	87992	27	15.0	28	0.122
TAC(2022)+20%	19093	16275	2818	0.162	0.128	0.034	87348	27	20.0	34	0.131
F=F_{2022}	23981	20377	3604	0.21	0.165	0.043	83358	21	51	68	0.182
$F_{msy\ lower}$	21721	18473	3248	0.186	0.148	0.038	85182	23	37	52	0.156
F_{msy}	31261	26495	4766	0.28	0.22	0.057	77687	12.6	96	119	0.30
$F_{msy\ upper}$	46507	39174	7333	0.45	0.36	0.092	65176	-5.6	192	230	0.62

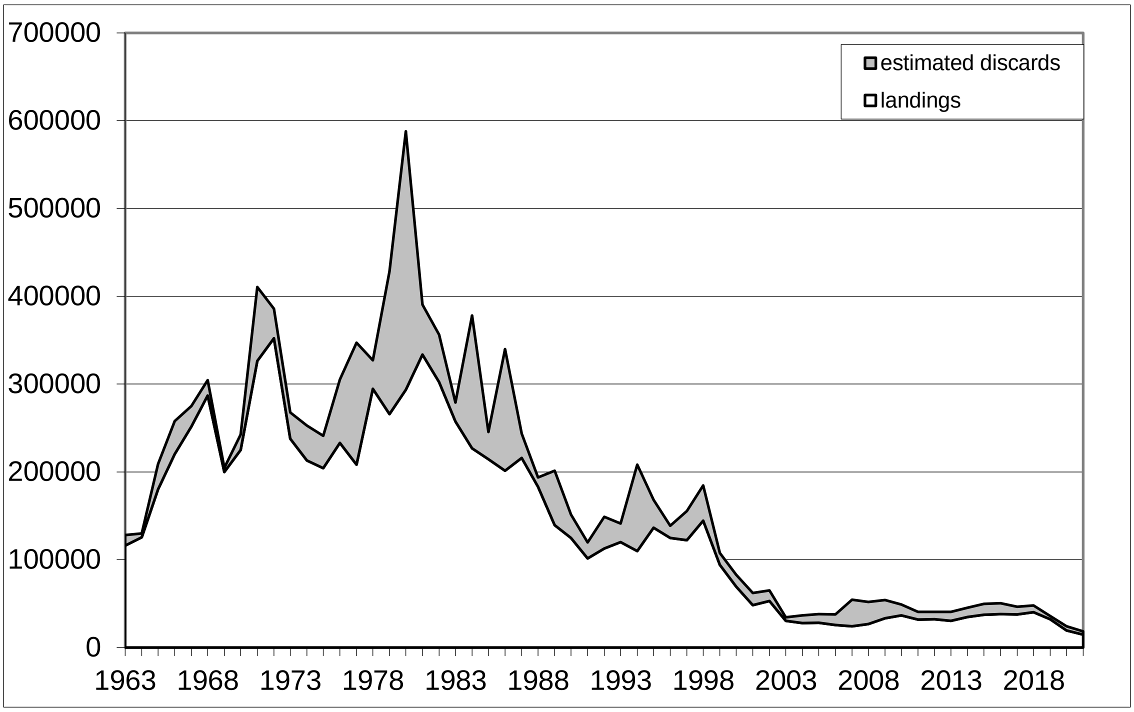

Figure 4.1a. Cod in Subarea 4, Division 7.d and Subdivision 20: stacked area plot of reported landings and estimated discards (including BMS landings; in tonnes).

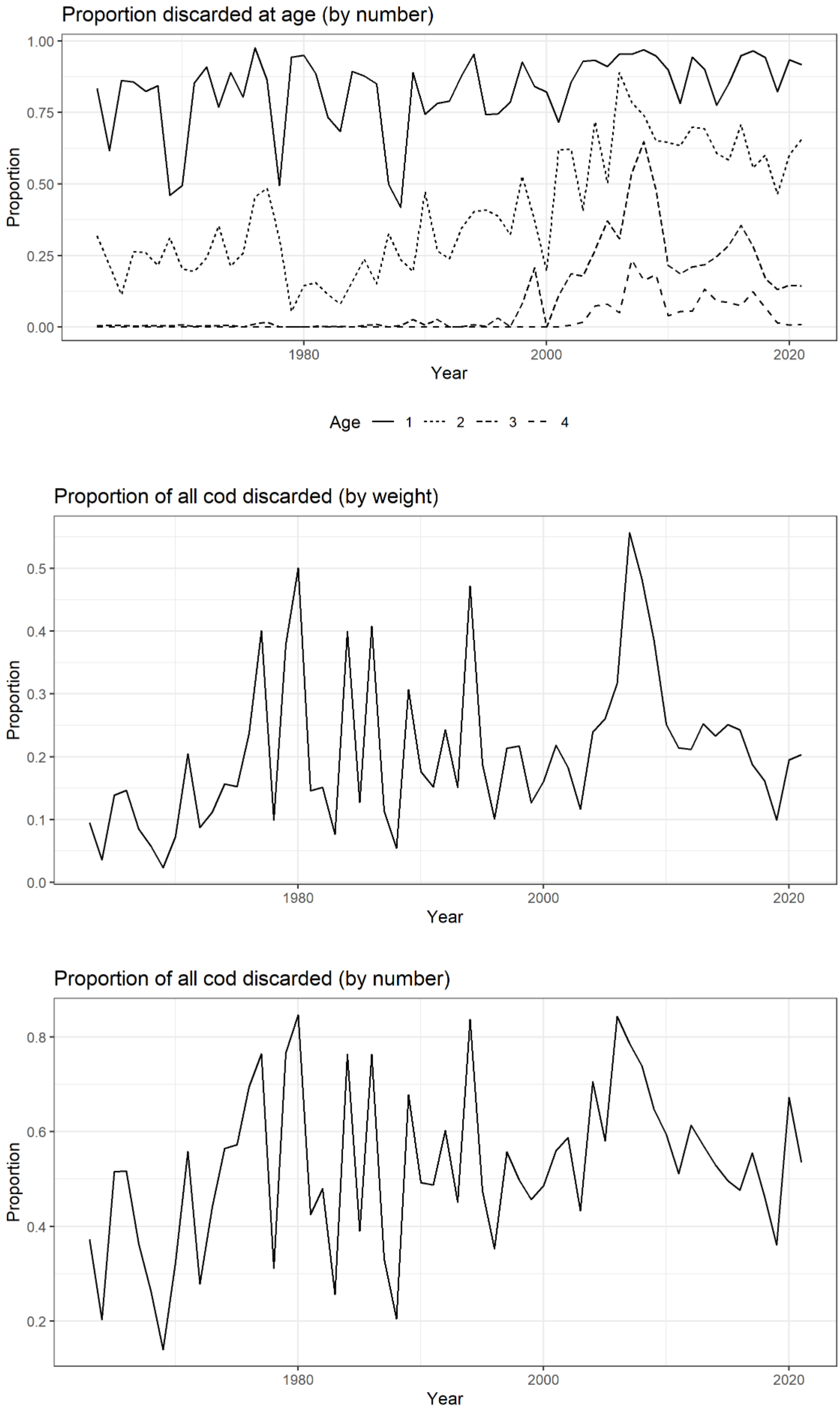

Figure 4.1b. Cod in Subarea 4, Division 7.d and Subdivision 20: (top) proportion of total numbers caught at age that are discarded; (middle) proportion of total weight caught that is discarded; and (bottom) proportion of the total numbers caught that are discarded.

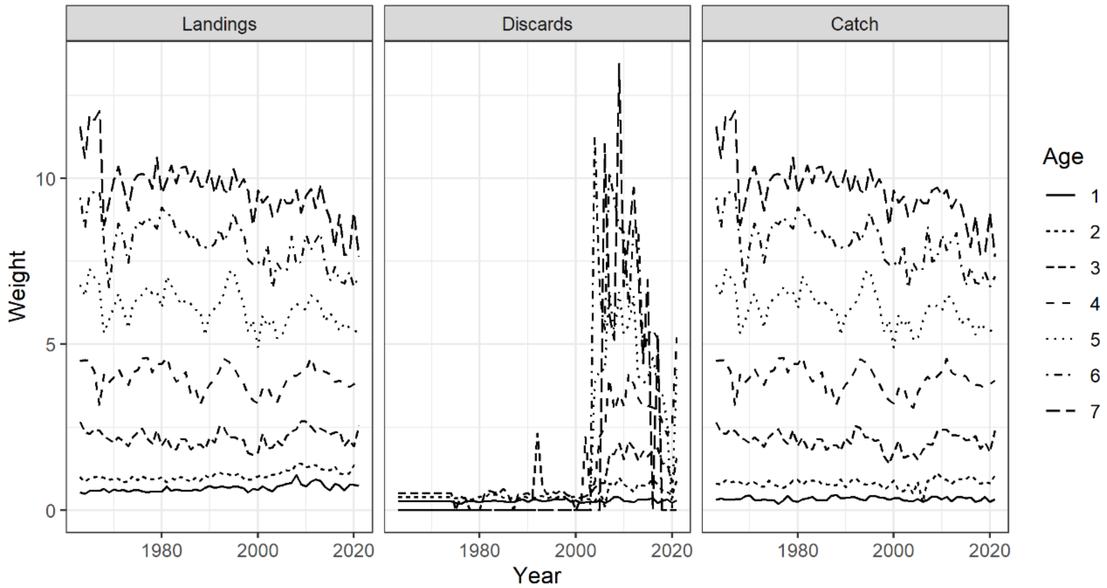

Figure 4.2a. Cod in Subarea 4, Division 7.d and Subdivision 20: Mean weights at age by catch component for ages 1–7.

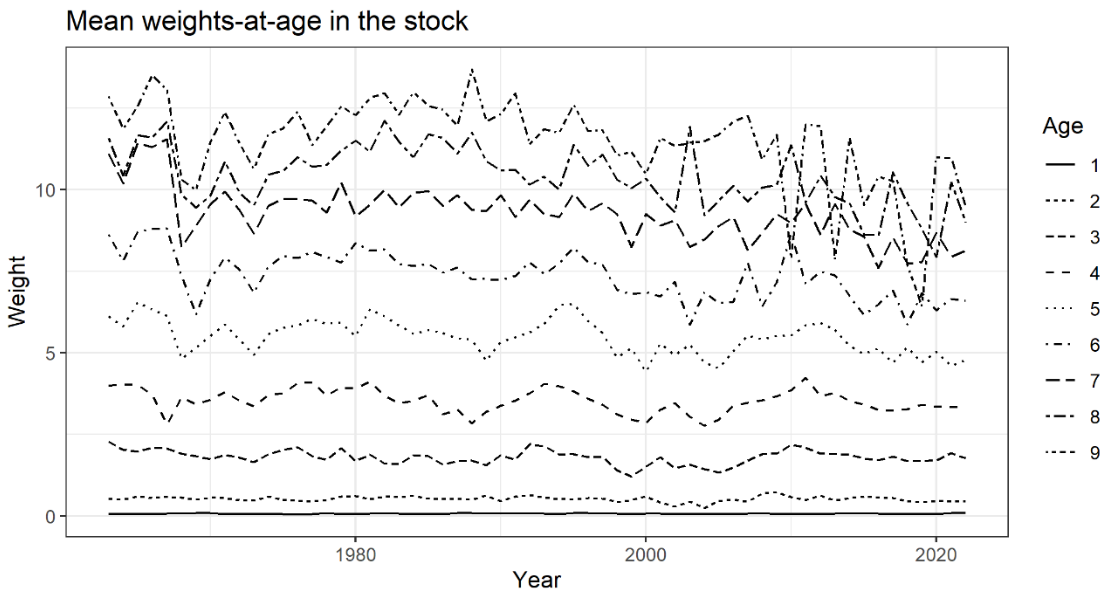

Figure 4.2b. Cod in Subarea 4, Division 7.d and Subdivision 20: Mean weights at age in the stock. Values for 2022 are derived from NS–IBTS–Q1 survey data for ages 1–2 and taken as a three-year average for ages 3+.

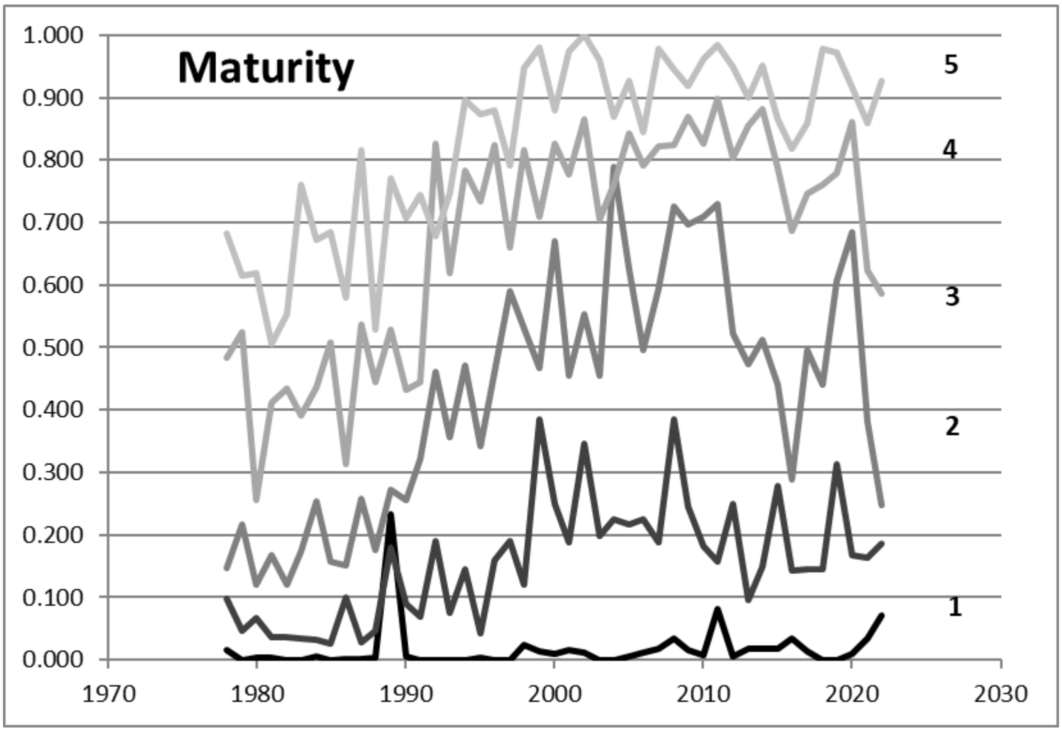

Figure 4.2c. Cod in Subarea 4, Division 7.d and Subdivision 20: Annually varying maturity-at-age.

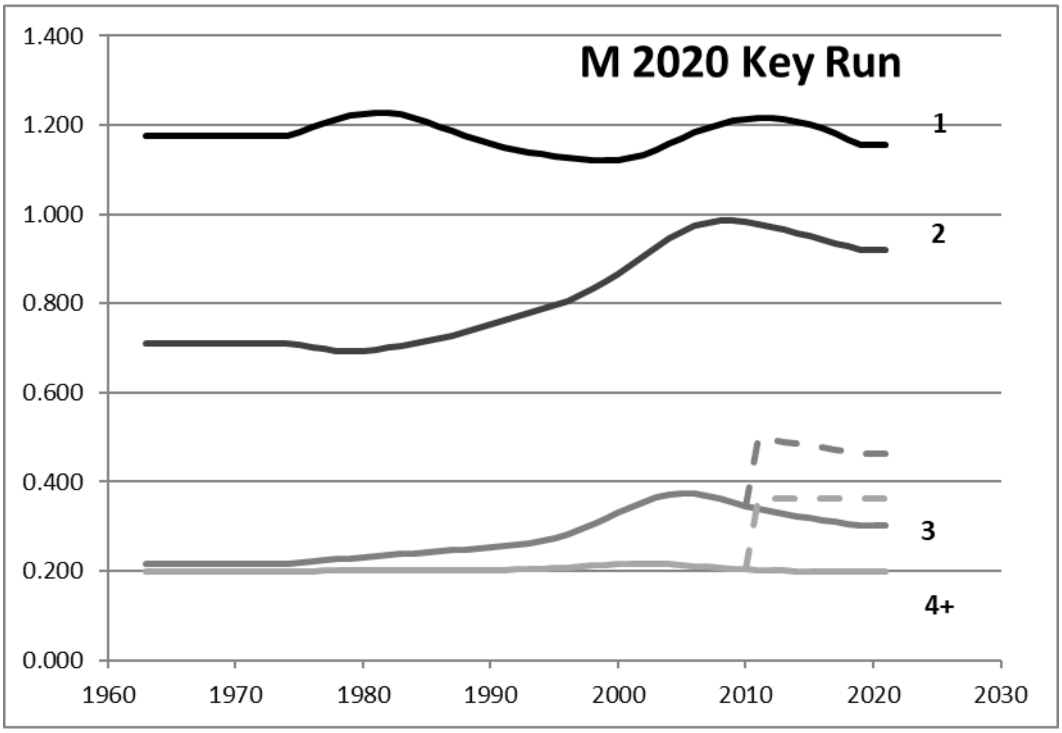

Figure 4.2d. Cod in Subarea 4, Division 7.d and Subdivision 20: Smoothed, annually varying natural mortality from the 2020 key run (solid lines; ICES WGSAM, 2020). Values for 1963–1973 are set equal to the 1974 value, while values for 2020–2021 are set equal to 2019. An ad hoc adjustment is made for ages 3+ to mimic a 15% emigration from the assessment area from 2011 (dashed lines).

Figure 4.3a. Cod in Subarea 4, Division 7.d and Subdivision 20: Distribution charts of cod ages 1–3+ caught in the IBTS–Q1 survey 2003–2022 in the North Sea.

Figure 4.3a contd. Cod in Subarea 4, Division 7.d and Subdivision 20: Distribution charts of cod ages 1–3+ caught in the IBTS–Q1 survey 2003–2022 in the North Sea.

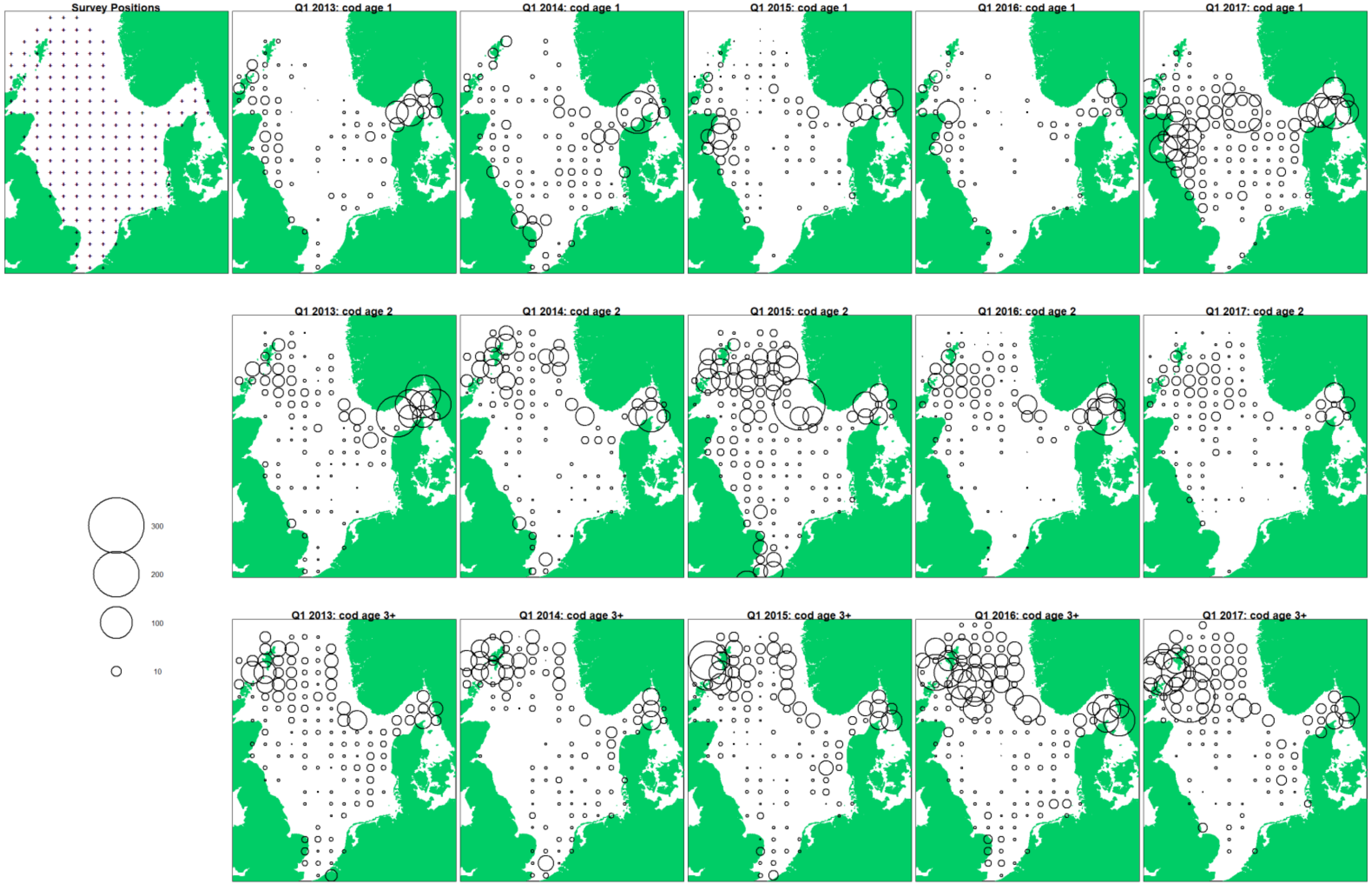

Figure 4.3a contd. Cod in Subarea 4, Division 7.d and Subdivision 20: Distribution charts of cod ages 1–3+ caught in the IBTS–Q1 survey 2003–2022 in the North Sea.

Figure 4.3a contd. Cod in Subarea 4, Division 7.d and Subdivision 20: Distribution charts of cod ages 1–3+ caught in the IBTS–Q1 survey 2003–2022 in the North Sea.

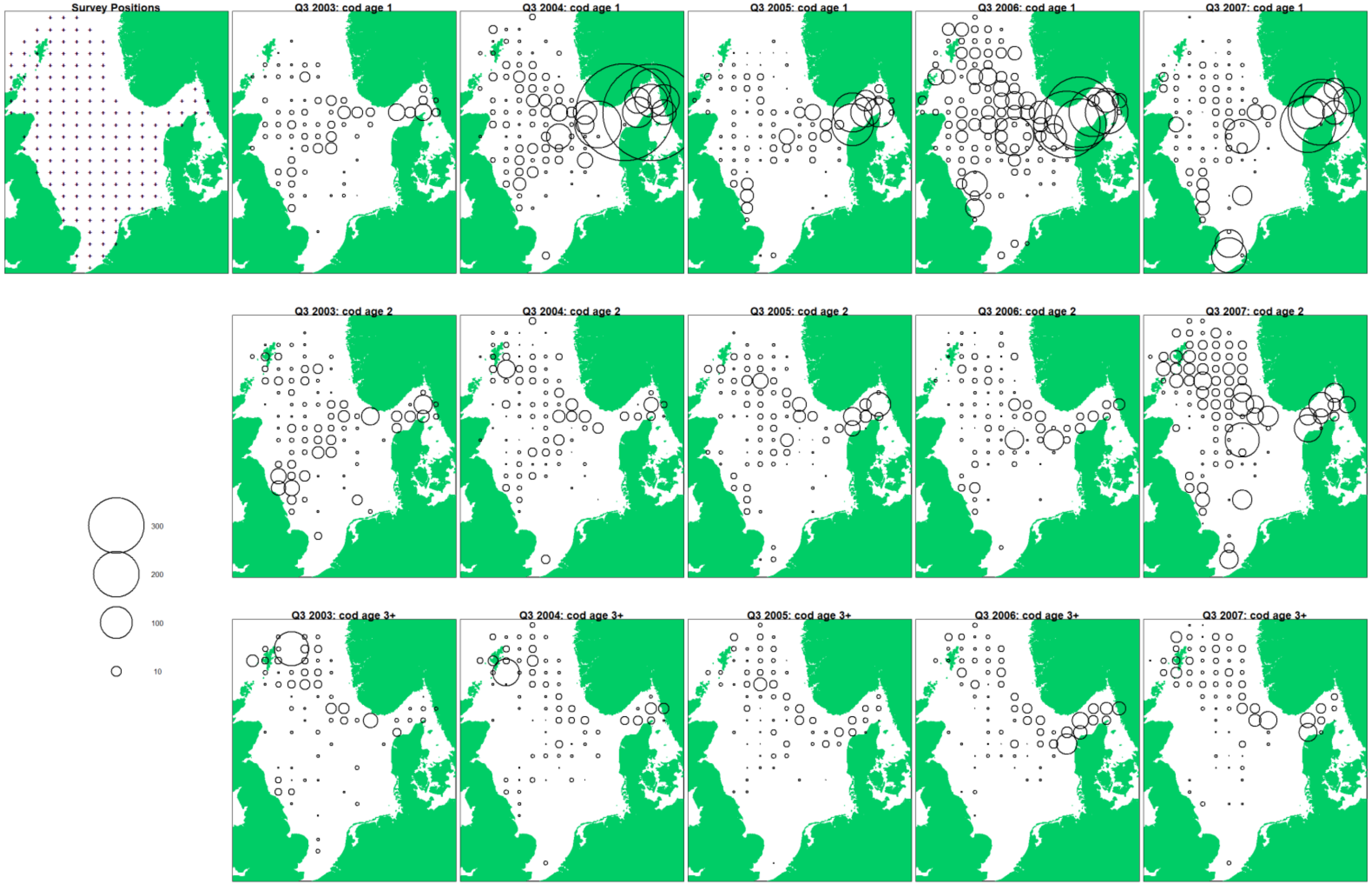

Figure 4.3b. Cod in Subarea 4, Division 7.d and Subdivision 20: Distribution charts of cod ages 1–3+ caught in the IBTS–Q3 survey 2003–2021 in the North Sea.

Figure 4.3b contd. Cod in Subarea 4, Division 7.d and Subdivision 20: Distribution charts of cod ages 1–3+ caught in the IBTS–Q3 survey 2003–2021 in the North Sea.

Figure 4.3b contd. Cod in Subarea 4, Division 7.d and Subdivision 20: Distribution charts of cod ages 1–3+ caught in the IBTS–Q3 survey 2003–2021 in the North Sea.

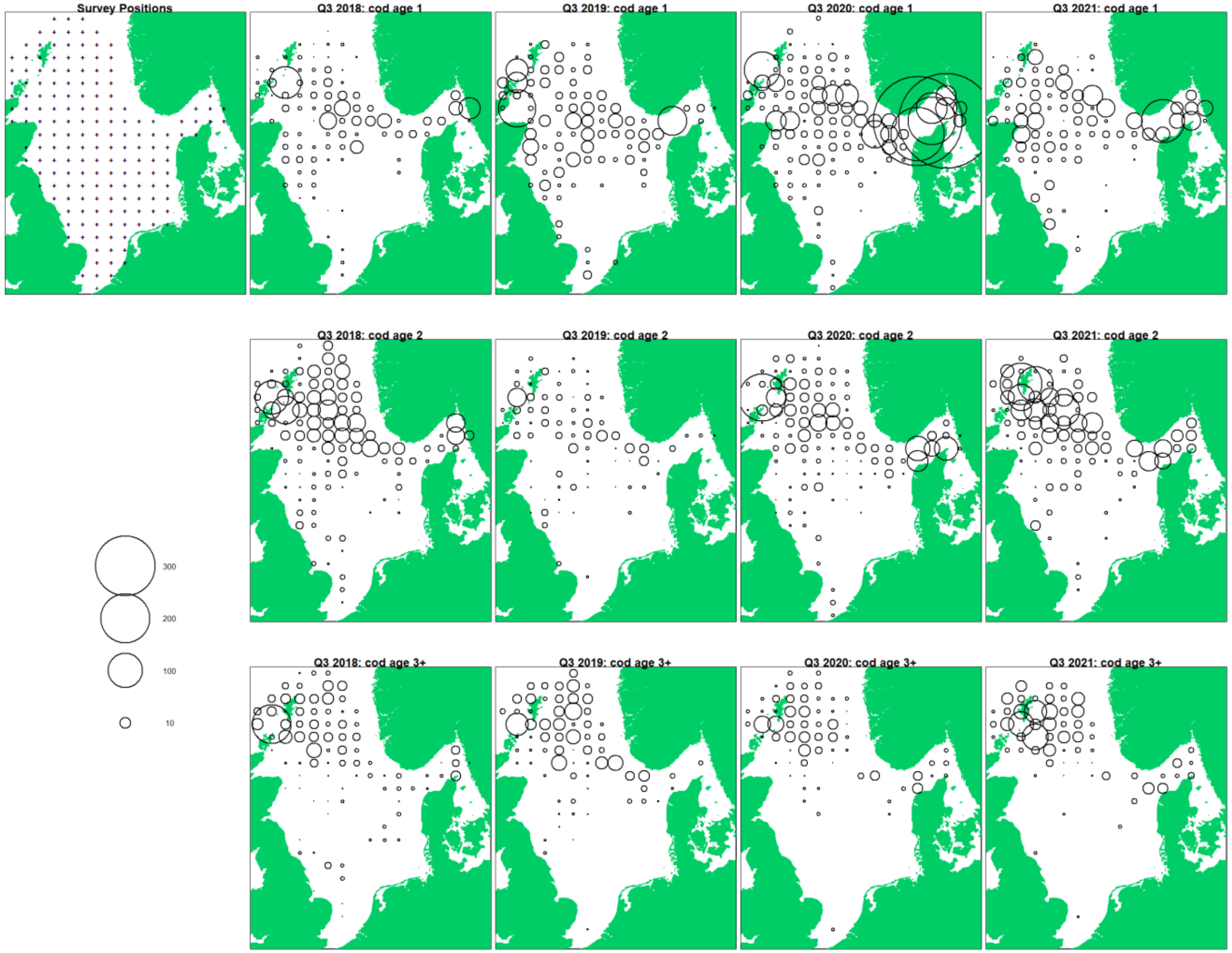

Figure 4.3b contd. Cod in Subarea 4, Division 7.d and Subdivision 20: Distribution charts of cod ages 1–3+ caught in the IBTS–Q3 survey 2003–2021 in the North Sea.

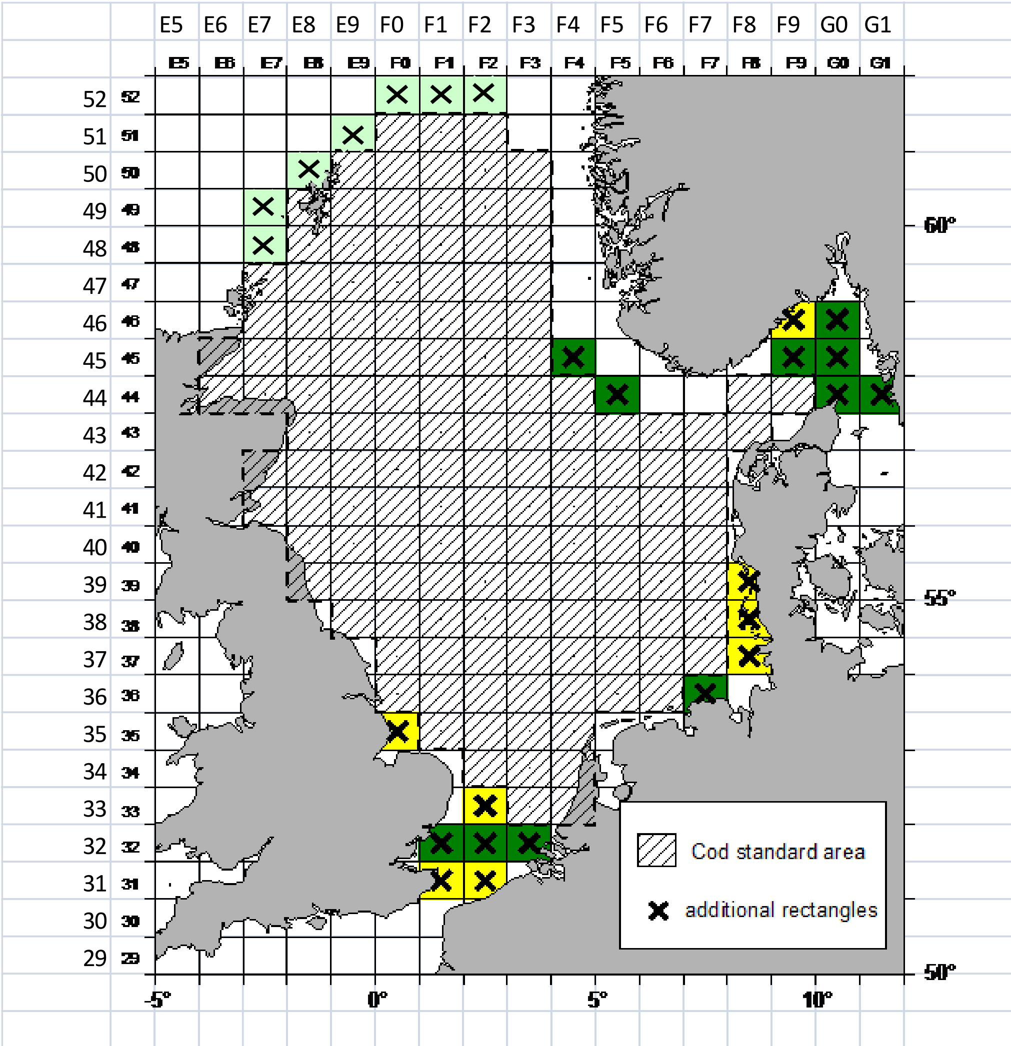

Figure 4.3c. Cod in Subarea 4, Division 7.d and Subdivision 20: Extension of cod standard area used for the NS–IBTS extended index. Crosses indicate suggested extensions to the survey (ICES WKROUND, 2009; ICES WKCOD, 2011); green squares (light and dark) indicate where the IBTS group indicate data is available; yellow squares indicate where intermittent coverage does not allow inclusion and the IBTS WG considered should be omitted; light green squares indicate the recommended extension around Shetland (ICES WKCOD, 2011).

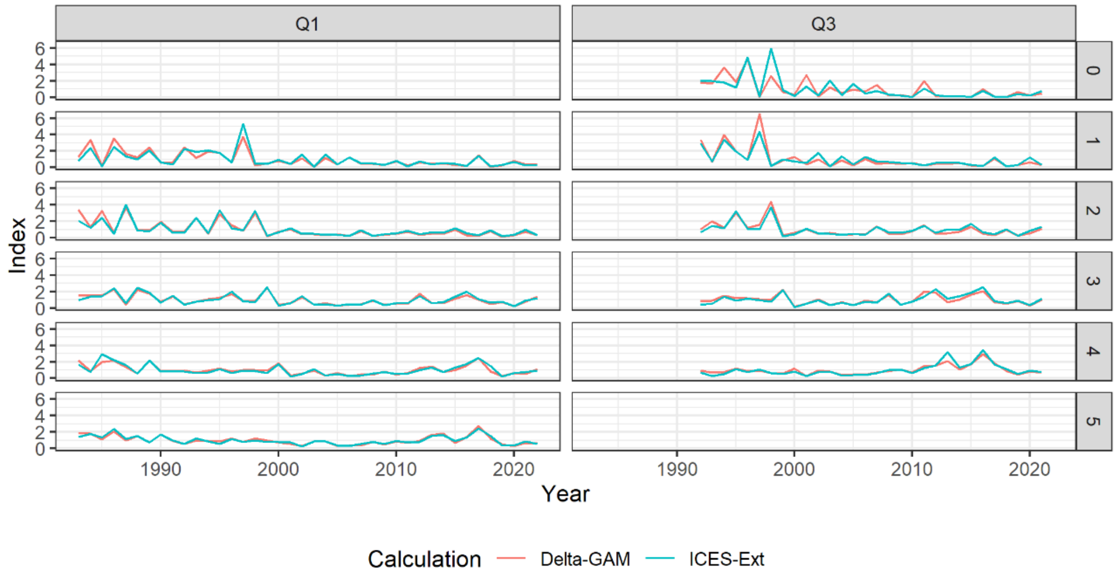

Figure 4.3d. Cod in Subarea 4, Division 7.d and Subdivision 20: Comparison of the Q1 and Q3 NS–IBTS Delta–GAM indices used in the assessment to the corresponding NS–IBTS extended indices (ICES-Ext). The indices are mean-standardised. Note the index for age 0 is forward shifted to represent age 1 in the assessment.

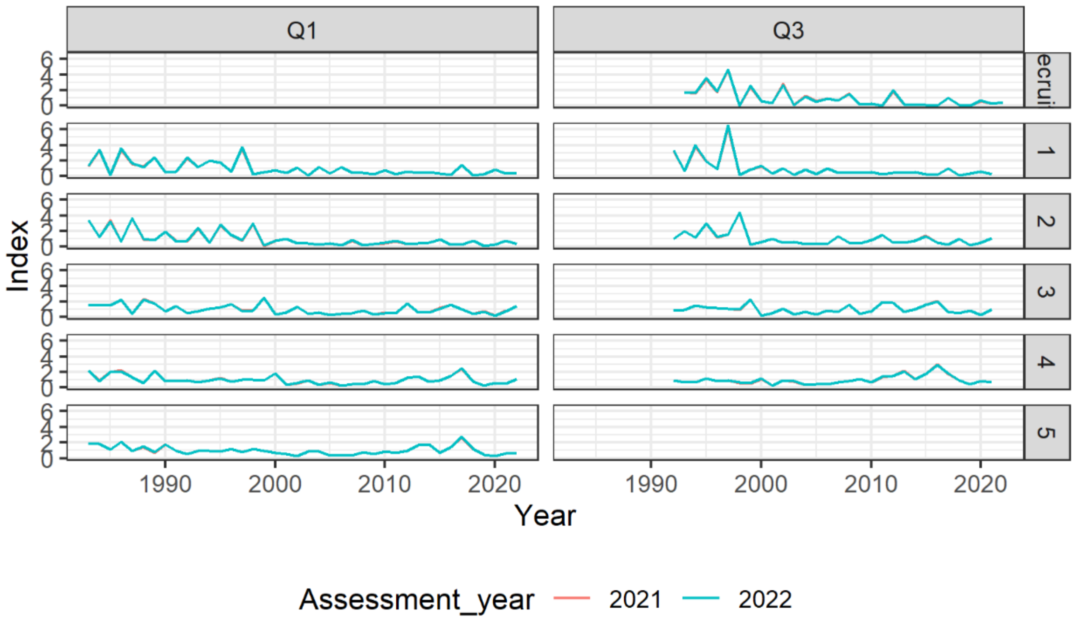

Figure 4.3e. Cod in Subarea 4, Division 7.d and Subdivision 20: Comparison of the Q1 and Q3 NS–IBTS Delta–GAM indices used in the assessment to the corresponding Delta-GAM indices used in the 2021 assessment (ICES WGNSSK 2021). The indices are mean-standardised.

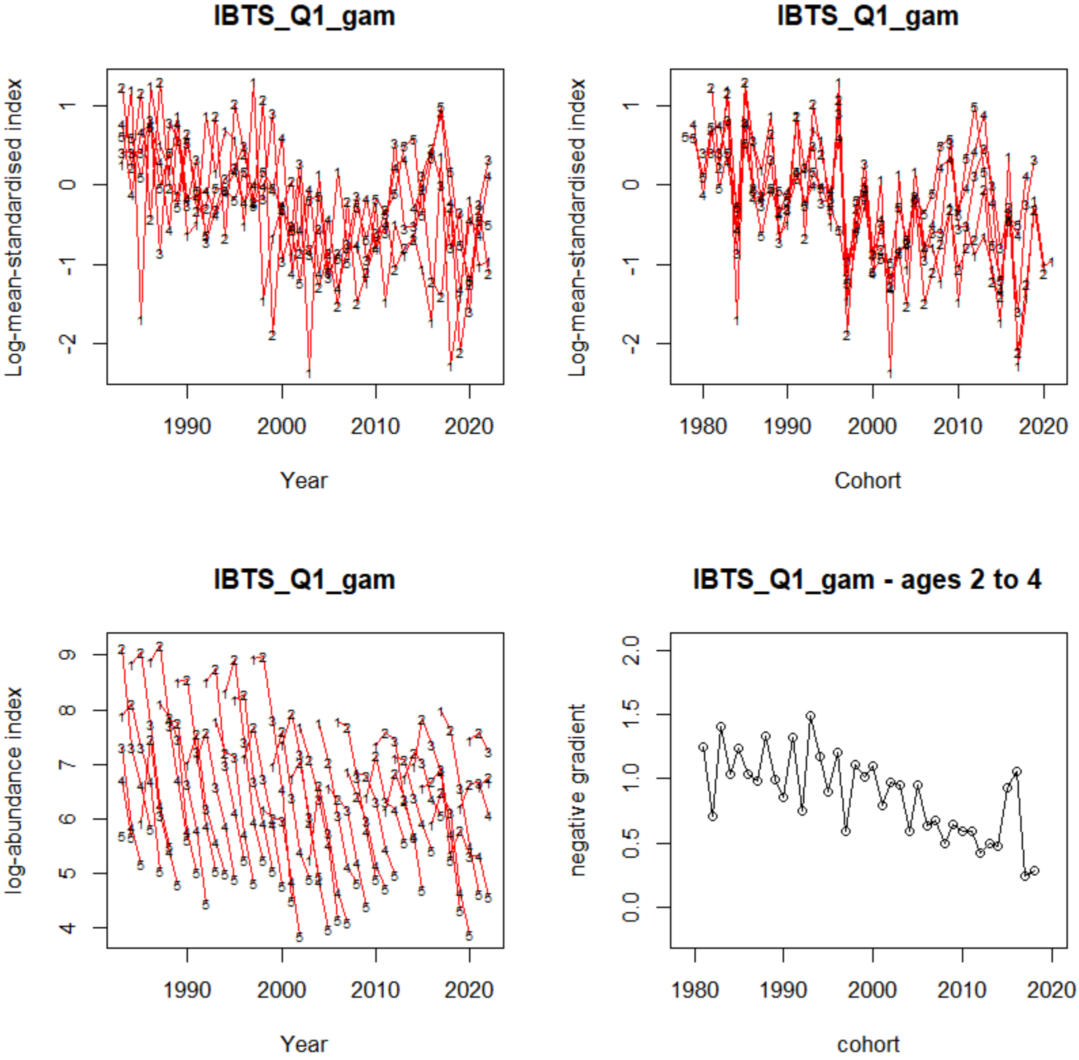

Figure 4.4a. Cod in Subarea 4, Division 7.d and Subdivision 20: Log mean standardised indices plotted by year (top left) and cohort (top right), log abundance curves (bottom left) and associated negative gradients for each cohort across the reference fishing mortality of age 2–4 (bottom right), for the IBTS–Q1 groundfish survey (NS–IBTS Delta–GAM index).

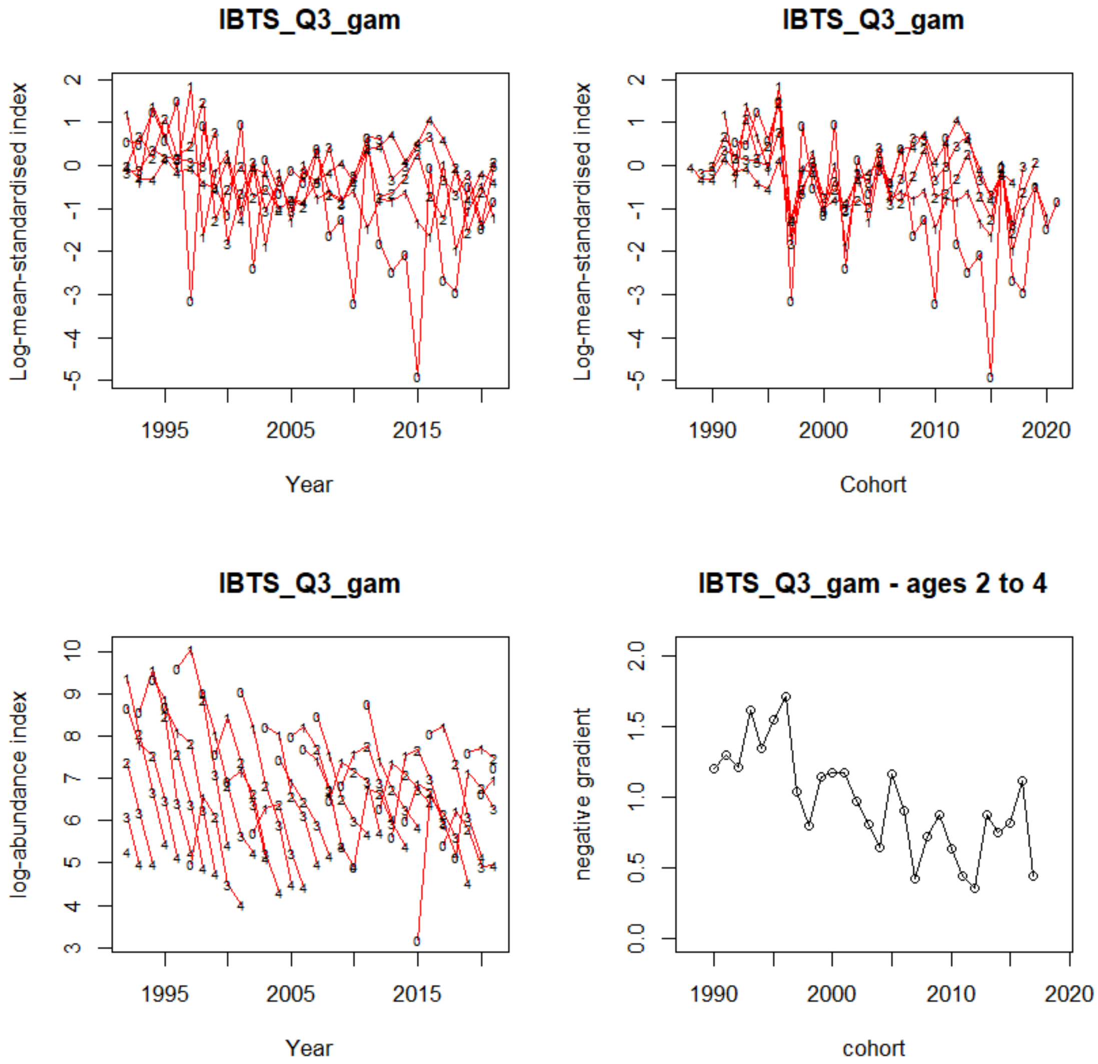

Figure 4.4b. Cod in Subarea 4, Division 7.d and Subdivision 20: Log mean standardised indices plotted by year (top left) and cohort (top right), log abundance curves (bottom left) and associated negative gradients for each cohort across the reference fishing mortality of age 2–4 (bottom right), for the IBTS–Q3 groundfish survey (NS–IBTS Delta–GAM index).

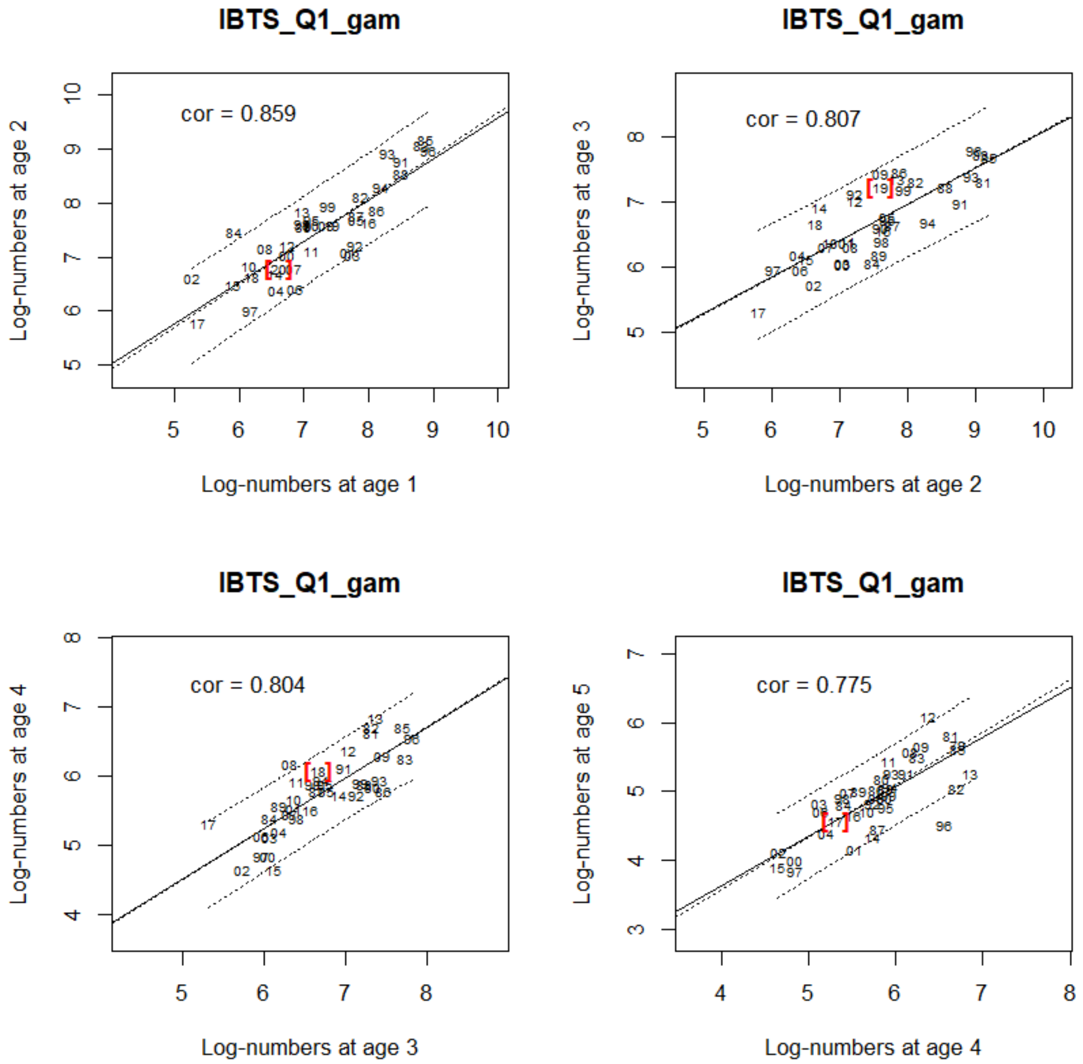

Figure 4.5a. Cod in Subarea 4, Division 7.d and Subdivision 20: Within survey correlations for IBTS–Q1 (NS–IBTS Delta–GAM index) for the period 1983–2022. Individual points are given by cohort (year-class), the solid line is a standard linear regression line, the broken line nearest to it a robust linear regression line, and “cor” denotes the correlation coefficient. The pair of broken lines on either side of the solid line indicate prediction intervals. The most recent data point appears in red square brackets.

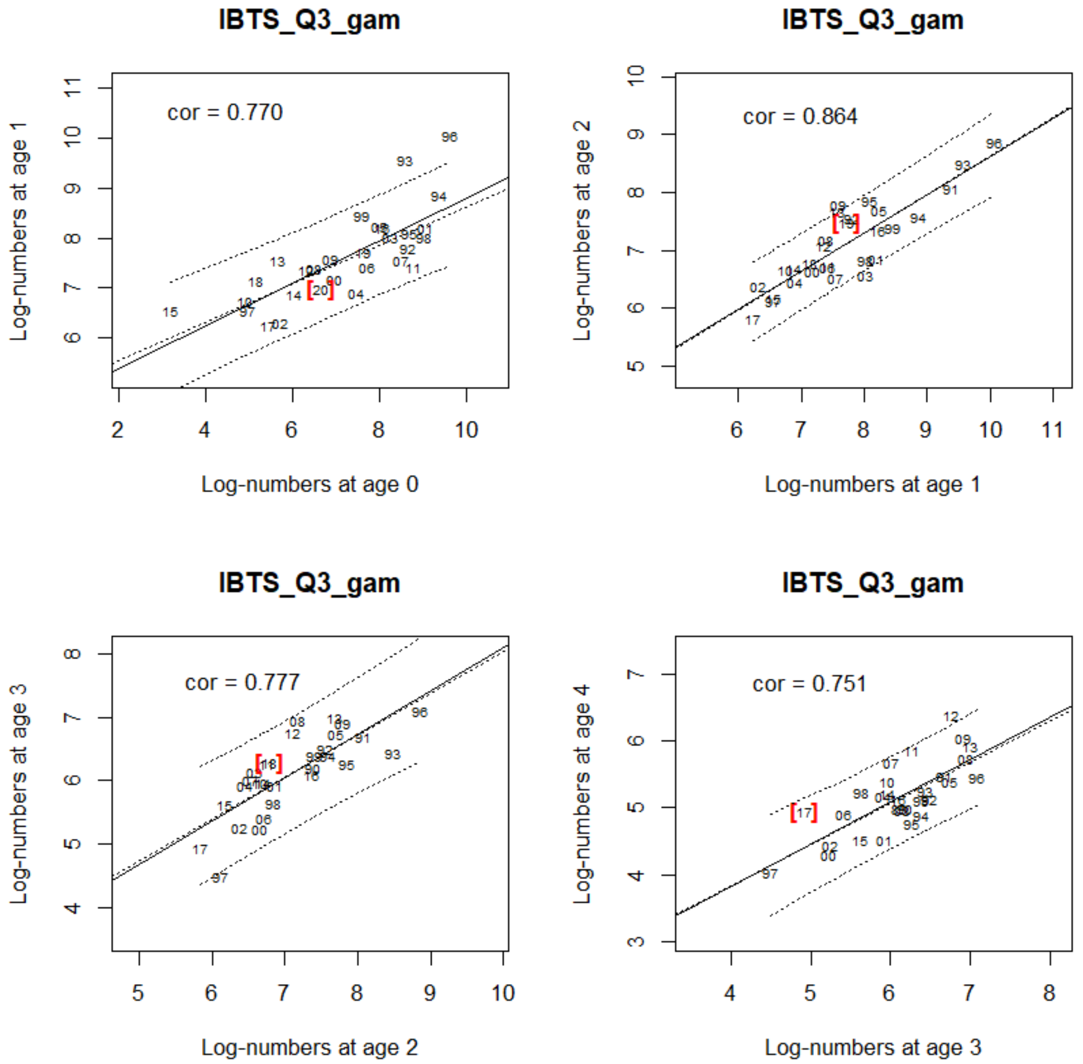

Figure 4.5b. Cod in Subarea 4, Division 7.d and Subdivision 20: Within-survey correlations for IBTS–Q3 (NS–IBTS Delta–GAM index) for the period 1992–2021. Individual points are given by cohort (year-class), the solid line is a standard linear regression line, the broken line nearest to it a robust linear regression line, and "cor" denotes the correlation coefficient. The pair of broken lines on either side of the solid line indicate prediction intervals. The most recent data point appears in red square brackets.

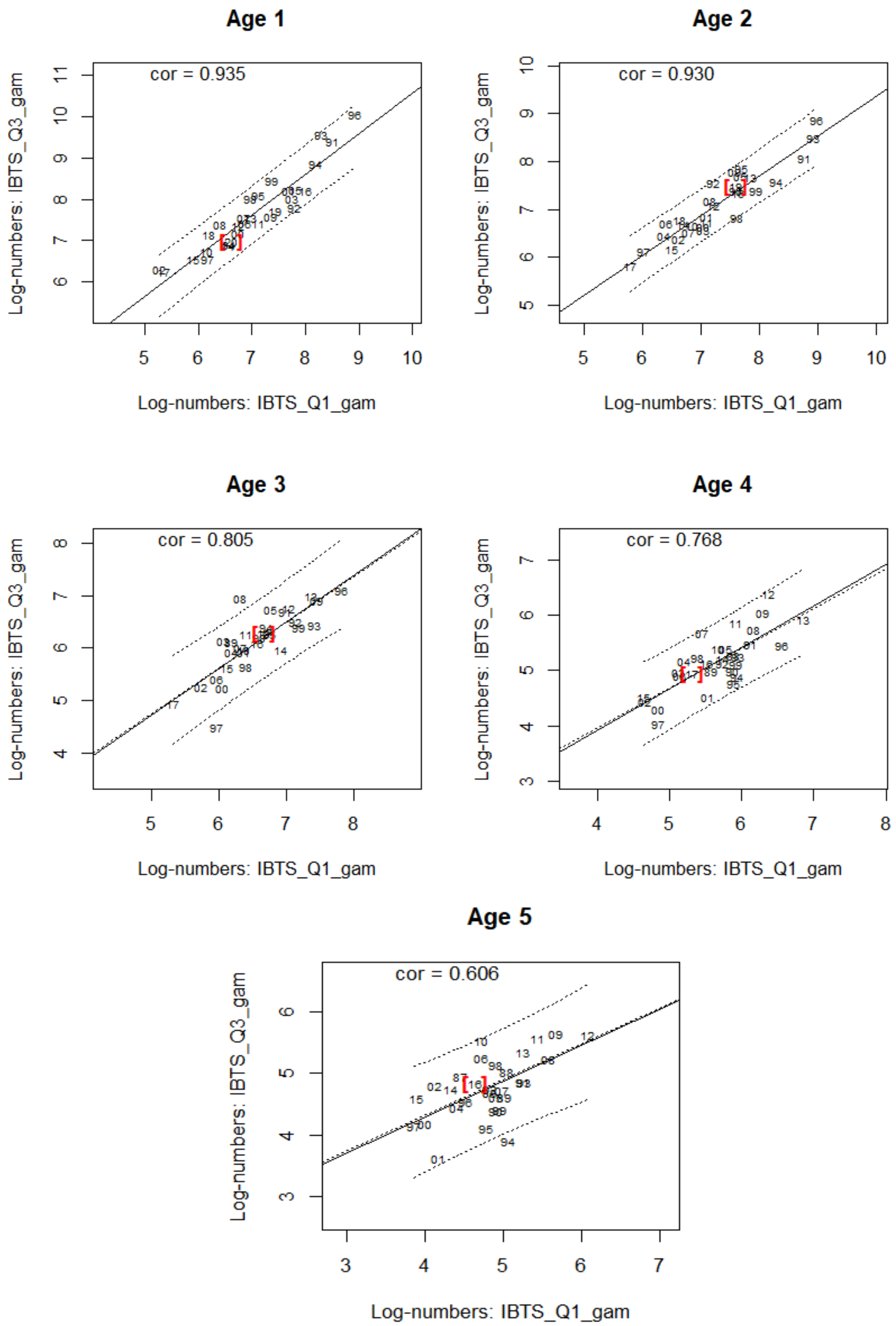

Figure 4.5c. Cod in Subarea 4, Division 7.d and Subdivision 20: Between-survey correlations for IBTS–Q1 and Q3 surveys (NS–IBTS Delta–GAM indices) for the period 1992–2021. Individual points are given by cohort (year-class), the solid line is a standard linear regression line, and the broken line nearest to it a robust linear regression line. The pair of broken lines on either side of the solid line indicate prediction intervals. The most recent data point appears in red square brackets.

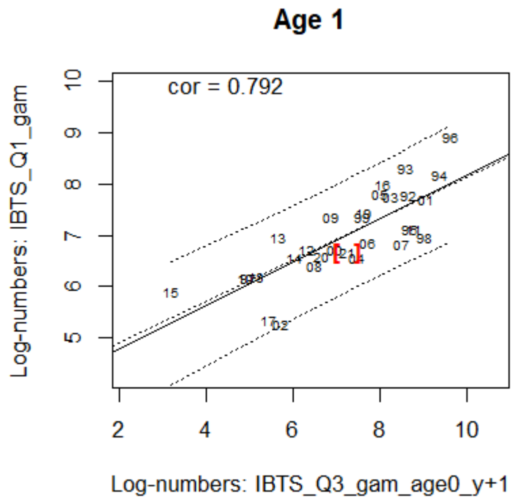

Figure 4.5d. Cod in Subarea 4, Division 7.d and Subdivision 20: Between-survey correlations for the IBTS–Q1 age 1 and IBTS–Q3 recruitment indices (age 0 forward shifted to 1st January the following year) for the period 1993–2022. Individual points are given by cohort (year-class), the solid line is a standard linear regression line, and the broken line nearest to it a robust linear regression line. The pair of broken lines on either side of the solid line indicate prediction intervals. The most recent data point appears in red square brackets.

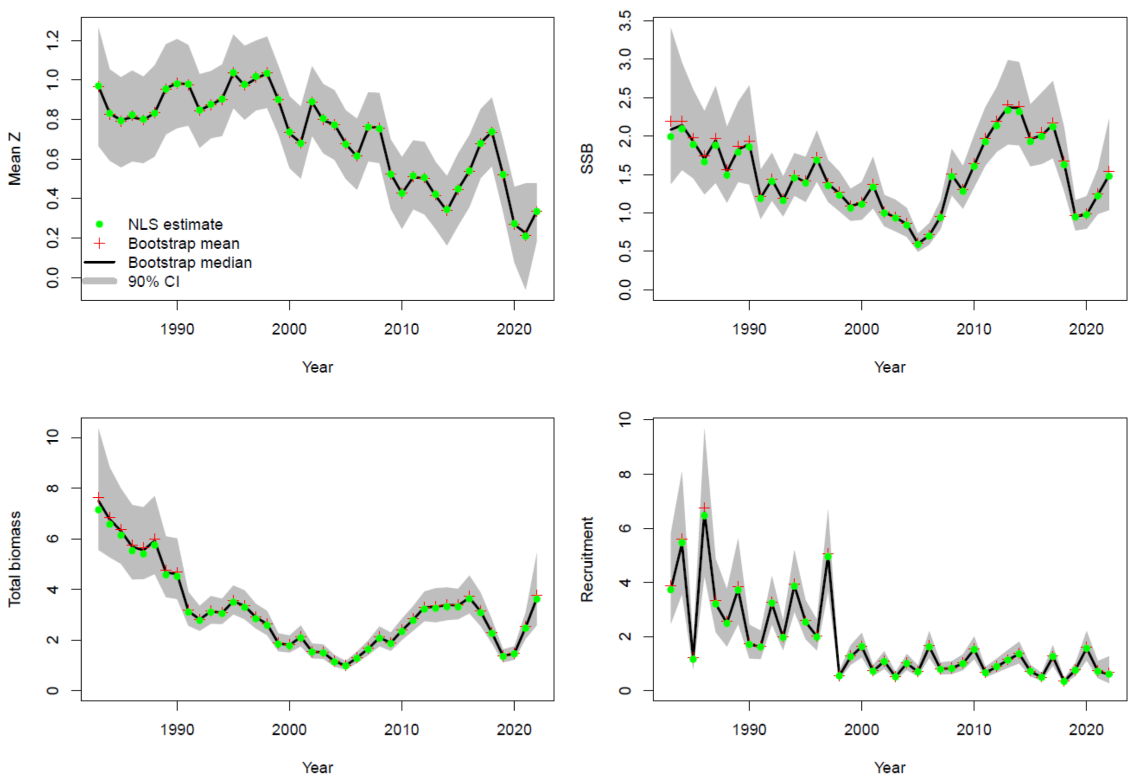

Figure 4.6a. Cod in Subarea 4, Division 7.d and Subdivision 20: SURBAR summary plots for estimates of total mortality, spawning stock biomass, total biomass and recruitment for a combined SURBAR run with both surveys (Q1 and Q3 NS–IBTS Delta–GAM indices, ages 1–5). The smoothing parameter l is set to 3, and reference age at 3. The shaded area represents 90% confidence bounds.

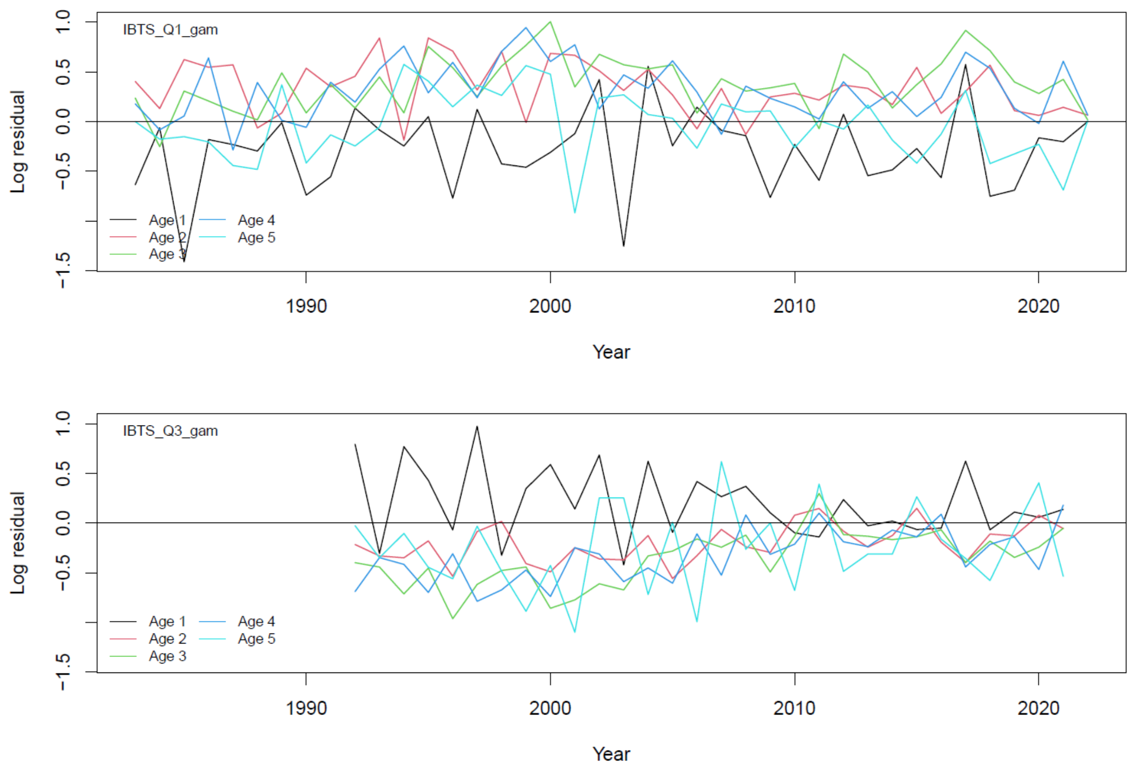

Figure 4.6b. Cod in Subarea 4, Division 7.d and Subdivision 20: SURBAR residual plots for a combined SURBAR run with both surveys (Q1 and Q3 NS–IBTS Delta–GAM indices, ages 1–5). The smoothing parameter l is set to 3, and reference age at 3.

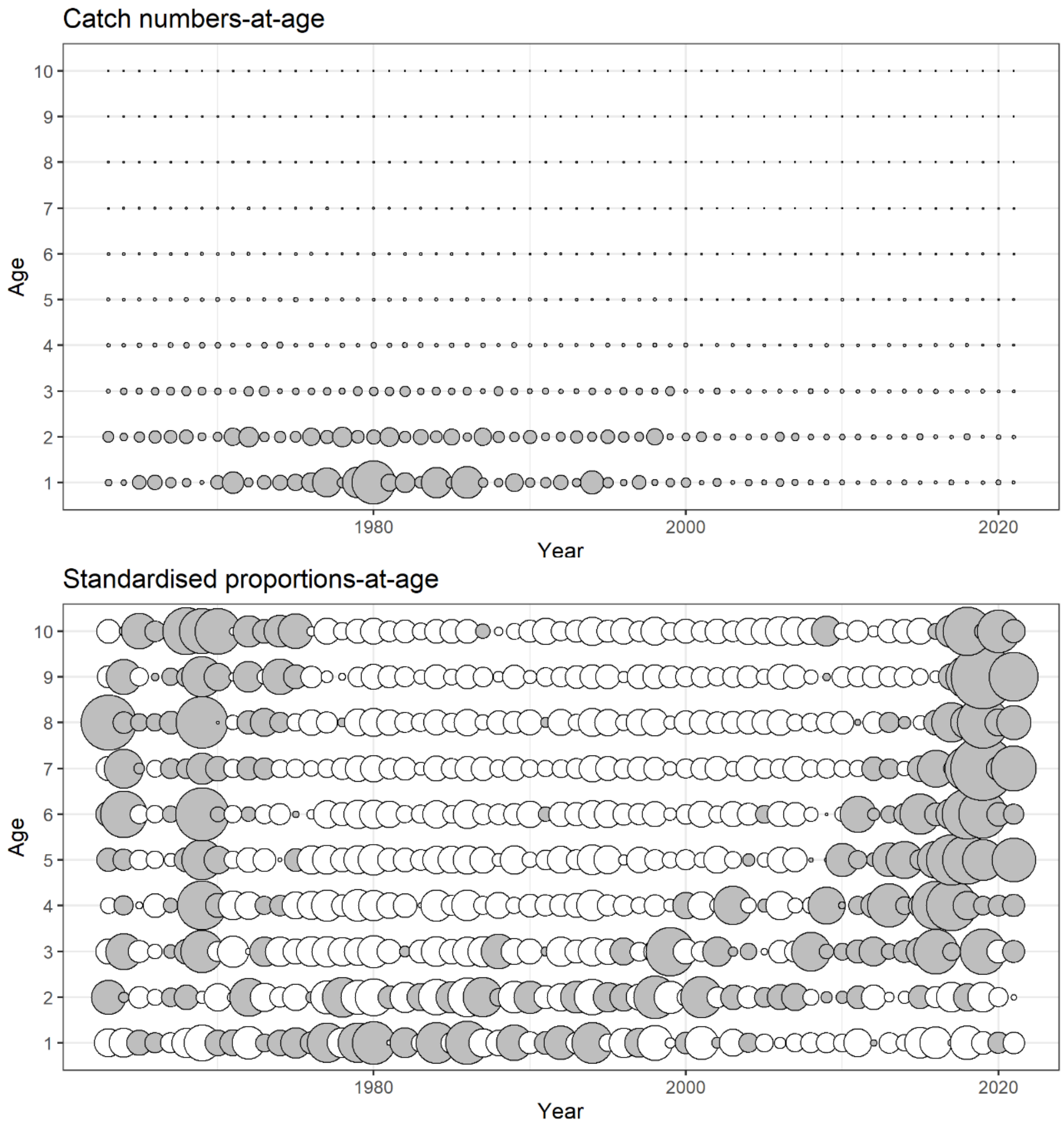

Figure 4.7. Cod in Subarea 4, Division 7.d and Subdivision 20: Total catch-at-age matrix expressed as (top) numbers-at-age and (bottom) proportions-at-age, which have been standardised over time (for each age, this is achieved by subtracting the mean proportion-at-age over the time series and dividing by the corresponding variance). Grey bubbles indicate proportions above the mean over the time series at each age.

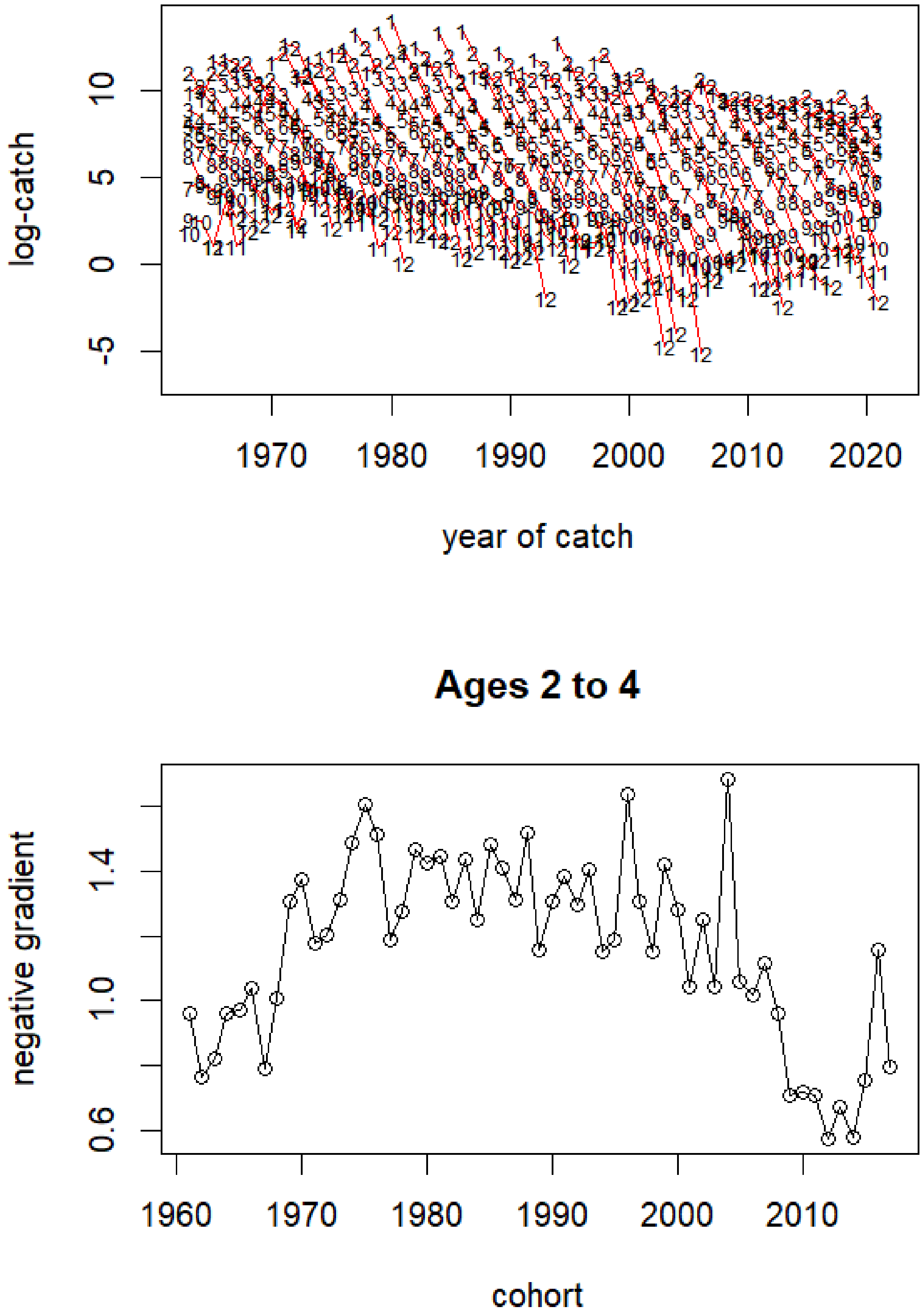

Figure 4.8. Cod in Subarea 4, Division 7.d and Subdivision 20: Log-catch cohort curves (top panel) and the associated negative gradients for each cohort across the reference fishing mortality of age 2–4.

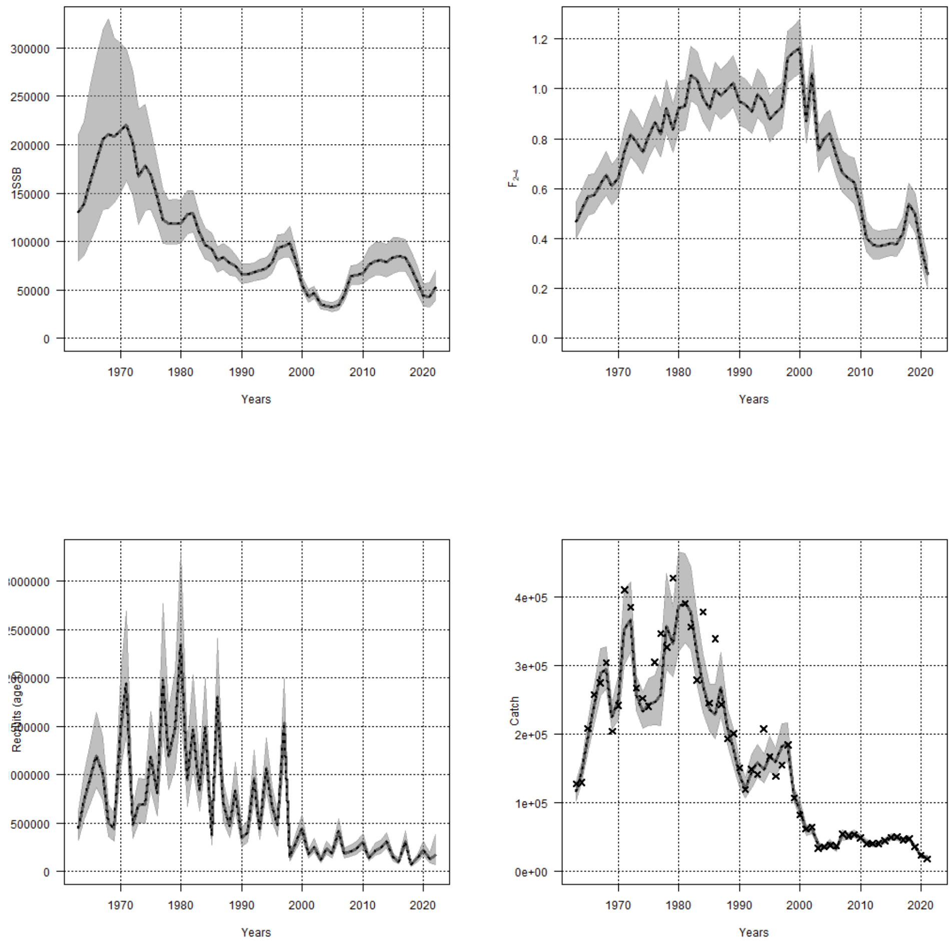

Figure 4.9. Cod in Subarea 4, Division 7.d and Subdivision 20: Estimated SSB, F (2–4), recruitment (age 1) and catch from the SAM assessment (black lines = estimate and shaded area = corresponding pointwise 95% confidence intervals).

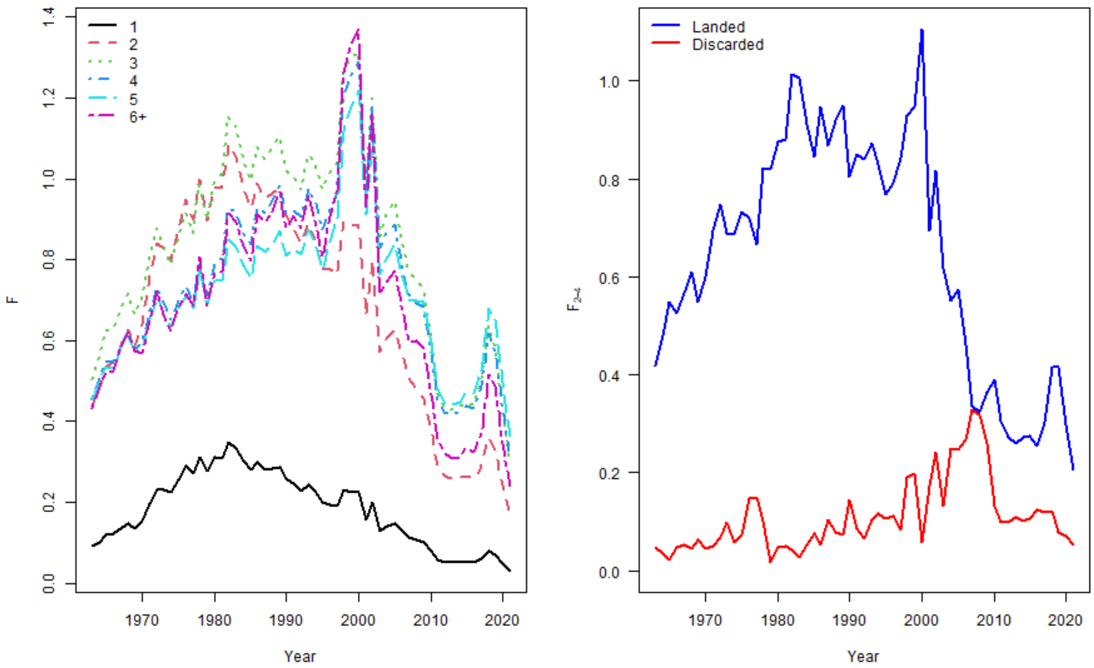

Figure 4.10a. Cod in Subarea 4, Division 7.d and Subdivision 20: SAM estimates of fishing mortality. The left panel shows fishing mortality for each age while the right panel shows mean fishing mortality for ages 2–4 (shown in Figure 4.9) but split into landings and discards components by using ratios calculated from the landings and discards numbers at age from the reported catch data.

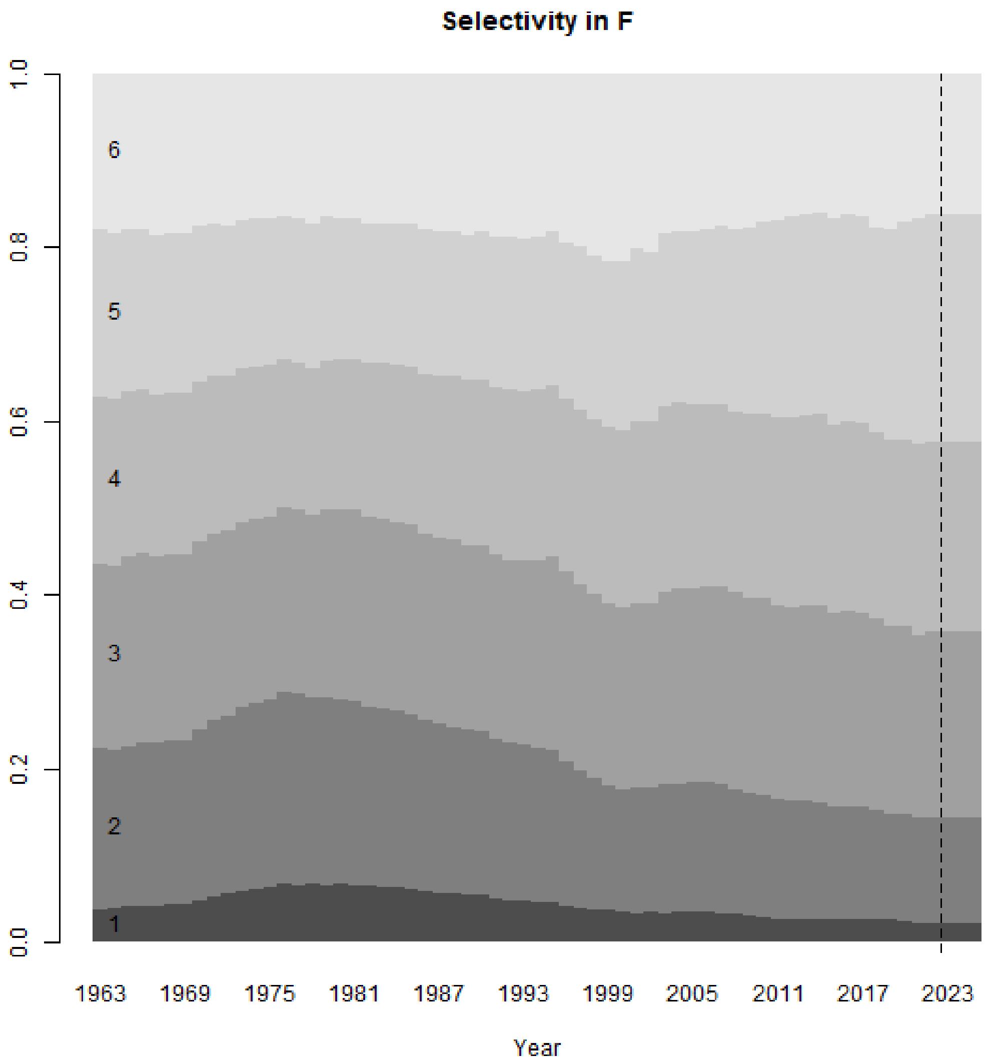

Figure 4.10b. Cod in Subarea 4, Division 7.d and Subdivision 20: SAM estimates of selectivity derived as the proportions of total fishing mortality at age over time. The dashed line represents the beginning of the forecast period.

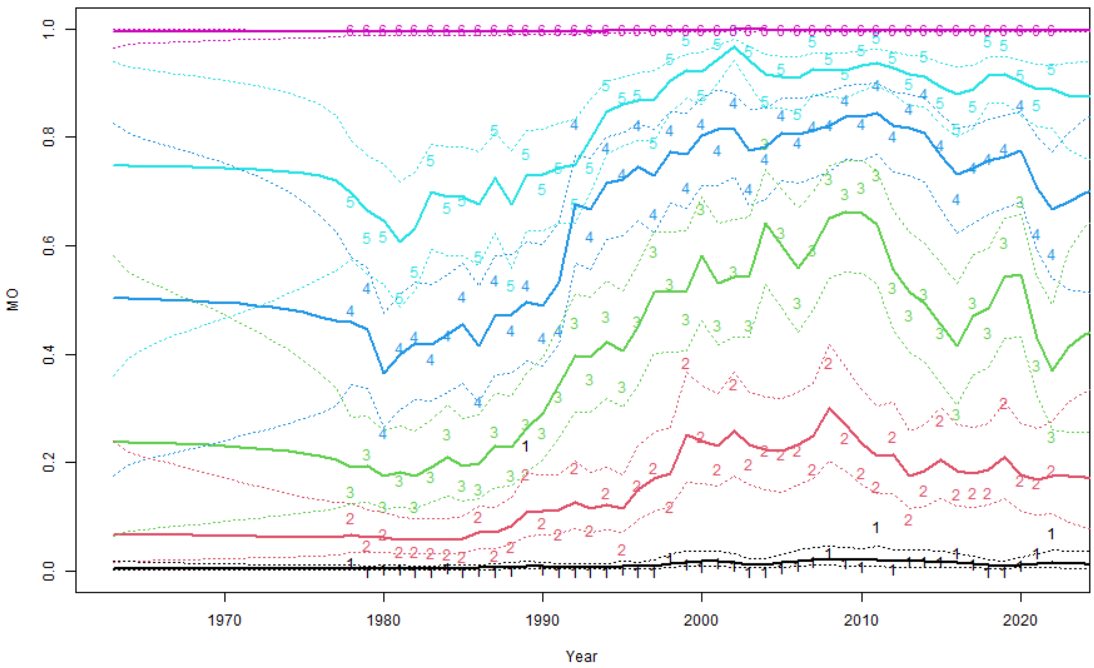

Figure 4.11. Cod in Subarea 4, Division 7.d and Subdivision 20: SAM fits to maturity data. Numbers are the input data shown in Table 4.5b and Figure 4.2c. The solid lines are the SAM estimates of maturity-at-age, extending to the forecast period, with the dotted lines showing 95% confidence intervals.

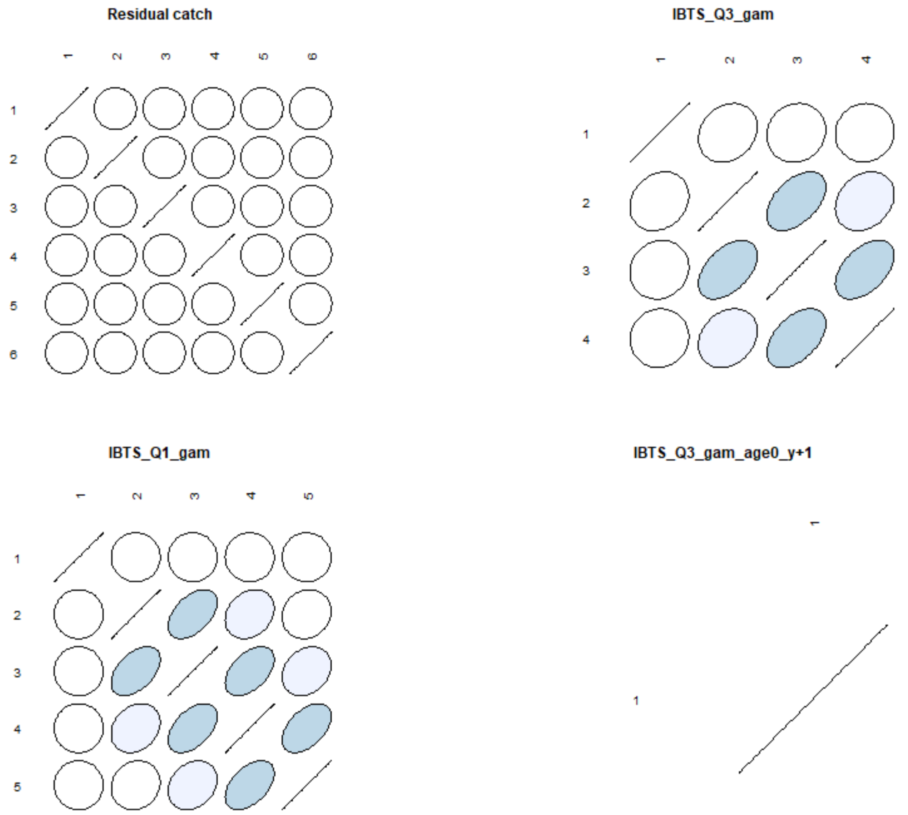

Figure 4.12. Cod in Subarea 4, Division 7.d and Subdivision 20: Estimated correlation matrices between ages for the (top left) total catch, (bottom left) IBTS–Q1, (top right) IBTS–Q3 and (bottom right) the IBTS–Q3 recruitment index.

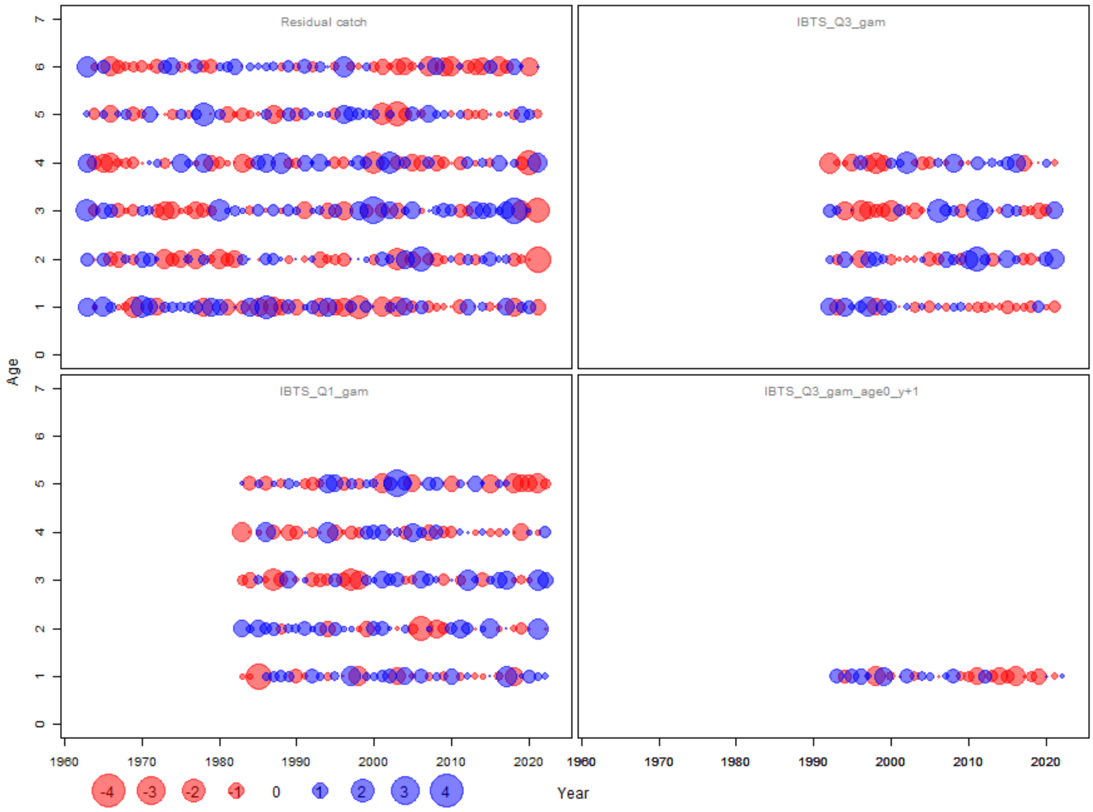

Figure 4.13a. Cod in Subarea 4, Division 7.d and Subdivision 20: One step ahead (OSA) residuals for the SAM assessment for (top left) total catch, (bottom left) IBTS–Q1, (top right) IBTS–Q3 and (bottom right) the IBTS–Q3 recruitment index. Blue circles indicate a positive residual and red circles a negative residual.

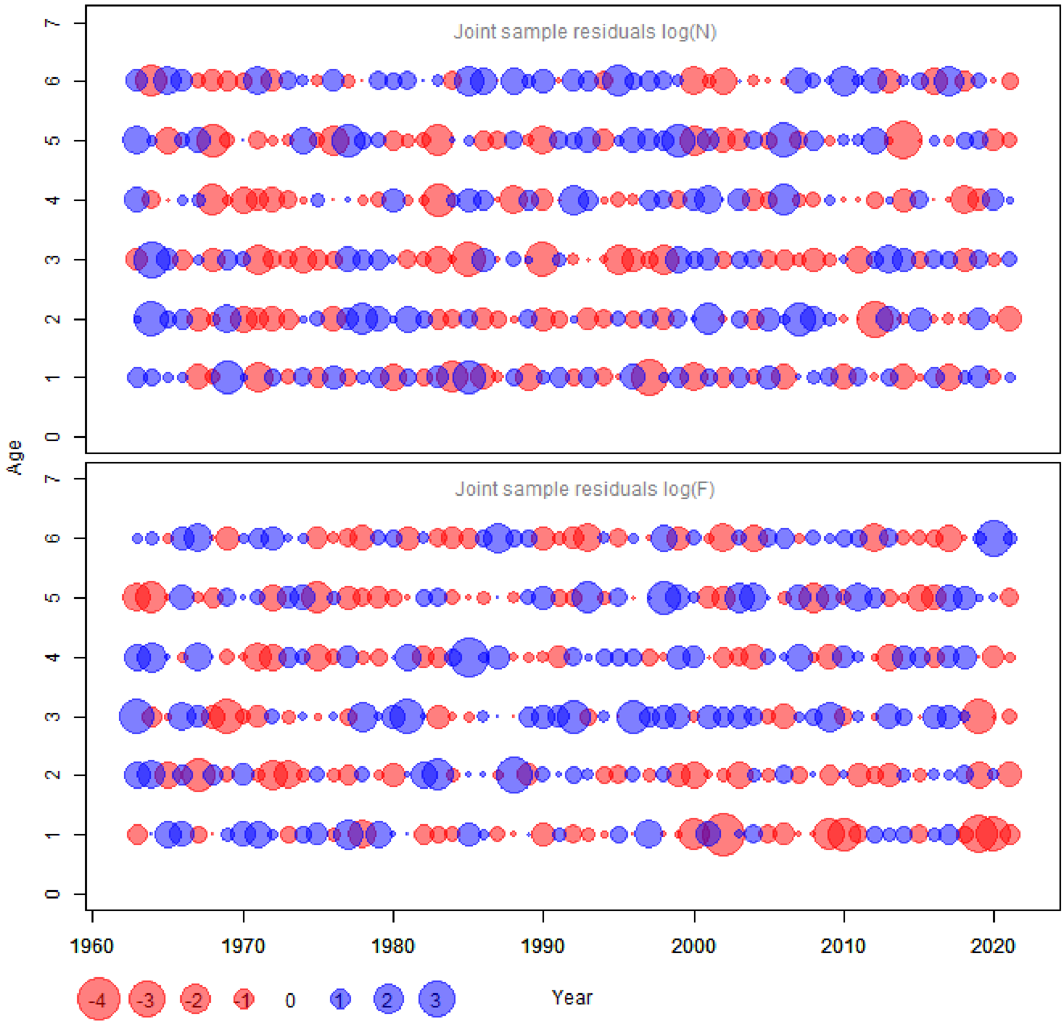

Figure 4.13b. Cod in Subarea 4, Division 7.d and Subdivision 20: SAM standardised joint-sample residuals of process increments for (top) stock numbers and (bottom) fishing mortality. Blue circles indicate a positive residual and red circles a negative residual.

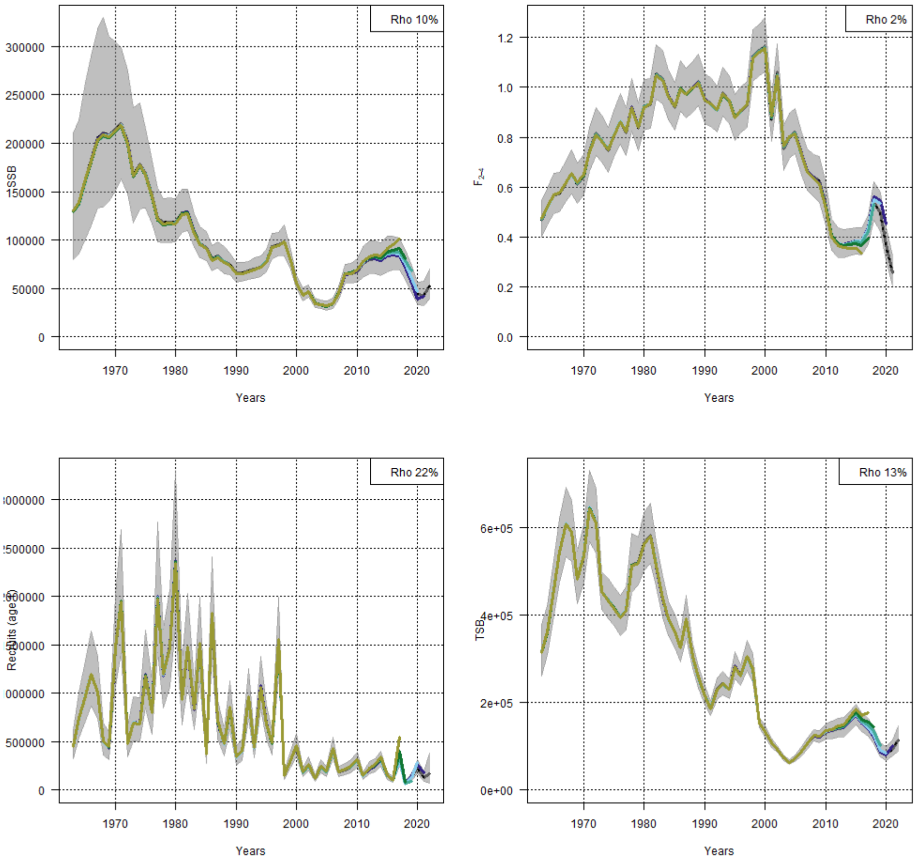

Figure 4.14. Cod in Subarea 4, Division 7.d and Subdivision 20: Retrospective estimates (5 years) from the SAM assessment. Estimated yearly SSB (top left), average fishing mortality (top right), recruitment age 1 (bottom left) and TSB (bottom right), together with corresponding pointwise 95% confidence intervals.

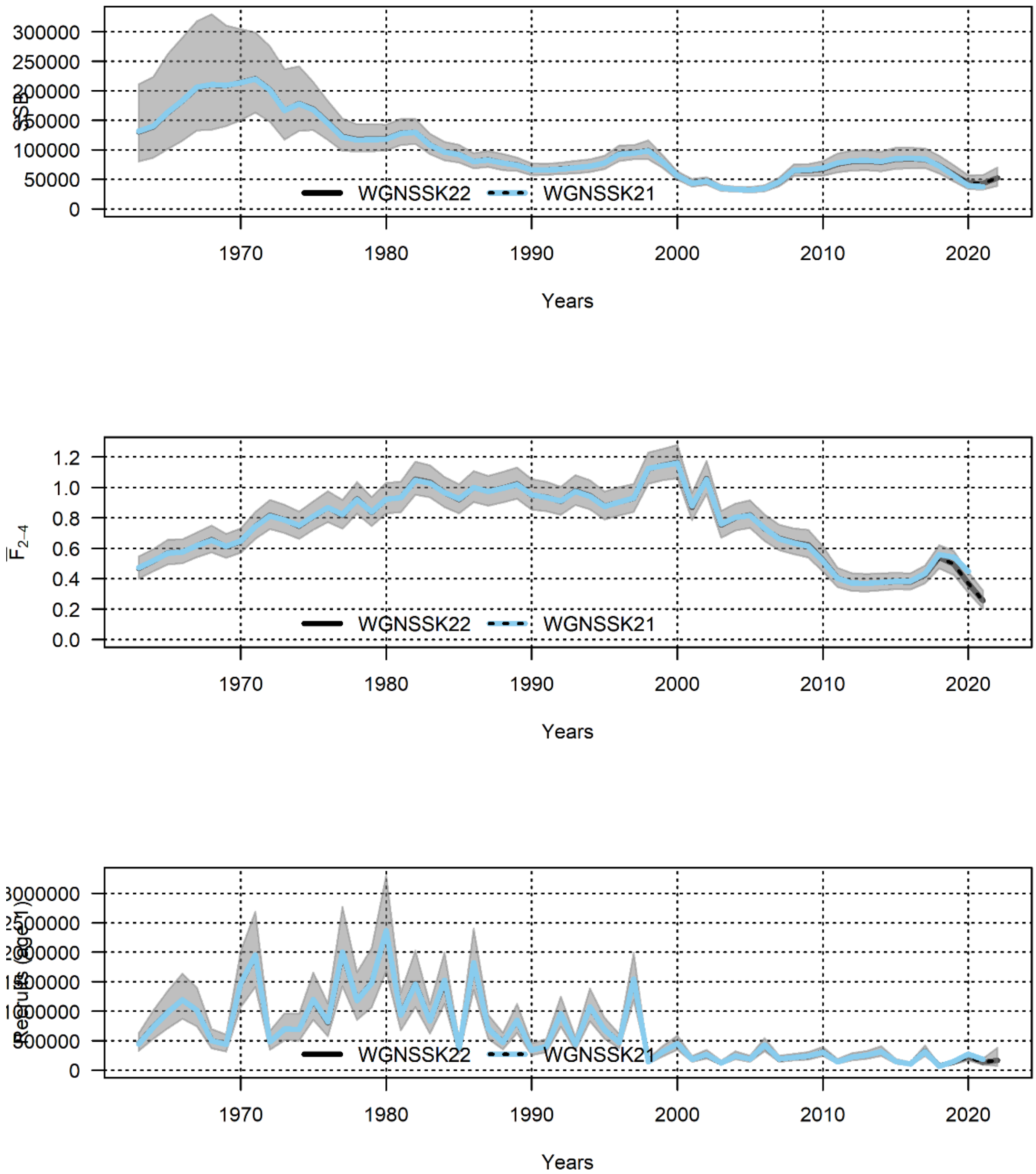

Figure 4.15a. Cod in Subarea 4, Division 7.d and Subdivision 20: Comparison of the final SAM assessment for 2022 with the final SAM assessment for 2021 (ICES WGNSSK 2021). Estimated yearly SSB (top), average fishing mortality (middle) and recruitment age 1 (bottom), together with corresponding pointwise 95% confidence intervals.

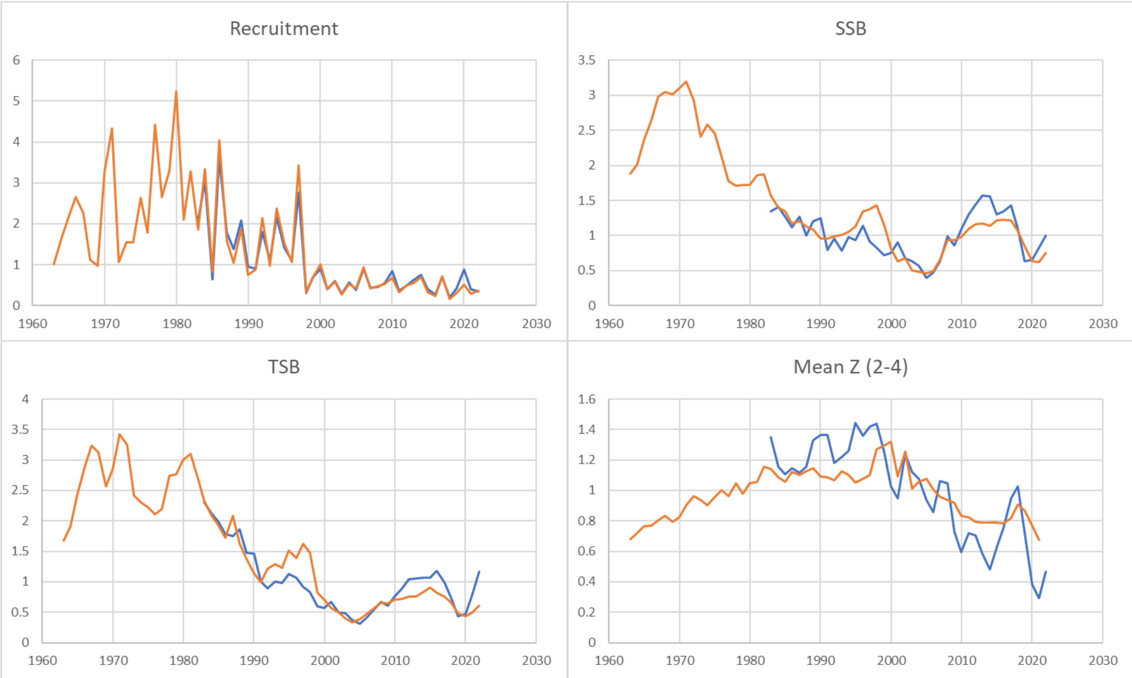

Figure 4.15b. Cod in Subarea 4, Division 7.d and Subdivision 20: Comparison of the final SAM assessment for 2022 (orange) with the SURBAR survey-based assessment (blue). All values have been mean-standardised using the year range for which estimates are available for both models.

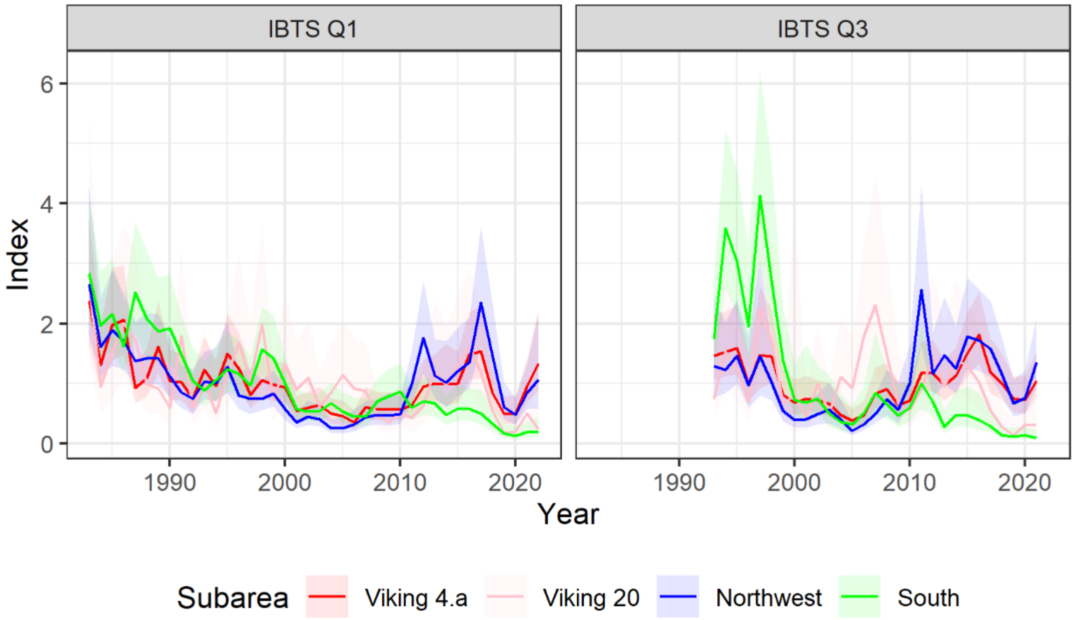

Figure 4.16a. Cod in Subarea 4, Division 7.d and Subdivision 20: Biomass indices by subregion (see Figure 4.16c), based on NS–IBTS–Q1 and Q3 data. The biomass indices are derived by integrating the fitted abundance surface from the Delta-GAM model (Section 4.2.4) over each of the subregions to obtain indices-at-age by area. These are then multiplied by smoothed weight-at-age estimates and summed to get the biomass indices. Shading represents 95% confidence intervals. Indices and confidence intervals are standardised by the mean of the index for each subregion.

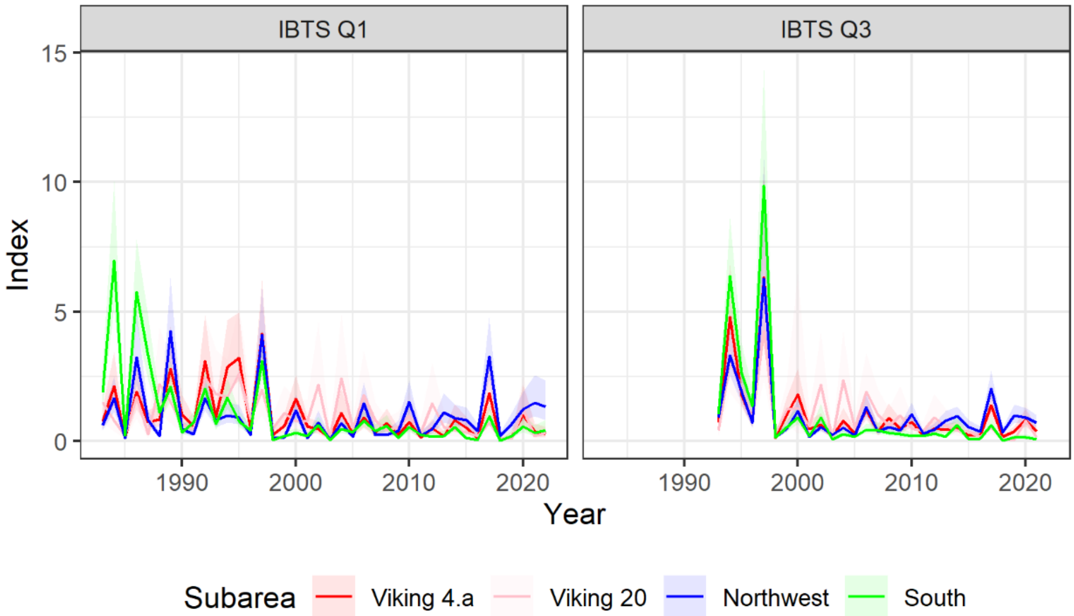

Figure 4.16b. Cod in Subarea 4, Division 7.d and Subdivision 20: Recruitment indices by subregion (see Figure 4.16c), based on NS–IBTS–Q1 and Q3 data. Indices and confidence intervals are standardised by the mean of the index for each subregion.

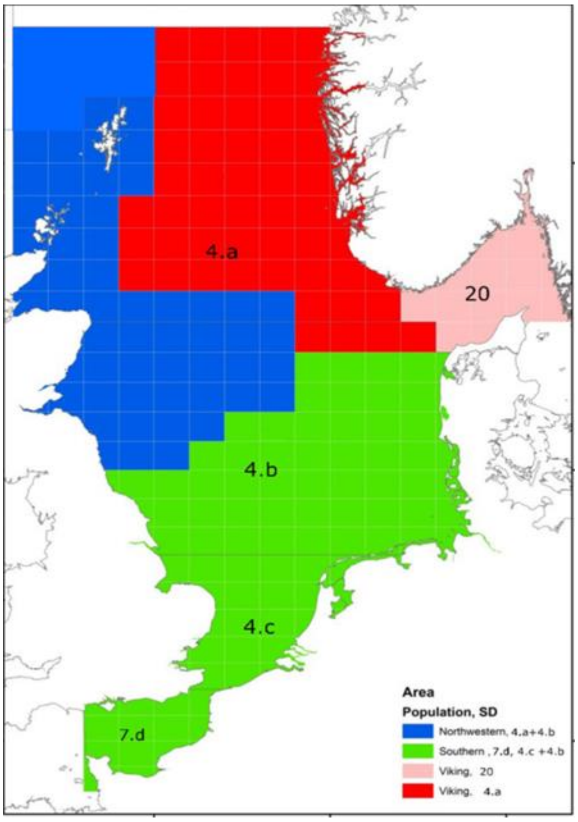

Figure 4.16c. Cod in Subarea 4, Division 7.d and Subdivision 20: Subregions used to derive area-specific biomass indices based on NS–IBTS–Q1 and Q3 data.

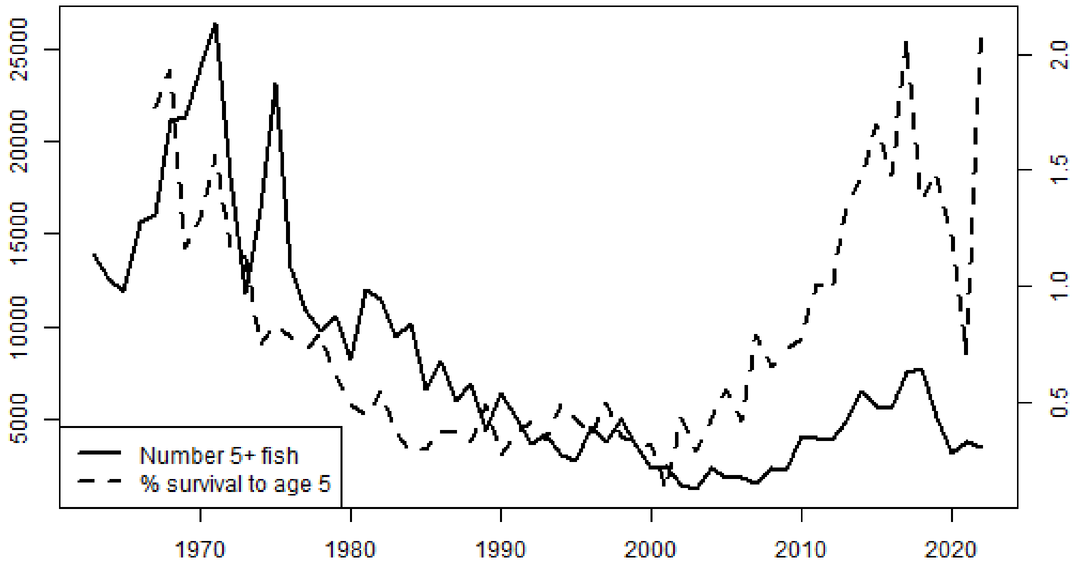

Figure 4.17. Cod in Subarea 4, Division 7.d and Subdivision 20: Estimates of the number of 5-year-old and older cod in the population (solid line; thousands) and the percentage of 1-year olds by number that have survived to age 5 in the given year (hashed line).

5 Dab in Subarea 4 (North Sea) and Division 3.a (Skagerrak, Kattegat)

5.1 General

Dab (*Limanda limanda*) was assessed for the first time by the Working Group on the Assessment of Demersal Stocks in the North Sea and Skagerrak (WGNSSK) in 2014 (ICES, 2014). Until 2013, dab was assessed by the Working Group on Assessment of New MoU Species (ICES, 2013a). This group was dissolved in 2014. Because only official landings and survey data were available at that time, dab was defined as a category 3 species according to the ICES guidelines for data limited stocks (ICES, 2012). Since 2015, dab was included in the official data call for the WGNSSK and discard estimates could be included into the dab assessment since then. In 2016 a benchmark assessment of dab was conducted by ICES. For this benchmark assessment, catch data from 2002 were requested and uploaded into the InterCatch data portal by all relevant countries (ICES, 2016). The benchmark agreed on the use of a survey-based assessment model (SURBAR; Needle, 2015) to inform stock status of North Sea dab (ICES, 2016). This model provides relative estimates of the spawning stock, recruitment, and estimates of total mortality. During the WGNSSK 2017 MSY_{proxy} reference points were determined applying the Surplus Production Model in Continuous Time (SPiCT, Pedersen and Berg, 2017), and catch advice for dab was provided for the years 2017 - 2019 applying the 2:3 rule based on the SURBAR spawning stock biomass index. In 2017 the combined TAC for dab and flounder was removed (EU COM, 2017/595). North Sea dab has become a non-target species with no TAC since then, and ICES has not been requested to provide advice on fishing opportunities for this stock for the years 2020 - 2022. In 2022 catch advice for the dab stock was requested again for the years 2023 – 2025. Catch data, indices and the SURBAR assessment were updated, and also the SPiCT assessment was updated during the WGNSSK 2022. However, the existing SPiCT assessment was not accepted as the basis of the advice, due to unacceptable strong patterns in the retrospective analysis. Therefore, the Length Based Indicator was used to evaluate stock status relative to the $F_{MSY\ proxy}$, and the empirical *chr* rule (ICES, 2021) was applied as the basis of advice, as recommended by ACOM before.

In 2021, catches decreased to 41 955 tonnes (compared to 42 674 tonnes in 2020). The relative SSB value further decreased, but is still on a comparable high level. Recruitment showed a consistently decreasing trend from 2015 to 2020, but increased in 2021 again. The LBI method revealed that the exploitation status is below the $F_{MSY\ proxy}$. In conclusion the perception of the stock did not change compared to the previous year. However, the application of the empirical *chr* rule resulted in a decrease of 30% of catch advice, based on the average catch of the most recent three years. The catch advice is no more than 29 249 tonnes, which corresponds to no more than 3 074 tonnes landings.

5.1.1 Biology and ecosystem aspects

Dab is a widespread demersal species on the Northeast Atlantic shelf and distributed from the Bay of Biscay to Iceland and Norway, including the Barents Sea and the Baltic Sea. In the North Sea it is one of the most abundant species distributed over the whole area in depths down to 100 m, but it was also found occasionally down to depths of 150 m. The main concentration of dab can be found in the south eastern North Sea especially that of the younger age groups 1–2. Older age groups are more distributed in the central and more Northern parts of the North Sea (Figure 5.14). Generally, dab abundance decreases towards the northern parts of the North Sea.

Dab feeds on a variety of small invertebrates, mainly polychaete worms, shellfish and crustaceans. Early sexual maturation was reported for dab, maturing at ages of 2 to 3 years corresponding to approximately 11 cm to 14 cm total length. Peak spawning in the south eastern North Sea occurs from February to April.

5.1.2 Stock ID and possible assessment areas

The several spawning grounds and the wide distribution of dab indicate the presence of more than one stock. Meristic data (Lozán, 1988) corroborate the hypothesis of several stocks for dab, distinguishing significantly between populations from western British waters, the North Sea and the Baltic Sea.

5.1.3 Management regulations

Dab is mainly a bycatch species in fisheries for plaice and sole. The discard rates for dab can be extremely high (~90%). No minimum landing size is defined for dab. According to EU–Regulations a precautionary TAC was given in EU waters of Division 2.a and Subarea 4 together with flounder (*Plathichthys flesus*). This combined TAC was never fully utilized. In 2017, the European Commission requested ICES to evaluate the possible effects on the stocks of dab and flounder having no TAC. ICES advised that given the current fishing patterns of the main fleets catching dab and flounder, which are the same fleets targeting plaice and sole, the risk of having no TAC for dab and flounder is considered to be low (ICES, 2017a). Therefore, the European Commission removed the combined TAC for these two stocks in 2017 (EU COM, 2017/595).

5.2 Fisheries data

5.2.1 Historical landings

Dab is a bycatch species mainly in the fisheries for plaice and sole but also in fisheries targeting demersal round fish. According to official catch statistics, annual landings of dab in ICES Subarea 4 and Division 3.a has been increasing above 10 000 tonnes since 1979 (Figure 5.1–5.3, Table 5.13). The apparent decrease in official landings in the 1980s and 1990s are due to unreported landings by the Netherlands. However, since 1999 total landings for both areas (Subarea 4 and Division 3.a) steadily decreased. This trend continued until 2017 with total official landings of 3529 tonnes. In 2021 the official landings decreased to 3604 tonnes compared to 3976 tonnes in 2020.

The main fishing gear in the North Sea is the beam trawl with mesh sizes between 80 and 100 mm. Large effort reductions took place in this fishery over the last decade (STECF, 2016). The largest part of the landings in Subarea 4 is taken by the Netherlands, followed by Denmark, the UK, and Belgium (Figure 5.2, Table 5.14). In Division 3.a, Denmark lands by far the largest amount of dab (Figure 5.3, Table 5.15). Dab is among the most discarded fish species in the North Sea. In the beam trawl fishery on plaice and sole and the otter trawl fishery on plaice up to 95% of dab catches are discarded (e.g. van Helmond *et al.*, 2012).

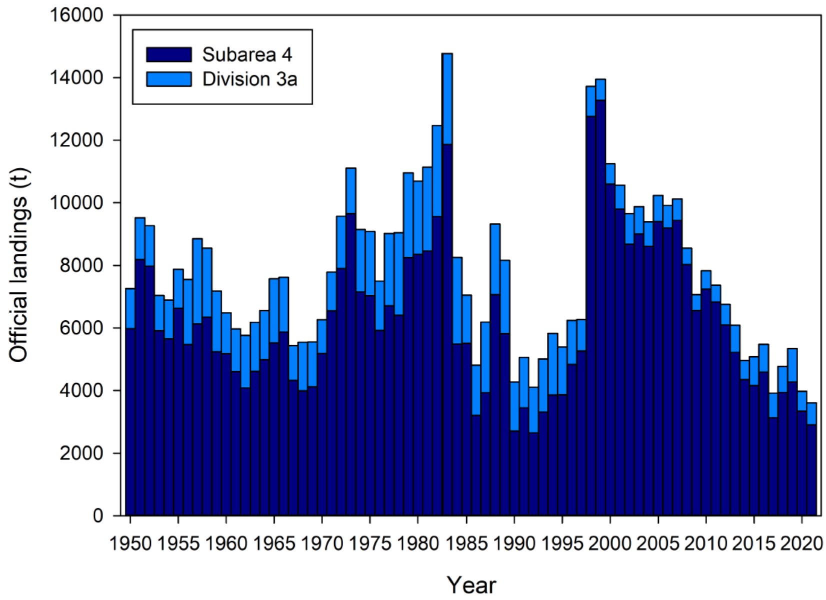

Figure 5.1. Dab in Subarea 4 and Division 3.a: Total official landings of dab in Subarea 4 and Division 3.a in 1950–2021.

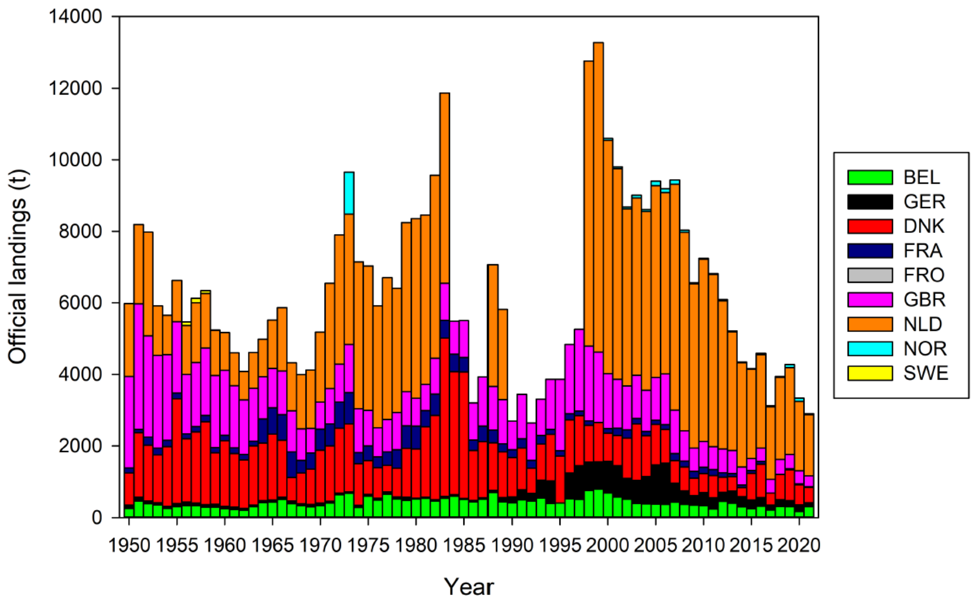

Figure 5.2. Dab in Subarea 4 and Division 3.a: Official landings of dab in Subarea 4 by country 1950 to 2021.

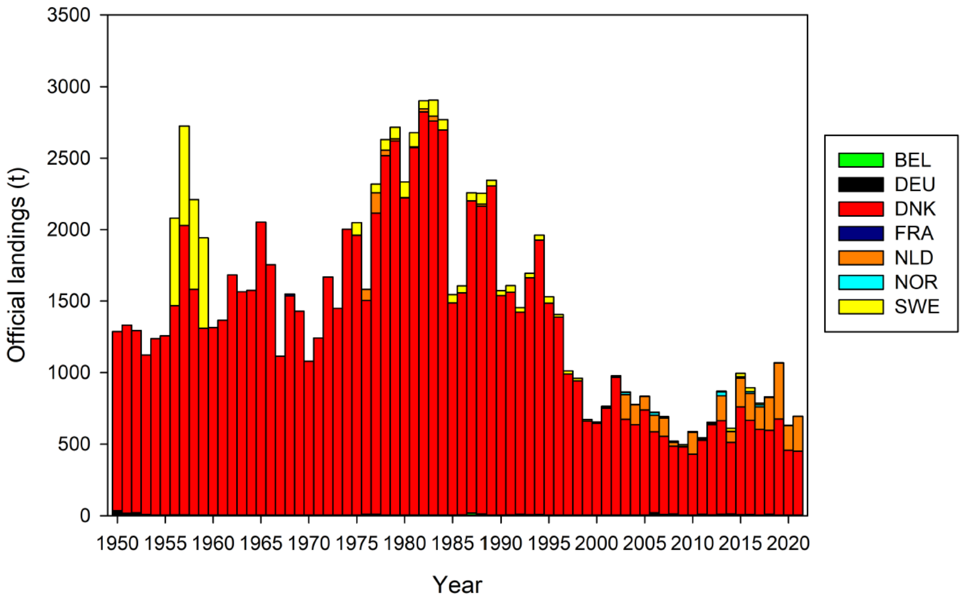

Figure 5.3. Dab in Subarea 4 and Division 3.a: Official landings of dab in Division 3.a by country 1950–2021.

5.2.2 InterCatch

For the current assessment year, dab landing and discard data from 2002–2021 were available in the InterCatch system. Discard information for 2021 was provided for only 36% (compared to 54% in 2020 and 76% in 2019) of total landings in relation to weight (Figure 5.4).

In 2021, the largest catch (landings and discards) was reported by The Netherlands for the TBB_DEF_70-99_0_0_all fleet with 16 6621 tonnes (Figure 5.5 and Figure 5.6). The largest amount for landings (1 902 tonnes) was reported by the Dutch TBB_DEF_>=120_0_0_all fleet, which is by far the largest amount of landings for this fleet since 2002. In general, the TBB_DEF_70-99_0_0_all fleet landed most dab in the past. But for this fleet the dab landings decreased considerably from 2007 – 2021, with the lowest observed landings in 2021 (714 tonnes). By far the largest catch in 2021 was taken by The Netherlands again (31 391 tonnes in total), followed by Denmark with 3 502 tonnes, and Germany with 2 898 tonnes. The total dab catch estimated with InterCatch for 2021 was 41 955 tonnes (- 719 tonnes compared to 2020) from which 4 343 tonnes were landings and 37 612 tonnes discards (90% of the total catch). It should be noted that not all métiers were sampled in every quarter and that the raising procedure with the InterCatch tool may not be adequate in all cases. Further, there are a number of métiers for which zero landings were reported and a discard raising for these fleets is not possible with the InterCatch tool, which is based on a discard ratio between landings and observed discards. Especially for bycatch species without economic interest zero landings do not necessarily imply zero discards. However, the Dutch TBB_DEF_70-99_0_0_all fleet is by far the most important one in terms of total catch and information on discard weights was provided for every quarter for this fleet.

In general, it was attempted to use the same groupings for discard raising as for the previous data years. However, this was not possible for all cases and compared to the previous year slight changes had to be made. The grouping is generally based on gear type and mesh size and where possible also by area. For the sample allocation scheme landings and discards were grouped by season. The following groupings were used for the 2021 data discard raising:

Group 1: MIS_MIS_HC all area (3.a and 4) raised with all other métiers because no specific MIS_MIS_HC all data were available in 2021 data.

Group 2: Passive gears area 4 raised with all passive gears area 4 and 3.a

Group 3: OTB_CRU_70-99_all raised with discard rates available for all other OTB_CRU_70-99_all métiers.

Group 4: OTB_CRU_90-119 raised with discard rates available for all other OTB_CRU_90-119_all métiers.

Group 5: OTB_DEF_>120_all area 4 - raised with discard rates available for all other OTB_DEF_>120_all métiers area 4.

Group 6: OTB_DEF_>120_all area 3.aN - raised with discard rates available for all other OTB_DEF_>120_all métiers area 3.aN.

Group 7: SSC_SDN_DEF>120_all areas raised with discard rates available for all other SSC_SDN_DEF_>=120_all métiers.

Group 8: TBB_DEF_70-99 all raised with discard rates available for all other TBB_DEF_70-99 all métiers.

Group 9: TBB_DEF_100-119_all areas raised with discard rates available for all other TBB_DEF_100-119 all métiers.

Group 10: OTB_DEF_100-119 raised with discard rates available for all other OTB_DEF_100-119 all métiers.

Group 11: SSC_DEF_100-119 (including SSC_DEF_all_all and SDN_DEF_all_all) raised with the OTB_DEF_100-119 métier (only 1 NED métier).

Group 12: OTB_SSC_SDN_DEF_70-99_all raised with Dutch OTB_DEF_70-99_all and all TBB_DEF_70-99_0_0_all métiers.

Group 13: all remaining métiers (except MIS_MIS_0_0_0_IBC) raised by all métiers

Group 14: TBB_DEF_>=120_0_0_all raised with BEL TBB_DEF_>=120_0_0_all metier (only métier available)

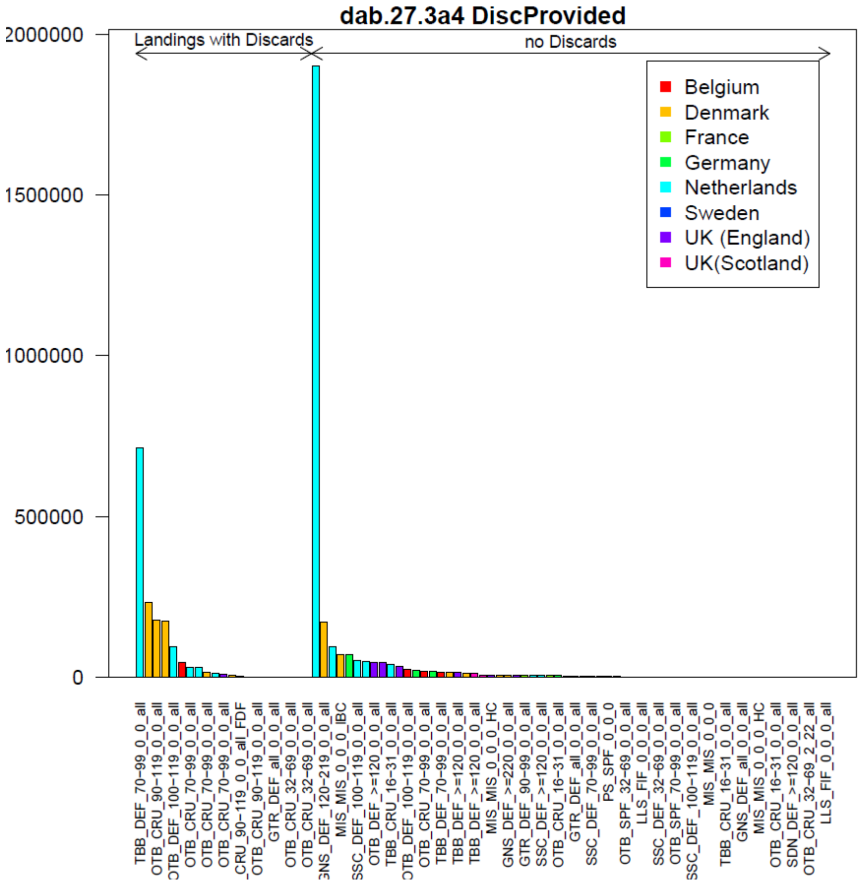

Figure 5.4. Dab in Subarea 4 and Division 3.a: Dab landings and discards (kg) provision for Subarea 4 and Division 3.a by métier and country in 2021 as uploaded into InterCatch.

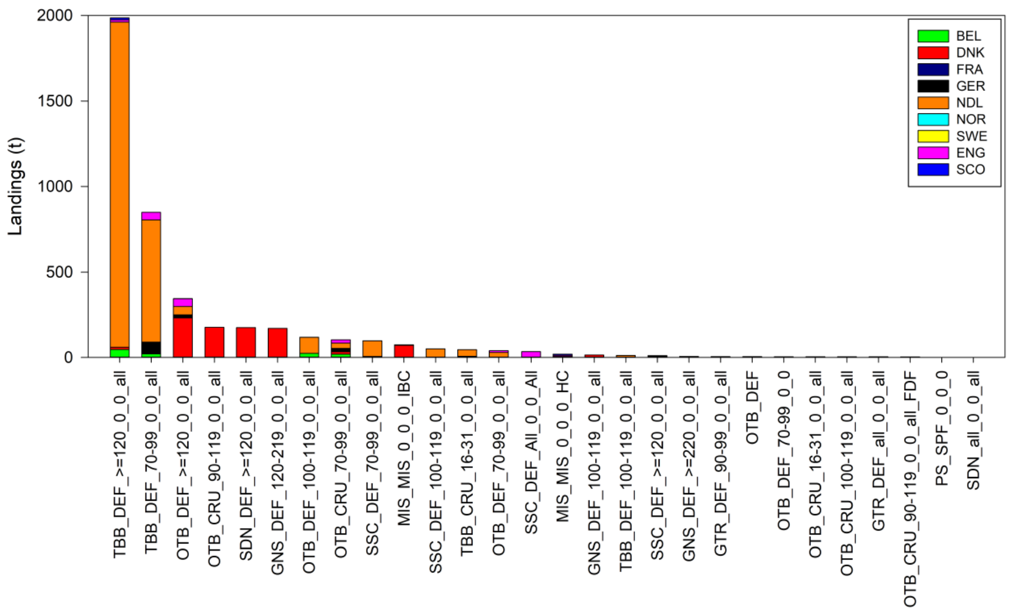

Figure 5.5. Dab in Subarea 4 and Division 3.a: Dab landings (tonnes) for Subarea 4 and Division 3.a by métier and country in 2021 as uploaded to InterCatch.

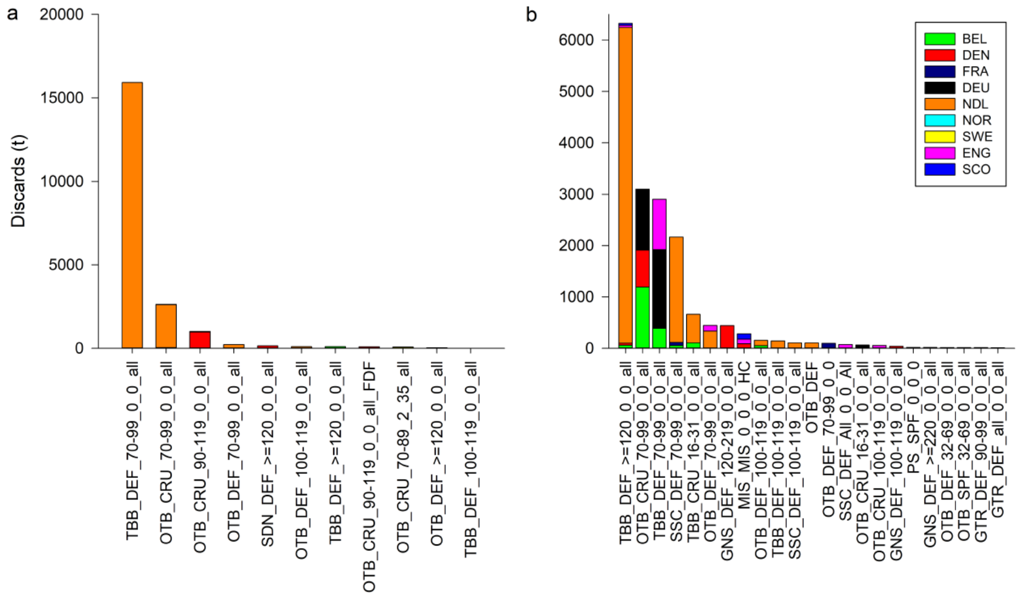

Figure 5.6. Dab in Subarea 4 and Division 3.a: Dab discards for Subarea 4 and Division 3.a by métier and country in 2021. Reported discards (a), raised discards (b).

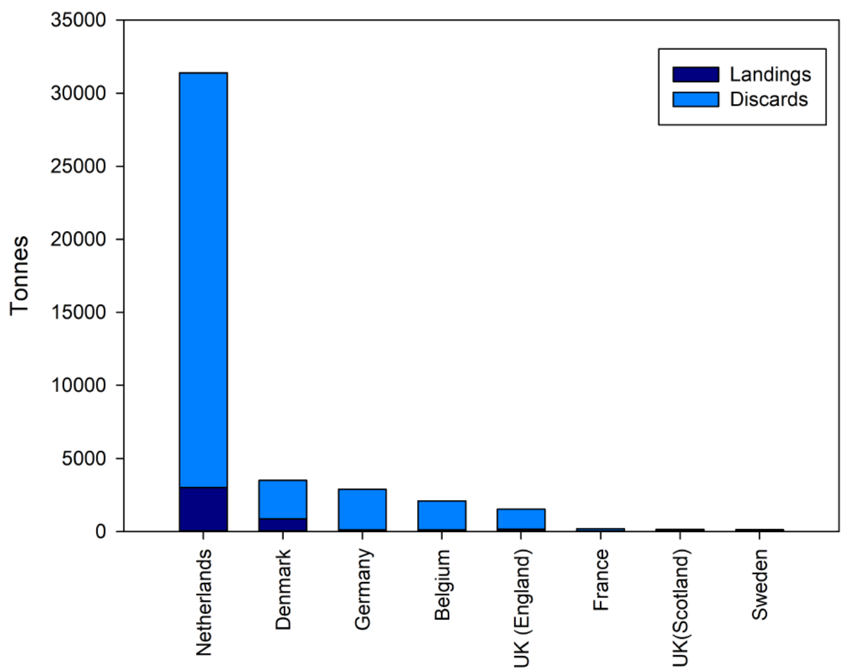

Figure 5.7. Dab in Subarea 4 and Division 3.a: Dab landings and estimated discards for Subarea 4 and Division 3.a by countries in 2021.

5.3 Survey data/recruit series

Surveys providing information on distribution, abundance and length frequency for dab in Subarea 4 and Division 3.a, are the several Beam Trawl Surveys (BTS) in quarter 3 (Figure 5.8 and Figure 5.9) and the International Bottom Trawl Survey (NS-IBTS) in quarter 1 and quarter 3 (Figure 5.10).

The longest beam trawl survey time series exist for the RV Isis covering the south eastern part of the North Sea (Figure 5.9). This index showed high dab abundance in the early years (1987–1990) followed by a sharp decline until 1995. After a second peak in abundance in 1998 the abundance declined again until 2006, and afterwards increased again to such high values as were observed for the time period 1997–1999. The increasing abundance trend from 2005/2006 onwards was also observed for the RV Tridens beam trawl survey, and since 2010 also for the RV Solea beam trawl survey. No clear trend is visible in the RV Belgica survey data. A strong decrease was observed for the RV Solea survey for the year 2015, and again for 2019. Since 2017 RV Isis does not take part any more in the BTS and RV Tridens covers the whole survey area since then. A combined index of the two vessels also displayed a declining trend in dab abundance for the years 2015–2016. The three recent five index values from the Tridens, covering the whole area now, fluctuated strongly, but with the most recent two years displaying a slightly decrease. The Belgica and Solea index values for the most recent two years displayed an increase.

The International Bottom Trawl Survey in quarter 1 (NS-IBTS Q1) showed an increasing abundance trend from 1983 to 1990 and fluctuated since then without a clear trend until 2013. From 2013 to 2015 a strong increase in abundance was observed, followed by a strong decrease again in 2017 and 2018 (Figure 5.10). The index increased in 2022 compared to the most recent three years. The NS-IBTS Q3 also showed a highly variable abundance trend with a slight overall increase from the beginning of the time series in 1991 until 2014 (Figure 5.10). Since then, this abundance index steadily decreased until 2019. For the most recent two years it increased again.

In order to estimate a mature biomass index, a length weight relationship and maturity data derived from NS-IBTS Q1 data was estimated. The obtained length weight relationship and the maturity ogive (Figure 5.11) were then applied to estimate the mature biomass index in kg per hour. The mature biomass indices in kg/h (Figure 5.12) show in general the same trends as the NS-IBTS abundance indices, and for both quarters the decreasing trend was confirmed until 2018. Since then, the quarter 1 mature biomass index fluctuates without trend, with an increase for the 2022 value, and the quarter 3 mature biomass index was more or less stable for the most recent three years.

Only the beam trawl surveys provide data on age and weight for dab on a regular basis. During the benchmark in 2016, it was agreed to use an age-based survey index combining data from the Dutch and German beam trawl surveys taking into account a possible ship effect (i.e. gear effect; Berg *et al*., 2014). For age group 1 the index is highly variable and does not show any trends, but a strong decrease from 2017 to 2018 followed by strong increase in 2019. For the age groups 2–5, a decrease of the index was observed for the most recent years, but it seems to stabilize for the most recent index values. The indices for older age groups are extremely variable for the most recent years, but fluctuate on a rather high level compared to early years in the time series. This index served as an input for the survey-based assessment model (SURBAR) to inform the stock status of North Sea dab (Figure 5.13).

The spatial distribution of dab age groups follows a clear pattern with the youngest age groups (0 and 1) located near the coast of the south eastern North Sea and the older age groups more distributed in the central North Sea (Figure 5.14).

The weight at age data show a slightly decreasing trend for all age groups from 2002 to 2015, but an increase since 2016 for the age groups 1–5 (Figure 5.15).

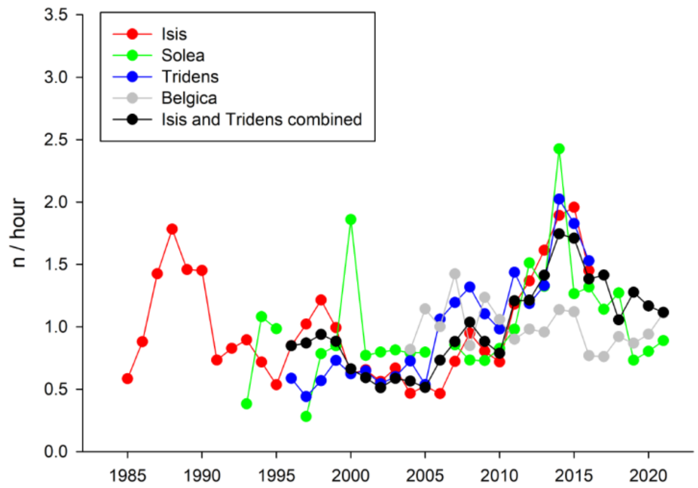

Figure 5.8. Dab in Subarea 4 and Division 3.a: Standardized dab beam trawl survey (BTS) indices (n/hour) in Subarea 4.

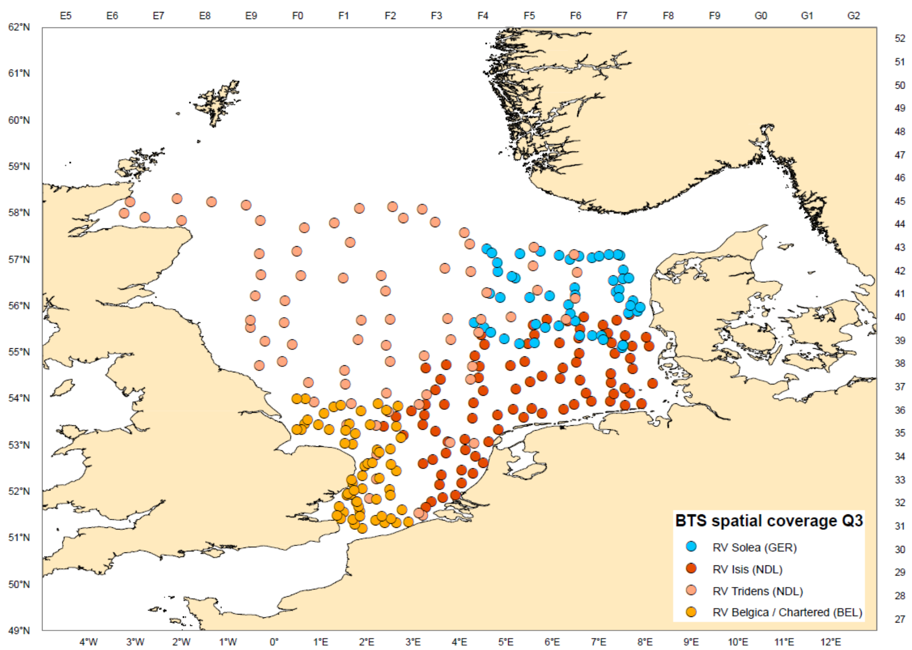

Figure 5.9. Dab in Subarea 4 and Division 3.a: Spatial coverage of the different beam trawl surveys (BTS) in the North Sea. Since 2017, the survey area from RV Isis is also covered by RV Tridens.

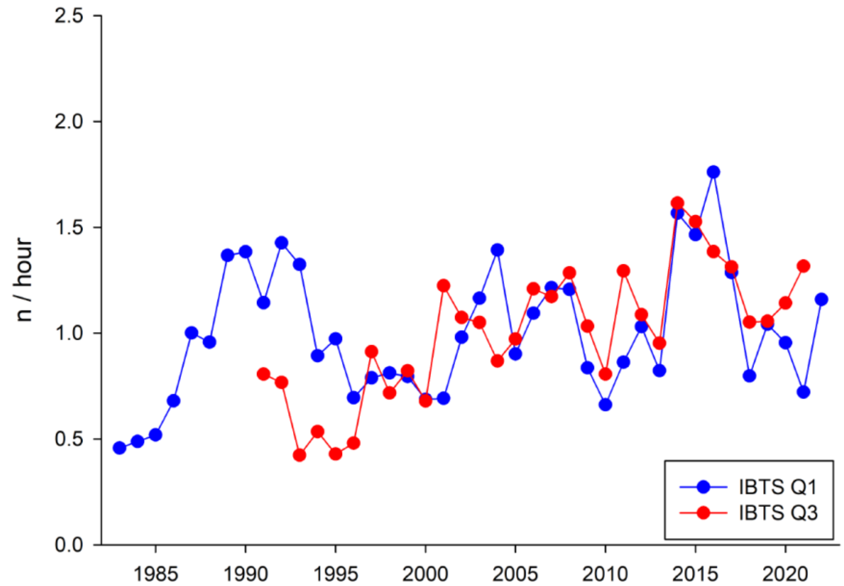

Figure 5.10. Dab in Subarea 4 and Division 3.a: Standardized dab survey indices (n/hour) from the International Bottom Trawl Survey (NS-IBTS).

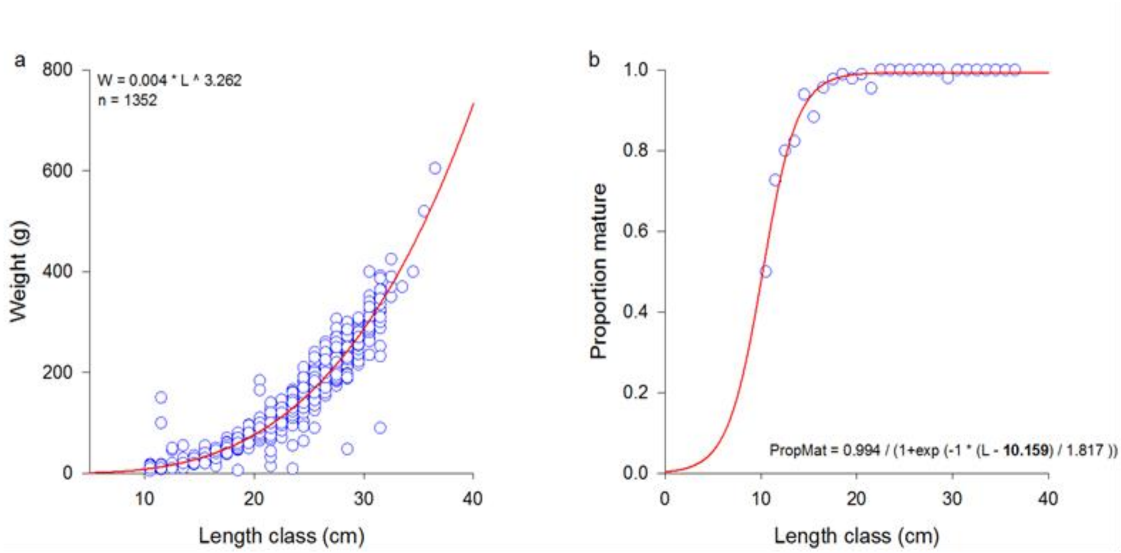

Figure 5.11. Dab in Subarea 4 and Division 3.a: Length weight relation (a) and length-based maturity ogive (b) obtained from survey data (NS-IBTS Q1).

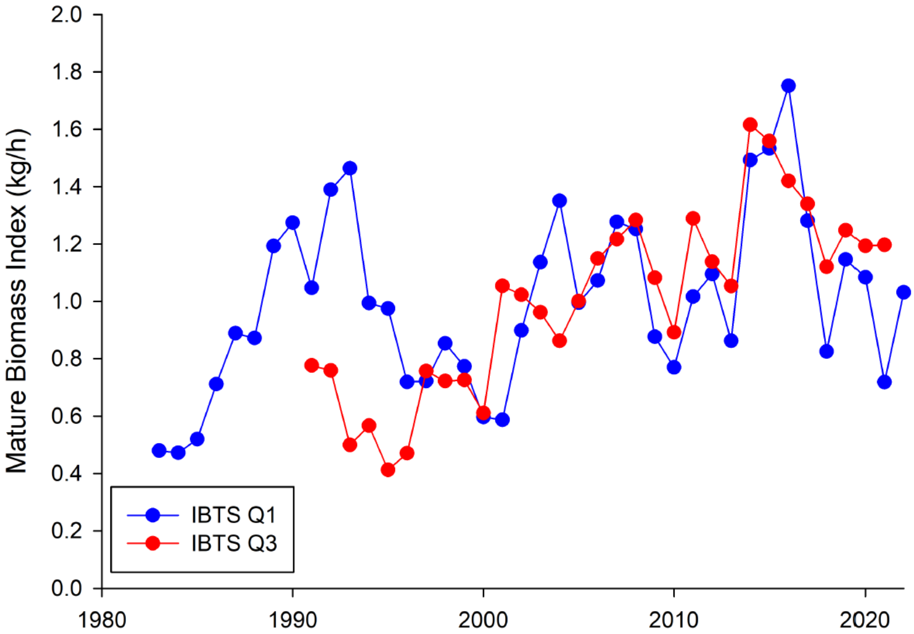

Figure 5.12. Dab in Subarea 4 and Division 3.a: Mature biomass index NS-IBTS Q1 and Q3.

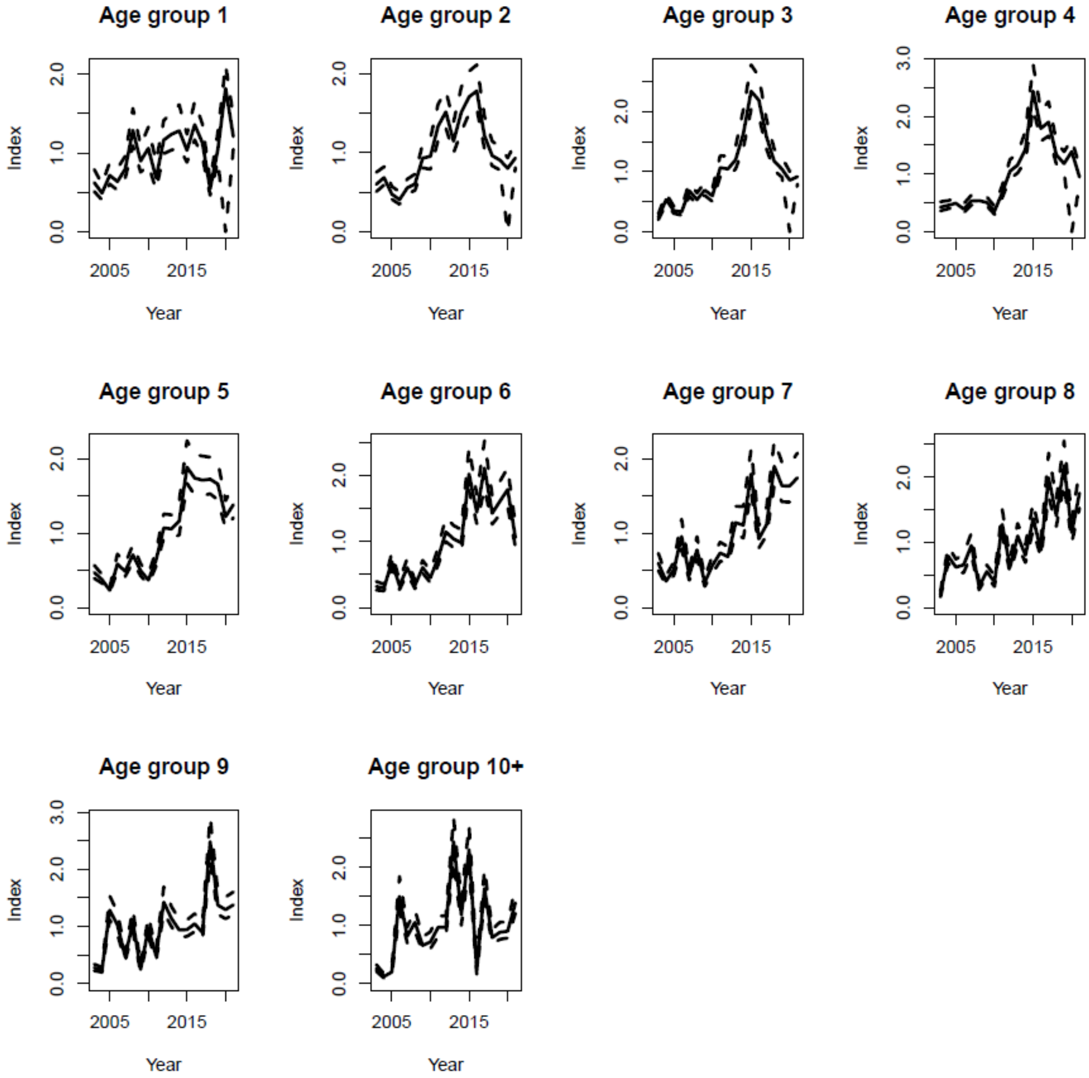

Figure 5.13. Dab in Subarea 4 and Division 3.a: Combined beam trawl index by age groups (2003–2021).

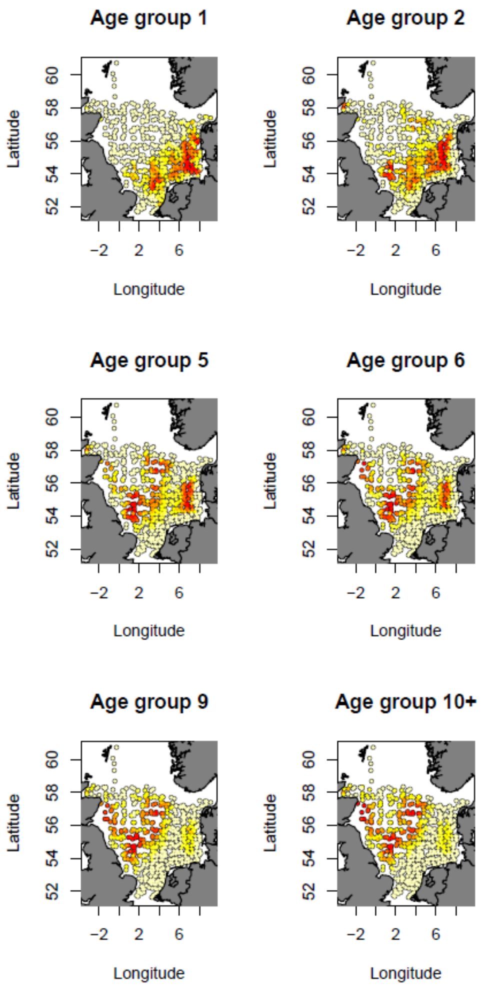

Figure 5.14. Dab in Subarea 4 and Division 3.a: Dab distribution in the North Sea by age group obtained by the Dutch and German Beam Trawl Surveys.

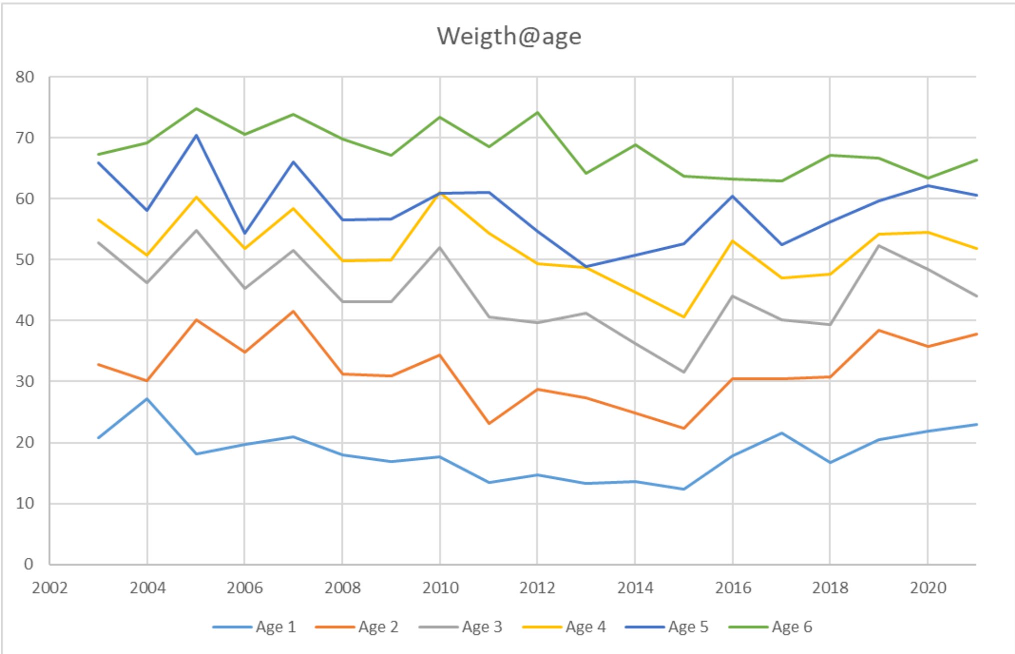

Figure. 5.15 Dab in Subarea 4 and Division 3.a: Weight at age derived from beam trawl survey data 2003–2021).

5.4 Survey Based Assessment (SURBAR)

In 2016, a benchmark assessment was carried out for dab (ICES, 2016). During this benchmark it was agreed to make use of the available data from the beam trawl surveys and to run a survey-based assessment model (SURBAR; Needle, 2015), taking the age structure of dab into account. The SURBAR results of the update assessment showed no clear trend in total mortality (z) for the years 2003–2021 (Figure 5.16, upper left panel). The mortality for the most recent three years was stable. The spawning stock biomass (relative biomass) increased for the years 2003–2016 (Figure 5.16, upper right panel), but decreased after the peak in 2016. The total stock biomass follows the trend of the SSB. The recruitment increased by a factor of 2.6 from 2003 to 2014, but decreased since 2015 until 2020 (Figure 5.16, lower right panel). Recruitment increased again in 2021. No pattern was detected in the log residual pattern of the age-based survey indices (Figure 5.17). There is a strong pattern in the retrospective for total mortality (Figure 5.21).

Table 5.1. Dab in Subarea 4 and Division 3.a: Settings and input data used for the final SURBAR assessment run.

Setting/Data	Values/source
Survey index	Combined beam trawl survey index 2003–current assessment year (BTS-Isis, BTS-Tridens, German BTS). Delta GAM Method by Berg *et al*. (2014).
Ages	1–6
Lambda	3
zbar	1–6
Spawning time	0.4
Maturity ogive	Fixed ogive, age 1 = 60%, age 2 = 80%, age 3 and older 100%
Weight at age	Data from Dutch Beam Trawl Surveys (2003–current assessment year)

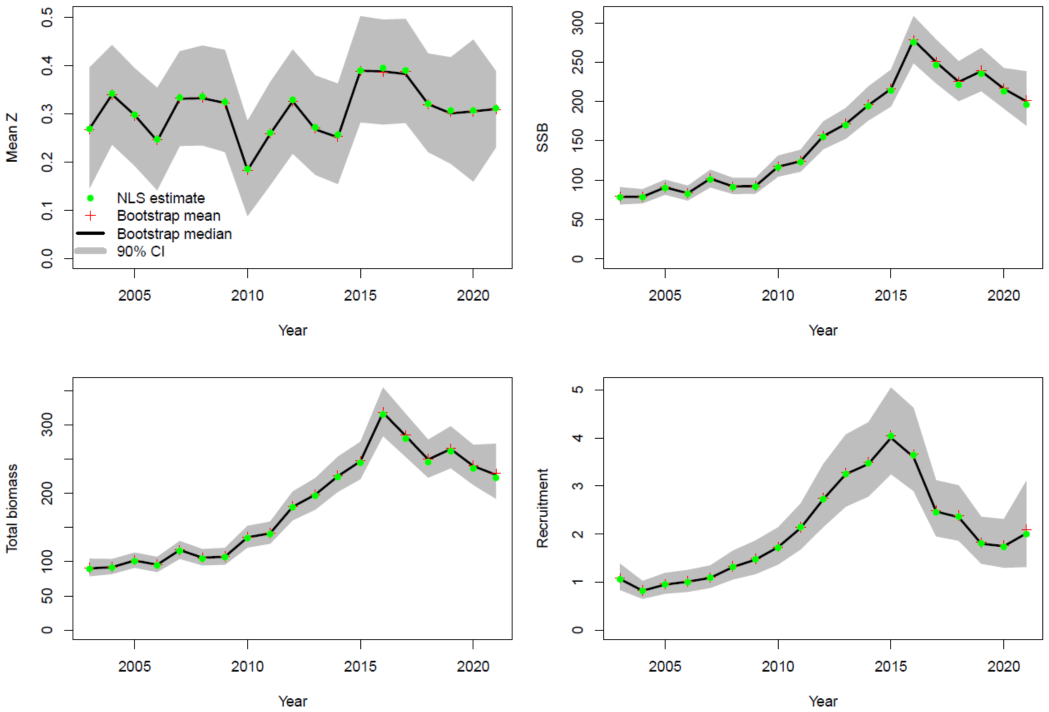

Figure 5.16. Dab in Subarea 4 and Division 3.a: SURBAR model results for dab total mortality (z), spawning stock biomass (SSB), total stock biomass (TSB) and recruitment.

Figure 5.17. Dab in Subarea 4 and Division 3.a: SURBAR model results of log residuals.

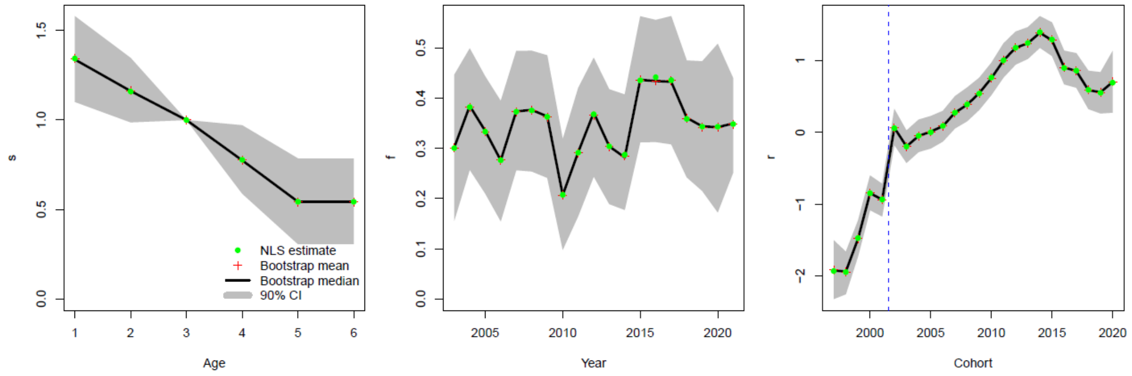

Figure 5.18. Dab in Subarea 4 and Division 3.a: SURBAR model results displaying the age, year and cohort effects.

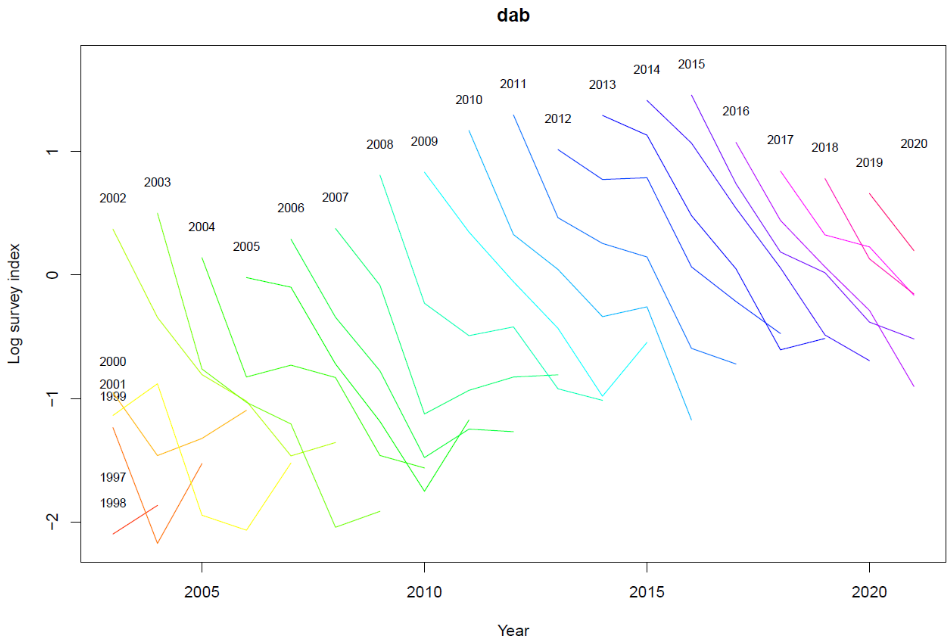

Figure 5.19. Dab in Subarea 4 and Division 3.a: SURBAR model results: catch curves.

Figure 5.20. Dab in Subarea 4 and Division 3.a: SURBAR mean-standardized log survey index.

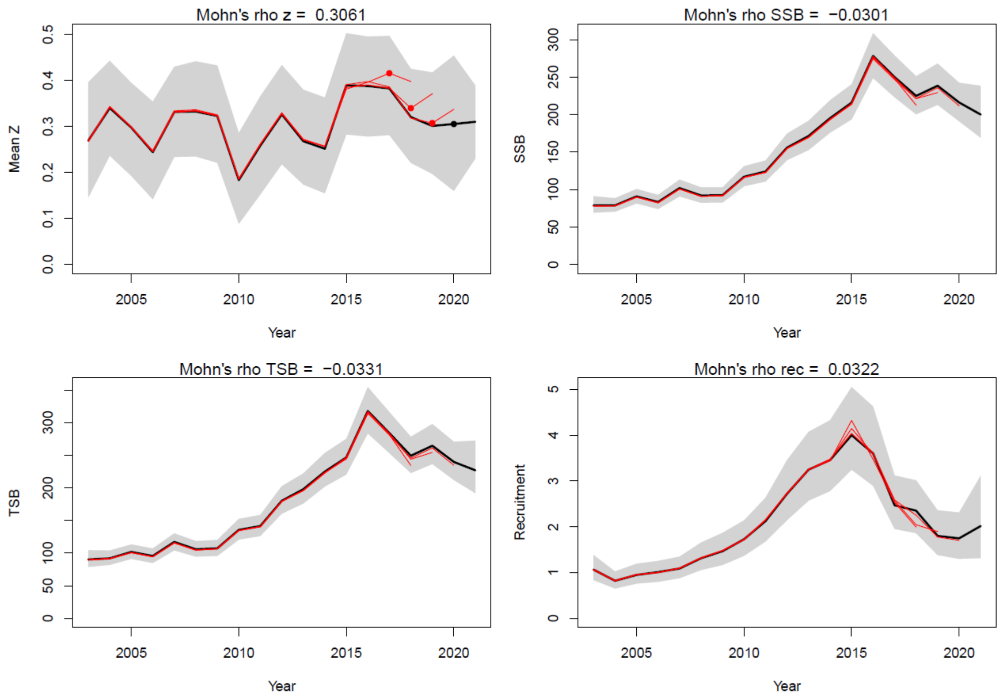

Figure 5.21. Dab in Subarea 4 and Division 3.a: SURBAR Retrospective runs with corresponding Mohn's rho values.

5.5 MSY Proxy analyses for dab in Subarea 4 and Division 3.a.

5.5.1 Dab 27.3a4 Surplus Production Model in Continuous Time (SPiCT)

In order to estimate MSY proxy reference points for dab a Surplus Production Model in Continuous Time (SPiCT; Pedersen and Berg, 2017) was applied. Three fishery independent survey time series and a catch time series (2002–2021) were used as input for the model (details of model input and settings given in Table 5.2). The survey time series were reduced by the recruits (i.e. > 12 cm or > age 1) in order to obtain a better proxy for the exploitable biomass, which is a prerequisite for any production model.

Table 5.2. Dab in Subarea 4 and Division 3.a. SPiCT settings and input data.

Setting/Data	Values/Source
Catch time series	InterCatch data 2002–2021
BTS Isis	1987–2002, >12 cm
BTS Tridens	1996–2002, >12 cm
Combined BTS (Isis, Tridens, Solea)	2003–2021, Age > 1 yr
SPiCT settings	no priors

The results of the SPiCT assessment for dab in Subarea 4 and Division 3.a (Fig. 5.22 – 5.27) showed that the relative fishing mortality is below the reference F_{MSY} proxy (Fig. 5.23, right panel) and the relative biomass is above the reference B_{MSY} * 0.5 proxy (Fig. 5.24; left panel). Also the estimated uncertainty boundaries around the relative F values show that these are below the reference F_{MSY} proxy for recent years, and those estimated for the relative biomass are above the reference B_{MSY}* 0.5 for recent years. However, it has to be noted here that the absolute F and biomass estimates are highly uncertain and must not be used for any further analyses or conclusions. Further, the retrospective display quite strong patterns (Fig. 5.27), especially the fifth peel is outside the uncertainty bounds. Therefore, the SPiCT model was no longer accepted by the working group, and it was not considered as the basis of the catch advice.

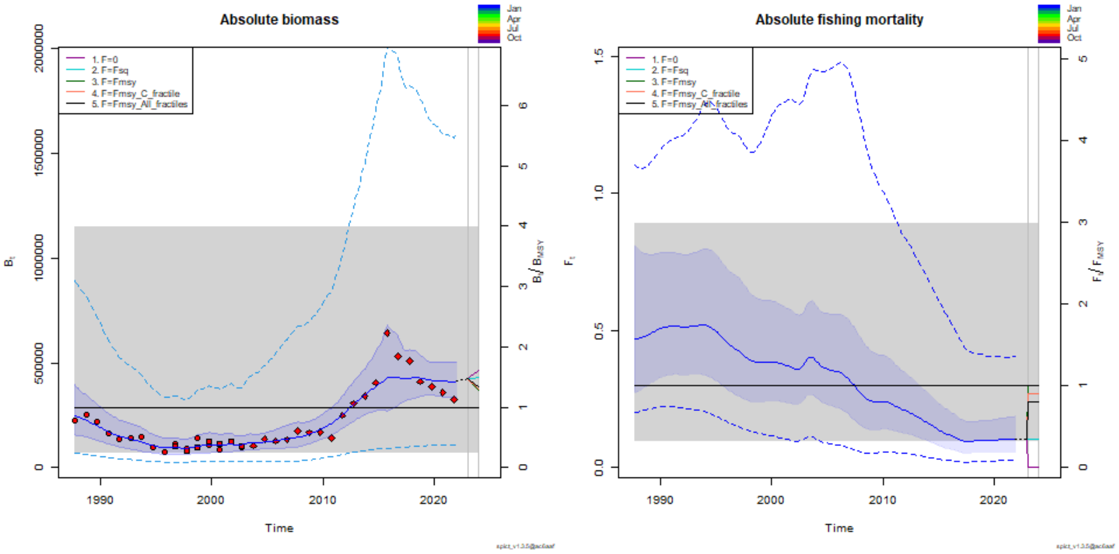

Figure 5.22. Dab in Subarea 4 and Division 3.a: SPiCT results. Absolute biomass (left panel) and absolute fishing mortality (right panel).

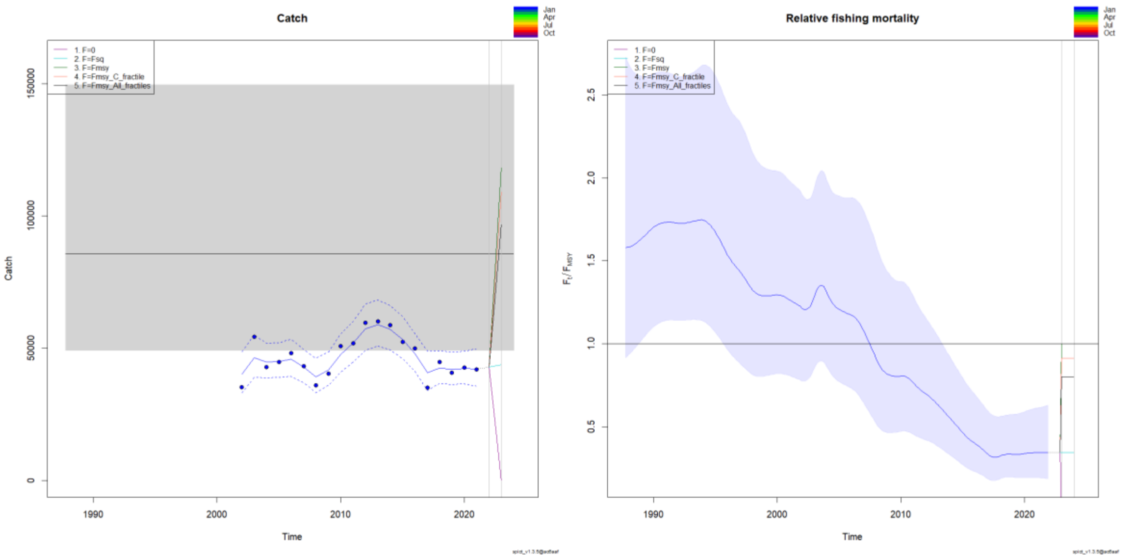

Figure 5.23. Dab in Subarea 4 and Division 3.a: SPiCT results. Catch time series (left panel) and relative fishing mortality (right panel).

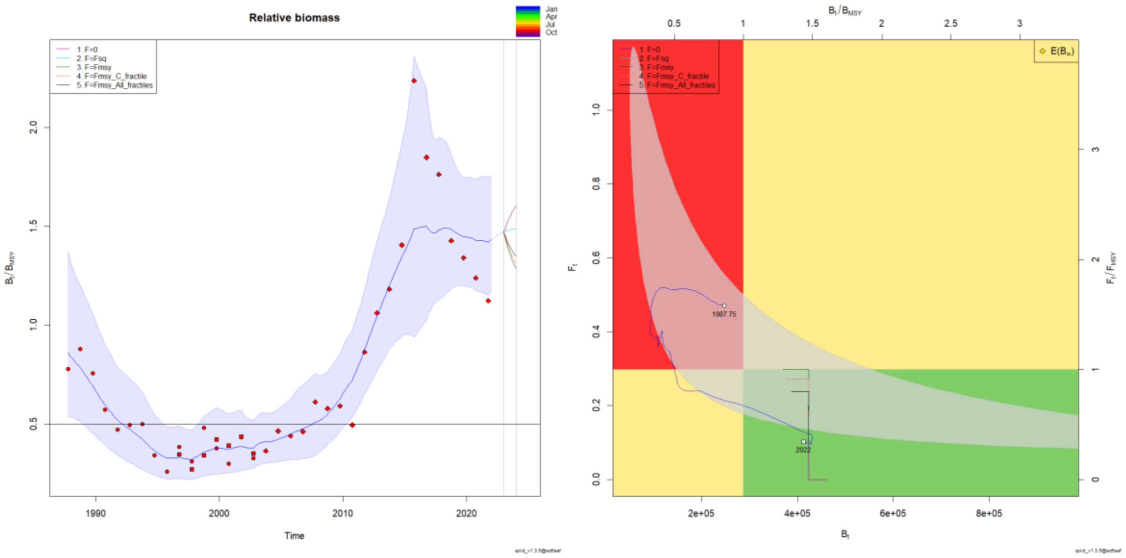

Figure 5.24. Dab in Subarea 4 and Division 3.a: SPiCT results. Relative biomass (left panel) and Kobe plot of relative fishing mortality over biomass estimate (right panel).

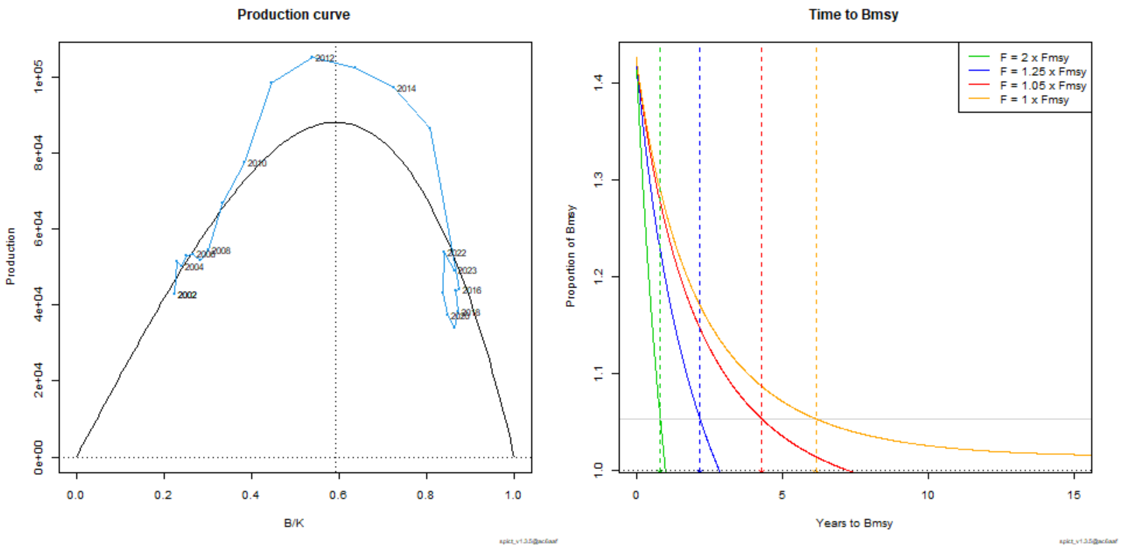

Figure 5.25. Dab in Subarea 4 and Division 3.a: SPiCT results. Production curve (left panel) and estimated time to B_{MSY} (right panel).

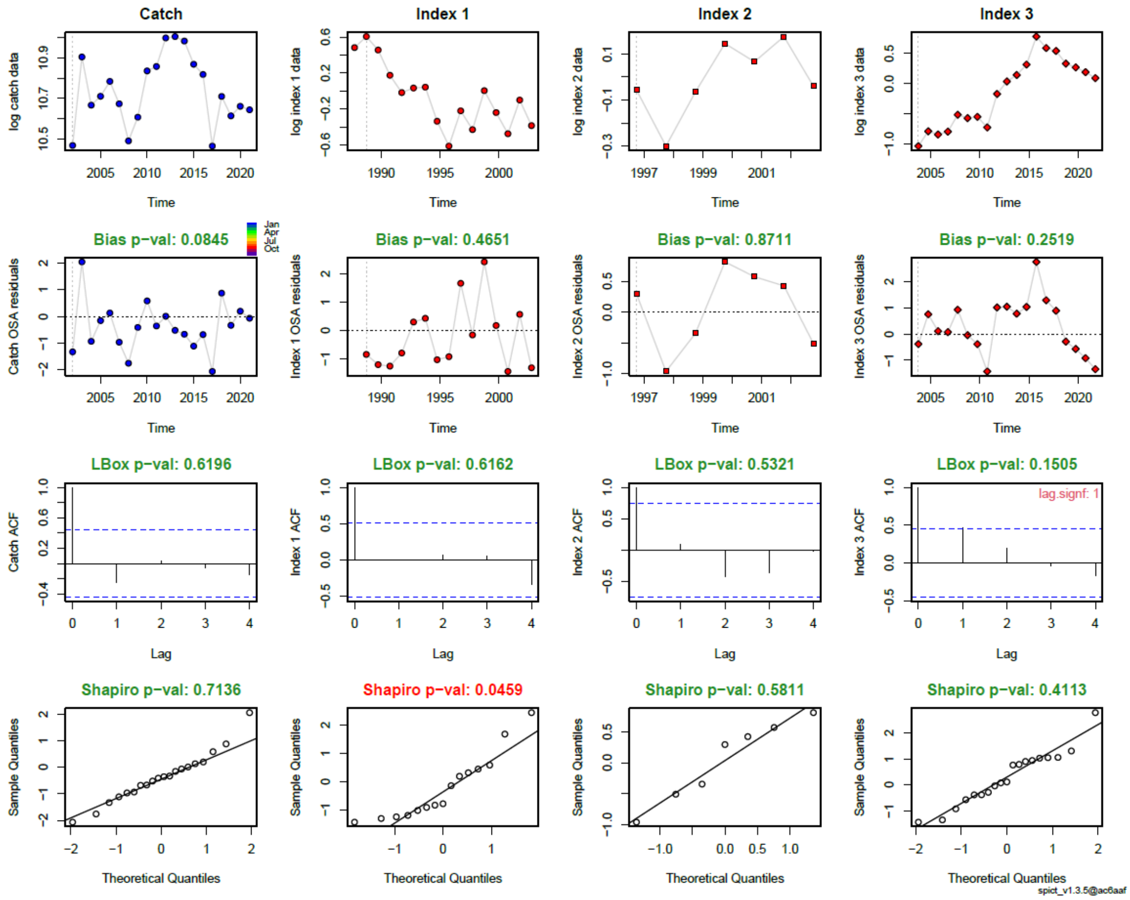

Figure 5.26. Dab in Subarea 4 and Division 3.a: SPiCT diagnostics.

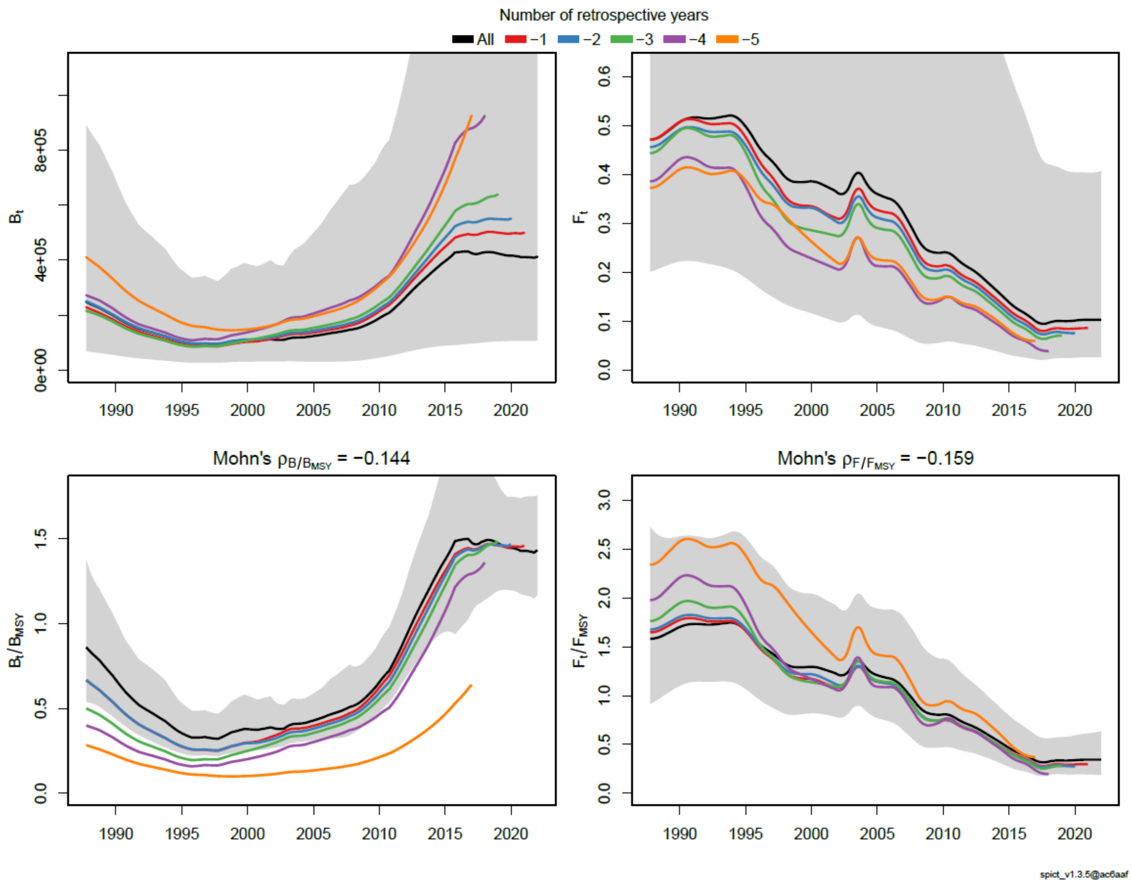

Figure 5.27. Dab in Subarea 4 and Division 3.a: SPiCT retrospective plots.

5.5.2 Dab 27.3a4 The Length Based Indicator Method (LBI)

Because SPiCT was not longer accepted by the WGNSSK, the Length Based Indicator method was applied in order to evaluate the stock status relative to MSY proxies. Length data from commercial samplings uploaded into the InterCatch system were used as input (2014 – 2021). During the last dab benchmark assessment in 2016 (ICES, 2016), von Bertalanffy growth parameters were estimated from survey data (L_{inf} = 24.9 cm, k = 0.39, t_0 = -0.7; BTS data 2003 - 2015). The $L_{mat50\%}$ was derived from literature (13.0 cm; Froese and Sampang, 2013). For the analysis the data were corrected for recruits, i.e. only lengths > 10.5 cm were taken into account. Individuals below this size are mainly caught in high numbers by the shrimper fleet near the coast and appear in the discard data. The resulting length distributions are very similar from year to year (Fig. 5.28). With respect to conservation all indicator ratios are above the reference (Table 5.3). This is also the case for all other indicators. The L_{mean} / $L_{F=M}$ ratio indicates that F was below $F_{MSY\ proxy}$ for this stock for the whole time period 2014 - 2021.

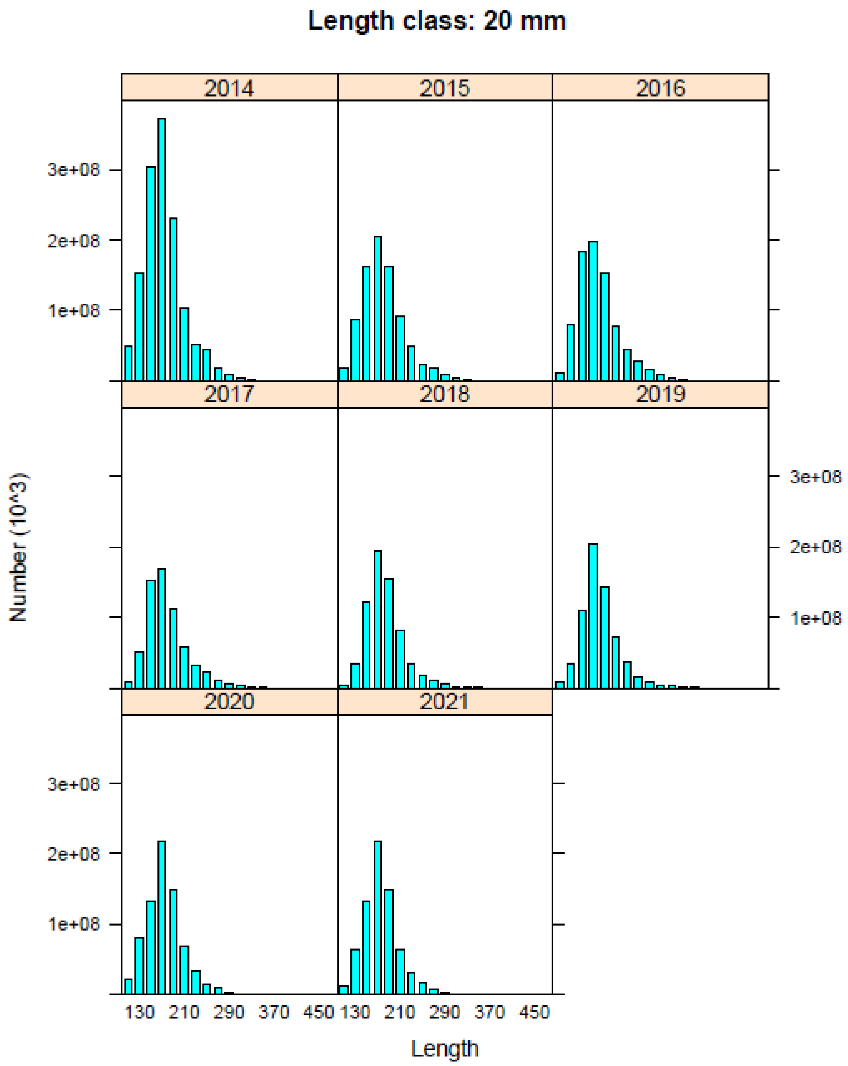

Figure 5.28 Dab in Subarea 4 and Division 3.a: Length distributions from commercial samplings. InterCatch data 2014 – 2021.

Table 5.3 Dab in Subarea 4 and Division 3.a. Summary of the Length Based Indicator Method.

	Conservation				Optimizing Yield	MSY
	L_c/L_{mat}	$L_{25\%}/L_{mat}$	$L_{max5\%}/L_{inf}$	P_{mega}	L_{mean}/L_{opt}	$L_{mean}/L_{F=M}$
Ref	>1	>1	>0.8	>30%	~1(>0.9)	≥1
2014	1.15	1.12	1.07	0.35	1.12	1.07
2015	1.15	1.19	1.11	0.43	1.15	1.09
2016	1.15	1.19	1.10	0.41	1.14	1.09
2017	1.15	1.19	1.11	0.39	1.13	1.08
2018	1.15	1.27	1.08	0.46	1.13	1.08
2019	1.15	1.27	1.08	0.44	1.13	1.07
2020	1.15	1.19	1.04	0.38	1.12	1.06
2021	1.15	1.19	1.04	0.39	1.12	1.06

5.6 The empirical *chr* rule as basis for the advice

Dab in the North Sea (dab.27.3a4) is a category 3 stock for which the 2:3 rule, based on a biomass index, was used as basis for the last catch advice given for the years 2018 and 2019 (ICES, 2017b). Since then, no catch advice was requested for this stock. However, in 2022 catch advice was requested again. The 2:3 rule should not be used any longer, and instead the empirical rules tested by WKLIFE X (ICES, 2020) should be applied. The growth parameter k = 0.39 was estimated during the last benchmark assessment for dab (ICES, 2016). Therefore, the constant harvest rate (*chr*) rule (ICES, 2020) was applied in the case of dab.

The *chr* rule applies a constant harvest rate that is considered a proxy for an MSY harvest rate, which is then applied to a biomass index:

$$C_{y+1} = I_{y-1} \times F_{MSYproxy} \times b \times m$$

with C_{y+1} is the catch advice, I_{y-1} the most recent index value, $F_{MSYproxy}$ is the ratio C_y / I_y for which the quantity f >1, where f is the ratio of the mean length L_{mean} in the catch and $L_{F=M}$, b is a biomass safeguard, and m is a multiplier applied to the *chr* rule to maintain the probability of the biomass declining below B_{lim} to less then 5%.

The biomass safeguard b is determined by the relation of the most recent index value to $I_{trigger}$ (with $I_{trigger}$ = 1.4 x I_{loss}; I_{loss} = defined as lowest observed index value). When the most recent index data is greater than $I_{trigger}$, b is set to 1. This was the case for dab. The precautionary multiplier m is applied with the *chr* rule to maintain the probability of the biomass declining below B_{lim} to less than 5%. Following the guidelines (ICES, 2022), this precautionary multiplier should be set to 0.5 when applying the *chr* rule. An uncertainty cap (*stability clause*) is applied, which limits the amount the advised catch can change upwards or downwards between years (+20% / -30%). This uncertainty cap was applied in the case of dab. The new catch advice was given relative to the average catch of the most recent three years, because no catch advice was requested for the years 2020 – 2022.

Applying the *chr* rule to the dab stock resulted in a catch advice of no more than 29 249 tonnes. This corresponds to 3 074 tonnes landings, if the average discard rate of 89% does not change (Table 5.4).

Table 5.4 Dab in Subarea 4 and Division 3.a. The basis for the catch scenarios. Catches are in tonnes.*

Previous catch advice A_y (average catch of last three years 2019, 2020, and 2021)		41 784 tonnes
Biomass index		
I: most recent biomass index (I_{2021})		196
MSY proxy harvest rate		
$F_{MSY\ proxy}$: MSY proxy harvest rate (average of the ratio of catch to biomass index for the years for which f>1, where f = $L_{mean}/L_{F=M}$)		207.810
Biomass safeguard		
$I_{2003} = I_{loss}$		78
Index trigger value ($I_{trigger}=I_{loss}\times1.4$)		110
Index 2021 (I_{2021})		196
b: index relative to trigger value, min{$I_{2021}/I_{trigger}$, 1}		1.00
Precautionary multiplier to maintain biomass above B_{lim} with 95% probability		
m: multiplier (generic multiplier based on life history)		0.5
Uncertainty cap (+20%/-30% compared to A_y, only considered if b=1)	Applied	-30%
Discard rate		89%
Catch advice for 2023, 2024, 2025**		29 249 tonnes
% advice change***		-30 %
Corresponding landings		3 074 tonnes

* The figures in the table are rounded. Calculations were done with unrounded inputs, and computed values may not match exactly when calculated using the rounded figures in the table.

** Formula: I × $F_{MSY\ proxy}$ × b × m, limited by uncertainty cap if applicable.

*** Advice value for 2023, 2024, 2025 relative to the average catch of recent three years (41 784 tonnes). Advice was not requested in recent years.

5.7 Issues list

- Métiers with zero landings but no discards reported. No raising possible for these cases. What is the possible impact on catch estimation? Are there other ways to estimate realistic discards for these métiers?
- No suitable data available for the shrimper fleets operating in coastal waters. No reliable discard raising possible for these fleets. What is the possible impact on catch estimation? Is there another way to estimate the discards of these fleets?
- Investigate extending the delta-GAM index with Belgian and German BTS data (prior to 2002). Further, the delta-GAM index still uses the haul duration to standardize number at length. However, the Working Group on Beam Trawl Surveys (ICES, 2021) recommends to use swept area as standardization. This should be changed and the currently used index and the survey trends based on swept area should be compared.
- Investigate the use of DYFS, DFS inshore surveys to estimate a recruitment index.
- SPiCT was not accepted any longer by the WGNSSK; possible improvements should be investigated to obtain an acceptable SPiCT model; could be used then as basis of the advice.
- Investigate which effort data are available and if these could be used as further input for the SPiCT model.

5.8 References

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Table 5.5. Official dab landings by ICES Subarea 4 and Division 3.a.

Year	Subarea 4	Division 3.a	Total
1950	5971	1287	7258
1951	8190	1332	9522
1952	7976	1294	9270
1953	5915	1123	7038
1954	5652	1237	6889
1955	6623	1257	7880
1956	5468	2081	7549
1957	6127	2724	8851
1958	6342	2210	8552
1959	5239	1943	7182
1960	5168	1314	6482
1961	4602	1367	5969
1962	4082	1683	5765
1963	4615	1565	6180
1964	4982	1575	6557
1965	5519	2052	7571
1966	5862	1755	7617
1967	4324	1115	5439
1968	3995	1548	5543
1969	4122	1430	5552
1970	5183	1079	6262
1971	6546	1242	7788
1972	7901	1669	9570
1973	9657	1449	11106
1974	7146	2003	9149
1975	7033	2049	9082
1976	5917	1583	7500
1977	6702	2318	9020
1978	6407	2630	9037
1979	8243	2716	10959
1980	8357	2333	10690
1981	8454	2679	11133
1982	9565	2902	12467
1983	11865	2906	14771
1984	5482	2769	8251
1985	5502	1545	7047
1986	3205	1608	4813
1987	3931	2258	6189
1988	7067	2254	9321

Year	Subarea 4	Division 3.a	Total
1989	5816	2346	8162
1990	2701	1574	4275
1991	3448	1609	5057
1992	2647	1454	4101
1993	3309	1695	5004
1994	3861	1961	5822
1995	3865	1530	5395
1996	4834	1405	6239
1997	5259	1012	6271
1998	12759	961	13720
1999	13276	673	13949
2000	10595	654	11249
2001	9799	765	10564
2002	8678	977	9655
2003	9008	865	9873
2004	8608	779	9387
2005	9402	836	10238
2006	9190	725	9915
2007	9434	694	10128
2008	8029	522	8551
2009	6561	498	7059
2010	7240	589	7829
2011	6824	545	7369
2012	6095	653	6748
2013	5213	871	6084
2014	4347	611	4958
2015	4162	995	5157
2016	4590	895	5485
2017	3130	788	3918
2018	3940	830	4770
2019	4273	1069	5342
2020*	3342	634	3976
2021*	2908	696	3604

*** Preliminary catch statistics**

Table 5.4. Official dab landings by country in Subarea 4.

Year	BEL	DEU	DNK	FRA	FRO	GBR	NLD	NOR	SWE	Subarea 4
1950	254	92	900	139	0	2555	2031	0	0	5971
1951	462	114	1800	90	0	3503	2221	0	0	8190
1952	386	74	1562	227	0	2823	2904	0	0	7976
1953	357	58	1337	189	0	2591	1383	0	0	5915
1954	255	62	1666	177	0	2393	1099	0	0	5652
1955	305	92	2923	161	0	1993	1149	0	0	6623
1956	338	99	1766	138	0	1660	1368	0	99	5468
1957	336	73	1983	154	0	1785	1669	0	127	6127
1958	290	71	2320	175	0	1885	1517	0	84	6342
1959	285	93	1433	146	0	2011	1265	0	6	5239
1960	246	70	1833	154	0	1813	1052	0	0	5168
1961	227	67	1497	161	0	1734	916	0	0	4602
1962	205	54	1357	147	0	1524	795	0	0	4082
1963	306	40	1660	128	0	1481	1000	0	0	4615
1964	424	48	1612	672	0	1177	1049	0	0	4982
1965	432	64	1841	734	0	1099	1349	0	0	5519
1966	507	65	1589	719	0	1215	1767	0	0	5862
1967	384	77	659	716	0	1147	1341	0	0	4324
1968	334	57	861	350	0	877	1516	0	0	3995
1969	302	69	984	448	0	689	1630	0	0	4122
1970	338	71	1476	588	0	752	1958	0	0	5183
1971	409	46	1546	618	0	986	2941	0	0	6546
1972	638	46	1816	727	0	1057	3617	0	0	7901
1973	678	41	1899	873	0	1349	3638	1179	0	9657
1974	281	59	1168	310	0	1227	4101	0	0	7146
1975	600	45	944	418	0	992	4031	0	3	7033
1976	489	52	852	306	0	816	3402	0	0	5917
1977	652	70	743	371	0	907	3959	0	0	6702
1978	520	64	799	513	0	1038	3473	0	0	6407
1979	484	87	1366	630	0	951	4724	0	1	8243
1980	518	24	1376	639	0	777	5023	0	0	8357
1981	542	31	1968	447	0	737	4729	0	0	8454
1982	460	42	2356	594	0	1002	5111	0	0	9565
1983	541	49	4428	495	0	1034	5318	0	0	11865
1984	603	35	3438	486	0	920	0	0	0	5482
1985	509	24	3535	404	0	1030	0	0	0	5502
1986	445	34	1400	289	0	1036	0	0	1	3205
1987	514	36	1574	434	0	1373	0	0	0	3931
1988	697	72	1324	349	0	1221	3404	0	0	7067

Year	BEL	DEU	DNK	FRA	FRO	GBR	NLD	NOR	SWE	Subarea 4
1989	443	117	1280	223	0	1232	2521	0	0	5816
1990	416	162	1103	214	0	802	0	0	4	2701
1991	491	290	1160	258	0	1249	0	0	0	3448
1992	464	218	699	217	0	1049	0	0	0	2647
1993	548	493	1016	235	0	1017	0	0	0	3309
1994	397	626	1307	133	0	1398	0	0	0	3861
1995	410	0	1306	155	1	1993	0	0	0	3865
1996	527	718	1484	177	0	1928	0	0	0	4834
1997	507	945	1399	124	0	2284	0	0	0	5259
1998	757	796	1024	126	0	2085	7971	0	0	12759
1999	802	758	1101	0	0	1964	8651	0	0	13276
2000	684	892	785	124	0	1534	6527	49	0	10595
2001	575	878	839	206	0	1368	5886	47	0	9799
2002	516	582	1126	228	0	1224	4951	51	0	8678
2003	396	642	1580	154	0	1204	4955	77	0	9008
2004	382	767	1136	121	0	1158	4989	55	0	8608
2005	372	1105	1128	121	0	1193	5352	131	0	9402
2006	369	1149	949	130	0	1415	5071	107	0	9190
2007	436	526	634	195	0	1212	6313	118	0	9434
2008	371	375	670	161	0	847	5544	61	0	8029
2009	349	262	489	196	0	648	4588	29	0	6561
2010	337	365	523	178	0	724	5097	16	0	7240
2011	243	312	622	165	0	645	4808	29	0	6824
2012	454	252	421	126	0	665	4136	41	0	6095
2013	406	333	404	84	0	647	3314	26	0	5214
2014	304	282	253	72	0	506	2907	23	0	4347
2015	247	244	747	75	0	339	2500	10	0	4162
2016	321	244	932	75	0	372	2611	35	0	4590
2017	210	137	340	0	0	381	2027	35	0	3130
2018	313	185	710	0	0	418	2292	22	0	3940
2019	310	166	860	32	0	402	2418	85	0	4273
2020*	171	188	557	25	0	368	1943	84	6	3342
2021*	308	108	433	13	0	304	1709	28	5	2908

*** Preliminary catch statistics**

Table 5.5. Official dab landings in ICES Division 3.a.

Year	Bel	Deu	Dnk	Fra	Nld	Nor	Swe	Division 3.a
1950	0	34	1253	0	0	0	0	1287
1951	0	17	1315	0	0	0	0	1332
1952	0	21	1273	0	0	0	0	1294
1953	0	9	1114	0	0	0	0	1123
1954	0	4	1233	0	0	0	0	1237
1955	0	3	1254	0	0	0	0	1257
1956	0	5	1462	0	0	0	614	2081
1957	0	5	2025	0	0	0	694	2724
1958	0	4	1578	0	0	0	628	2210
1959	0	2	1307	0	0	0	634	1943
1960	0	1	1313	0	0	0	0	1314
1961	0	0	1367	0	0	0	0	1367
1962	0	2	1681	0	0	0	0	1683
1963	0	0	1565	0	0	0	0	1565
1964	0	1	1574	0	0	0	0	1575
1965	0	1	2051	0	0	0	0	2052
1966	0	0	1755	0	0	0	0	1755
1967	0	0	1115	0	0	0	0	1115
1968	0	0	1535	13	0	0	0	1548
1969	0	0	1430	0	0	0	0	1430
1970	0	0	1079	0	0	0	0	1079
1971	0	0	1242	0	0	0	0	1242
1972	0	0	1669	0	0	0	0	1669
1973	0	0	1449	0	0	0	0	1449
1974	0	0	2003	0	0	0	0	2003
1975	0	0	1959	0	2	0	88	2049
1976	10	0	1493	0	80	0	0	1583
1977	11	0	2105	0	142	0	60	2318
1978	2	0	2515	0	39	0	74	2630
1979	3	0	2616	0	15	0	82	2716
1980	3	0	2218	0	3	0	109	2333
1981	0	0	2574	0	5	0	100	2679
1982	1	0	2823	0	22	0	56	2902
1983	1	0	2759	0	34	0	112	2906
1984	0	0	2695	0	0	0	74	2769
1985	1	0	1486	0	0	0	58	1545
1986	5	0	1551	0	0	0	52	1608
1987	19	0	2182	0	0	0	57	2258
1988	13	0	2150	0	15	0	76	2254

Year	Bel	Deu	Dnk	Fra	Nld	Nor	Swe	Division 3.a
1989	4	0	2302	0	0	0	40	2346
1990	3	0	1535	0	0	0	36	1574
1991	5	1	1556	0	0	0	47	1609
1992	10	0	1412	0	0	0	32	1454
1993	7	0	1656	0	0	0	32	1695
1994	9	0	1917	0	0	0	35	1961
1995	3	0	1482	0	0	0	45	1530
1996	0	0	1387	0	0	0	18	1405
1997	0	0	990	0	0	0	22	1012
1998	0	0	942	0	0	0	19	961
1999	0	0	661	0	0	0	12	673
2000	0	0	647	0	0	1	6	654
2001	0	0	751	0	0	7	7	765
2002	0	0	968	0	0	3	6	977
2003	0	0	674	0	173	14	4	865
2004	0	0	637	0	138	1	3	779
2005	0	0	738	0	95	0	3	836
2006	0	20	566	0	117	18	4	725
2007	0	9	547	0	126	3	9	694
2008	0	12	475	0	26	2	7	522
2009	0	4	478	0	3	1	12	498
2010	0	4	426	0	151	0	8	589
2011	0	10	517	0	0	11	7	545
2012	0	5	632	0	0	10	6	653
2013	0	11	654	0	174	26	6	871
2014	0	12	501	0	75	2	21	611
2015	0	8	752	0	203	8	24	995
2016	0	9	657	0	189	14	26	895
2017	0	3	601	0	157	14	13	788
2018	0	10	586	0	230	2	2	830
2019	0	1	675	0	390	1	2	1069
2020*	0	1	457	0	173	0	3	634
2021*	0	3	448	0	244	0	1	696

*** Preliminary catch statistics**

Table 5.6. Dab in Subarea 4 and Division 3.a.: InterCatch landings, discards and total catch (2002–2021).

Year	Landings	Imported discards	Raised discards	Total discards	Total catch	% discards
2002	8588	14448	12183	26631	35219	76%
2003	9433	22152	22778	44930	54363	83%
2004	8647	18559	15714	34273	42920	80%
2005	9537	21295	13996	35291	44828	79%
2006	10236	16106	21871	37977	48214	79%
2007	9881	8936	24392	33328	43208	77%
2008	8645	14781	12598	27379	36024	76%
2009	7040	20652	12769	33421	40461	83%
2010	8279	23688	18798	42486	50765	84%
2011	7422	28227	16234	44461	51883	86%
2012	7047	33220	19412	52632	59679	88%
2013	6611	36855	16621	53476	60087	89%
2014	5047	35383	18350	53733	58780	91%
2015	5082	26468	20904	47372	52454	90%
2016	5085	29023	15788	44811	49896	90%
2017	3598	22241	9274	31515	35113	90%
2018	4233	28630	11915	40559	44792	91%
2019	4991	26330	9372	35735	40726	88%
2020	3808	22291	16575	38866	42674	91%
2021	4343	20321	17273	37612	41955	90%

Table 5.7 Dab in Subarea 4 and Division 3.a. Assessment summary. Weights are in tonnes. Landings are official estimates from 1965–2001. Landings, discards and catches are ICES estimates from 2002–2021. Catch C, biomass index I, harvest rate C/I and fishing pressure proxy relative to MSY proxy f are given for the years 2014-2021 used in the application of the *chr* advice method (ICES 2022). Relative recruitment R, and total mortality Z from SURBAR.

Year	Landings	Discards	Catch C	Index I	Harvest Rate (C / I)	f = $L_{mean}/L_{F=M}$	R age 1	R low	R high	Z	Z low	Z high
1965	7571											
1966	7617											
1967	5439											
1968	5543											
1969	5552											
1970	6262											
1971	7788											
1972	9570											
1973	11106											
1974	9149											
1975	9082											
1976	7500											
1977	9020											
1978	9037											
1979	10959											
1980	10690											
1981	11133											
1982	12467											
1983	14771											
1984	8251											
1985	7047											
1986	4813											
1987	6189											
1988	9321											
1989	5641											
1990	4275											
1991	5057											
1992	4101											
1993	5004											
1994	5822											
1995	5395											
1996	6239											
1997	6271											
1998	5749											
1999	13949											
2000	11249											
2001	10564											
2002	8588	26631	35219									
2003	9433	44930	54363	78.22			0.838	1.061	1.386	0.146	0.269	0.396
2004	8647	34273	42920	78.31			0.653	0.82	1.026	0.236	0.342	0.443
2005	9537	35291	44828	90.03			0.76	0.954	1.195	0.193	0.298	0.395
2006	10236	37977	48213	82.56			0.799	1.001	1.256	0.142	0.247	0.354
2007	9881	33328	43209	100.91			0.88	1.094	1.35	0.234	0.334	0.43
2008	8645	27379	36024	90.98			1.056	1.317	1.657	0.235	0.336	0.441
2009	7040	33421	40461	91.76			1.167	1.477	1.869	0.221	0.325	0.432
2010	8279	42486	50765	116.23			1.367	1.717	2.142	0.088	0.186	0.286
2011	7422	44460	51883	122.96			1.682	2.145	2.638	0.152	0.261	0.366
2012	7047	52632	59679	155.07			2.147	2.729	3.459	0.218	0.329	0.433
2013	6611	53476	60087	169.96			2.572	3.251	4.075	0.174	0.272	0.38
2014	5047	53733	58780	193.99	302.999	1.066	2.781	3.474	4.329	0.155	0.257	0.363
2015	5082	47372	52454	213.79	245.348	1.093	3.249	4.043	5.051	0.282	0.39	0.502
2016	5085	44811	49896	275.38	181.192	1.086	2.896	3.647	4.629	0.278	0.395	0.495
2017	3598	31515	35113	246.24	142.597	1.078	1.953	2.453	3.122	0.281	0.39	0.497
2018	4233	40559	44792	221.12	202.570	1.076	1.863	2.364	3.018	0.221	0.321	0.425
2019	4991	35735	40726	235.27	173.096	1.075	1.383	1.808	2.361	0.197	0.307	0.417
2020	3808	38866	42674	212.80	200.527	1.063	1.301	1.734	2.314	0.16	0.307	0.454
2021	4343	37612	41955	195.91	214.148	1.064	1.316	2	3.113	0.23	0.312	0.389

6 Flounder in Subarea 4 (North Sea) and Division 3.a (Skagerrak, Kattegat)

6.1 General

Flounder (*Platichthys flesus*) in Subarea 4 and Division 3.a was assessed until 2013 in the Working Group on Assessment of New MoU Species (ICES, 2013a). Because only official landings and survey data were available, flounder was defined as a category 3 species according to the ICES guidelines for data limited stocks (ICES, 2012). Biennial advice for flounder is given since 2013 by ICES (ICES, 2013b) based on survey trends. Since 2015 flounder was included in the official data call for the WGNSSK and discard estimates were included into the assessment. During the WGNSSK 2017 methods to determine MSY proxy reference points were tested. Only the Length Based Indicator (LBI) method was accepted at that time and revealed that the North Sea flounder stock was fished at or below F_{MSY} proxy. Catch advice for flounder was prepared for 2018 and 2019 during the WGNSSK 2017 (ICES, 2017a). However, later in 2017 the combined TAC for dab and flounder was removed (EU COM, 2017/595), and North Sea flounder has become a non-target species with no TAC since then. ICES has not been requested to provide advice on fishing opportunities for flounder for the years 2020 and 2021. The assessment for flounder in Subarea 4 and Division 3.a was benchmarked in 2018 and a SPiCT model was set up to evaluate the stock status of flounder relative to MSY proxies (ICES, 2018a). However, updating the SPiCT assessment model with new available data, increased the uncertainties to unacceptable levels. Therefore, the LBI method was used again instead, as it was done for the previous advice (ICES, 2017b). In 2021 precautionary catch advice was again requested for the flounder North Sea stock. Therefore, catch data, survey indices, and the LBI method were updated and presented during the WGNSSK 2021 meeting (ICES, 2021). As in previous years the NS-IBTS Q1 index was used as stock indicator on which the 2 over 3 rule was applied (ICES, 2012). The LBI method showed that the fishing pressure was below F_{MSY} proxy. However, the trend of the index was decreasing for the last years, with the lowest observed value in 2020, therefore the precautionary buffer was applied. This resulted in a catch advice of 1650 tonnes for the years 2022 and 2023. This corresponded to landings of no more than 171 tonnes (discard rate = 29%, last three year average). No advice had to be prepared during the WGNSSK 2022. However, the stock assessment, official landings tables, and InterCatch data were updated. The updated survey indices displayed a further decrease for the NS-IBTS Q1 and an even more drastic decrease in the combined quarter 3 index. However, the LBI method showed that the fishing pressure was still below the F_{MSY} proxy, and the precautionary buffer was already applied for the last catch advice. Therefore, the working group concluded to not reopen the advice for this stock.

6.1.1 Biology and ecosystem aspects

Flounder is a euryhaline flatfish: the life cycle of each individual usually includes marine, brackish, and freshwater habitats. It has a coastal distribution in the Northeast Atlantic, ranging from the White Sea and the Baltic in the north, to the Mediterranean and Black Sea in the south. Flounder can live in low salinity water but they reproduce in water of higher salinity.

Flounder feeds on a wide variety of small invertebrates (mainly polychaete worms, shellfish, and crustaceans), but locally the diet may include small fish species like smelt and gobies. The most intensive feeding occurs in the summer, while food is sparse in the winter.

In the North Sea, Skagerrak and Kattegat flounder spawn between February and April. The adults move further offshore to the 25–40 m deep spawning grounds, the most important of which are situated along the coasts of Belgium, the Netherlands, Germany, and Denmark. During autumn, both mature and immature flounder withdraw from the inshore and estuarine feeding areas. Juvenile flounder migrate into coastal areas, where they spend the winter.

6.1.2 Stock ID and possible assessment areas

There is no information about stock identity and possible stock assessment areas in the North Sea, Skagerrak and Kattegat. Within the North Sea there may exist a number of sub-populations (ICES, 2013a).

6.1.3 Management regulations

There is no minimum landing size for this species in EU waters.

Flounder is mainly a bycatch species in fisheries for plaice and sole. The discard rates for flounder can be (~40%). No minimum landing size is defined for flounder. According to EU-Regulations a precautionary TAC was given in EU waters of Division 2a and Subarea 4 together with dab (*Limanda limanda*). This combined TAC was never fully utilized. In 2017, the European Commission requested ICES to evaluate the possible effects on the stocks of flounder and dab having no TAC. ICES advised that given the current fishing patterns of the main fleets catching flounder and dab, which are the same fleets targeting plaice and sole, the risk of having no TAC for the flounder and dab stock is considered to be low (ICES, 2017b). Therefore, the European Commission removed the combined TAC for these two stocks (EU COM, 2017/595).

6.2 Fisheries data

6.2.1 Historical landings

In the North Sea and in the Skagerrak and Kattegat flounder is mainly a bycatch in the fishery for commercially more important flatfish such as sole and plaice and in the mixed demersal fisheries. The largest part of official landings is reported for Subarea 4, especially for the last decade (Figure 6.1; Table 6.5). Landings in ICES Subarea 4 and Division 3.a by country are shown in Figures 6.2 and 6.3 and in Tables 6.3 and 6.4. The apparent decrease in official landings between 1984 and 1997 is due to unreported landings by the Netherlands. Further, there seem to be an issue with Danish and German official landings in Subarea 4 which drastically dropped after 1997 (Figure 6.3, red and black bars). At least the drastic decline in Danish landings could be explained by a combined TAC for dab and flounder which was established in 1998, i.e. that before 1998 partly combined dab and flounder landings may have been reported by the Danish fishery. Another reason maybe misreporting to flounder from other quota species from the fishery in area 4 before the TAC came in force in 1998.

Since 1950, annual landings from the North Sea have fluctuated, without any clear pattern (Figure 6.1). During the last decade, landings declined considerably. This decline goes hand in hand with a reduction in fishing effort of bottom trawl fleets in the North Sea since 2000 (STECF, 2016). The lowest official landings were reported for 2017, since then it increases slightly again. For 2021, total official landings were reported with 1730 tonnes, compared to 1767 tonnes in 2020. In Division 3.a, annual landings in general have decreased sharply from mid of the 1980s until 2015. Official landings increased slightly since then, but they are still on low levels compared with earlier years (Figure 6.2).

Flounder is of relatively little commercial importance in the North Sea and the Skagerrak/Kattegat. Landings data may have been misreported in previous years. However, the amount of misreporting is not known. In addition, the official landings may not reflect the total catches, because flounder is often discarded and discarding is influenced by the prices and the availability of other, commercially more important species and therefore cannot be estimated for years without observations.

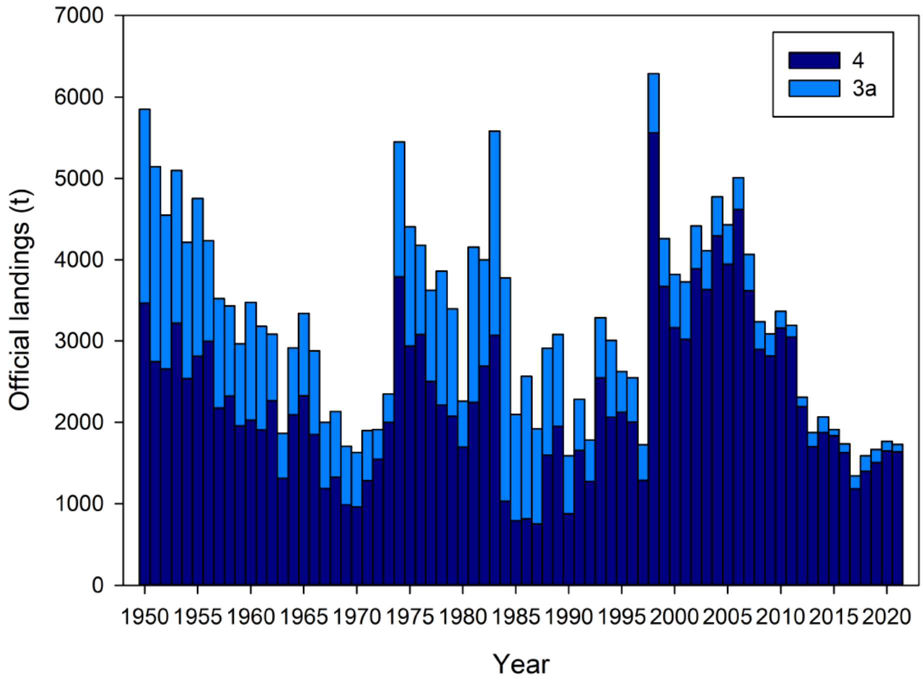

Figure. 6.1. Flounder in Subarea 4 and Division 3.a: Official landings in tonnes of flounder by area 1950–2021.

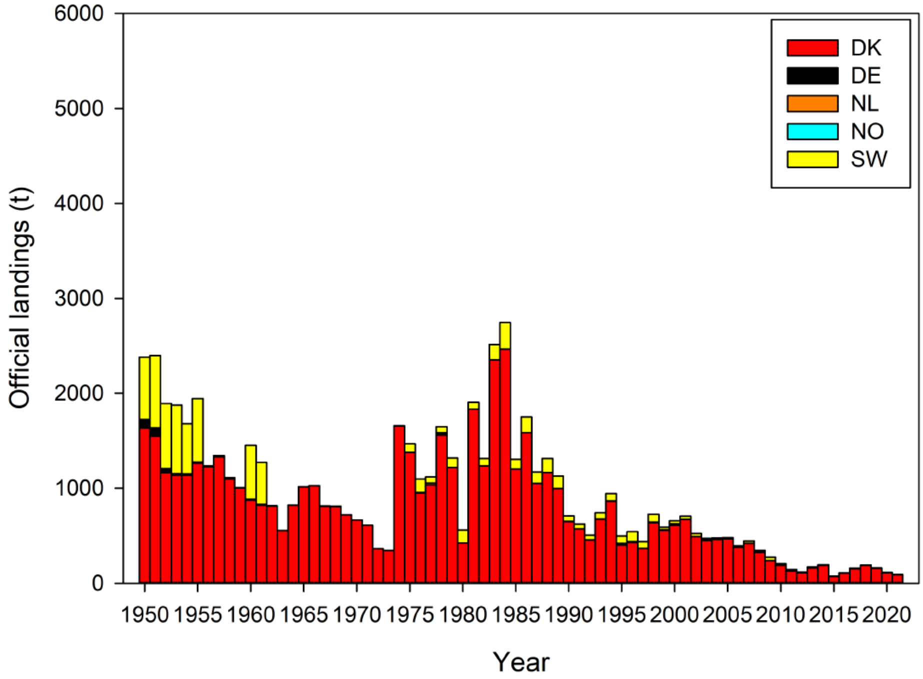

Figure 6.2. Flounder in Subarea 4 and Division 3.a: Official landings in tonnes of flounder in ICES Division 3.a by country. 1950–2021.

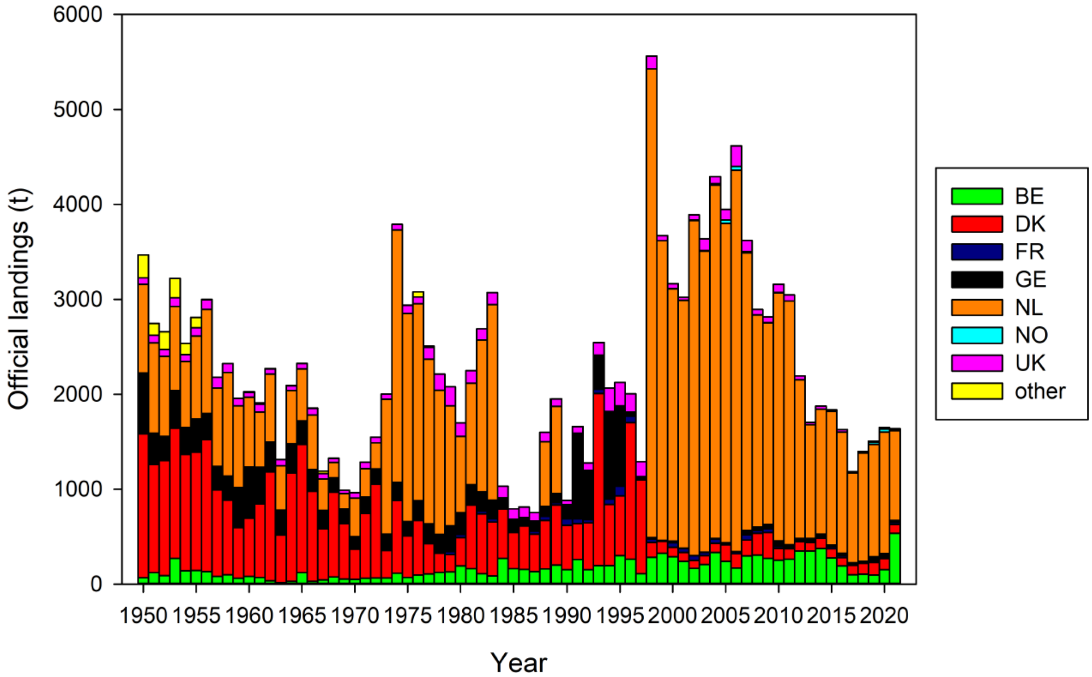

Figure 6.3. Flounder in Subarea 4 and Division 3.a: Official landings of flounder in ICES Subarea 4 by country 1950–2021.

6.2.2 InterCatch

Flounder landings and discards data from 2002–2021 were available in the InterCatch system for the current assessment year.

In general, it was tried only to raise equivalent or similar métiers with each other in InterCatch. Discard information was provided for 72% of all métiers in 2021 (Figure 6.4). However, for a number of métiers zero landings were reported. For these métiers no raising with InterCatch was possible. A further problem in the estimation of total flounder discards maybe the TBB_CRU_16-32_0_0_all metier, targeting brown shrimp in coastal areas of the Southeastern North Sea.

In 2021, by far the largest proportion of landings (848 tonnes, ~66% of total landings) was reported by Dutch beam trawlers (TBB_DEF_70_99_0_0_all), followed by the Belgium TBB_DEF_70-99_0_0_all fleet (103 tonnes), and the Danish GNS_DEF_120-219_0_0_all fleet (88 tonnes). Also the Dutch and Belgium shrimper fleets (TBB_CRU_16-31_0_0_all) landed a considerable amount of flounder with 75 tonnes in total. All other fleets did not land more than 15 tonnes each, except the Danish OTB_CRU_90-119_0_0_all fleet with 52 tonnes landed (Figure 6.5). The highest amount of discards in 2021 was reported for the Danish OTB_CRU_90-119_0_0_all fleet, followed by the German shrimper fleet with 32 tonnes (TBB_CRU_16-31_0_0_all), and the Dutch shrimper fleet with 17 tonnes.

The largest total catch estimated in 2021 was taken by the Netherlands (964 tonnes), followed by Denmark (622 tonnes), Belgium (148 tonnes) and Germany (54 tonnes). All other countries catch less than 30 tonnes each (Figure 6.7). The total catch estimated with InterCatch was 1836 tonnes from which 1293 tonnes were landings (compared to 1730 tonnes reported official landings) and 543 tonnes discards (30% of the total catch). However, it should be noted that not all métiers were sampled in every quarter and that the raising procedure may not be adequate for all cases. No data from Norway were imported into InterCatch for 2021, while official landings for Norway in 2021 were reported with 2 tonnes, compared to 30 tonnes official landings in 2020.

In general it was attempted to use the same groupings for discard raising as for the previous data years. However, this was not possible for all cases and compared to the previous year slight changes had to be made. The grouping is based on gear type and mesh size over areas and season. For the sample allocation scheme one landing and one discard group was set up, because data availability did not allow for a higher resolution. A separate discard group for the shrimper fleets was set up (TBB_CRU_16-31_0_0_all), because the length distribution with only small individuals (<=10cm) differs largely from the fleets operating more offshore. The following groupings were used for the 2021 data discard raising:

Group 1:	TBB_DEF_70-99_0_0_all and TBB_DEF_100-119_0_0_all raised with all TBB_DEF_70-99_0_0_all métiers
Group 2:	MIS_MIS_0_0_0_HC raised with all other métiers because no specific MIS_MIS_0_0_0_HC data were available.
Group 3:	all OTB, SSC, SDN, 70 – 119 métiers raised with all other métiers of same type and mesh size.
Group 4:	All passive gears raised with all passive gears (only SWE discard data available)
Group 5:	OTB_DEF>=120 with all OTB_DEF_>=120 métiers
Group 6:	SDN_SSC_DEF_>=120 with all other SDN_SSC_DEF_>120
Group 7:	TBB_DEF_>=100_0_0_0_all raised with all TBB_DEF métiers

Group 8: OTB_CRU_70-119 raised with all OTB_CRU_70-119 métiers

Group 9: all other métiers were raised with all métiers.

Length allocations for 2021 data: one discard group (including BMSL and LogBook D, excluding TBB_CRU_16-31_0_0_all data) and one landing group. In addition, one separate group for TBB_CRU_16-31_0_0_all discards was set up.

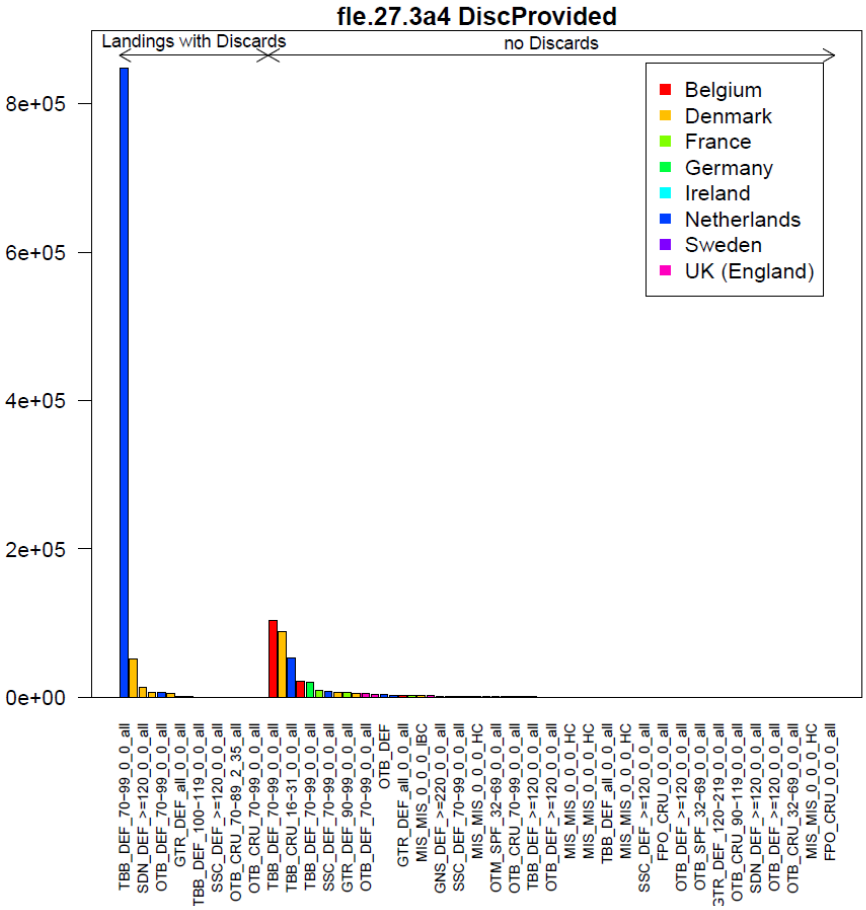

Figure 6.4. Flounder in Subarea 4 and Division 3.a: Provision of discards information by country and fleets imported to InterCatch for 2021 data.

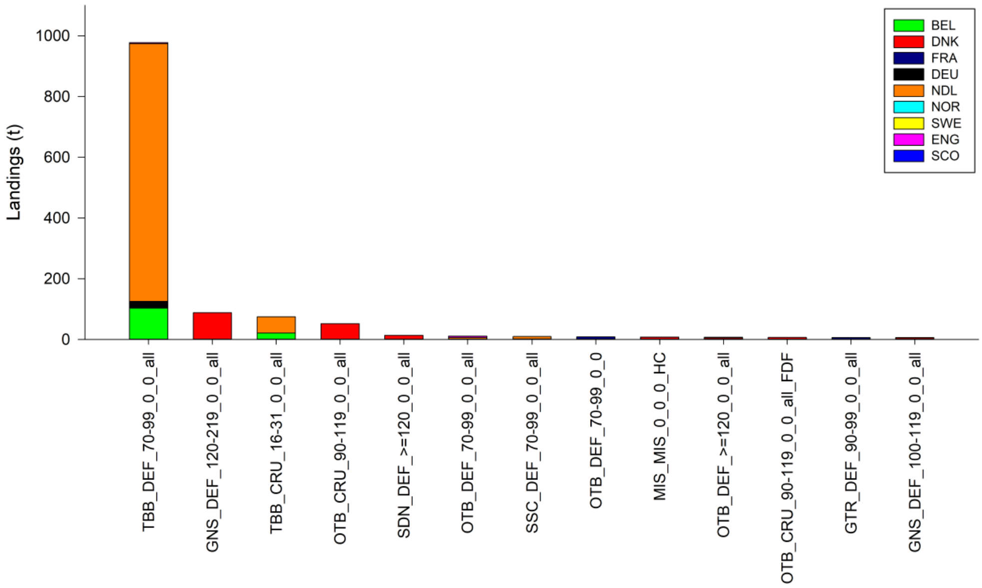

Figure 6.5. Flounder in Subarea 4 and Division 3.a: Flounder landings by métier and country in 2021 as uploaded to InterCatch.

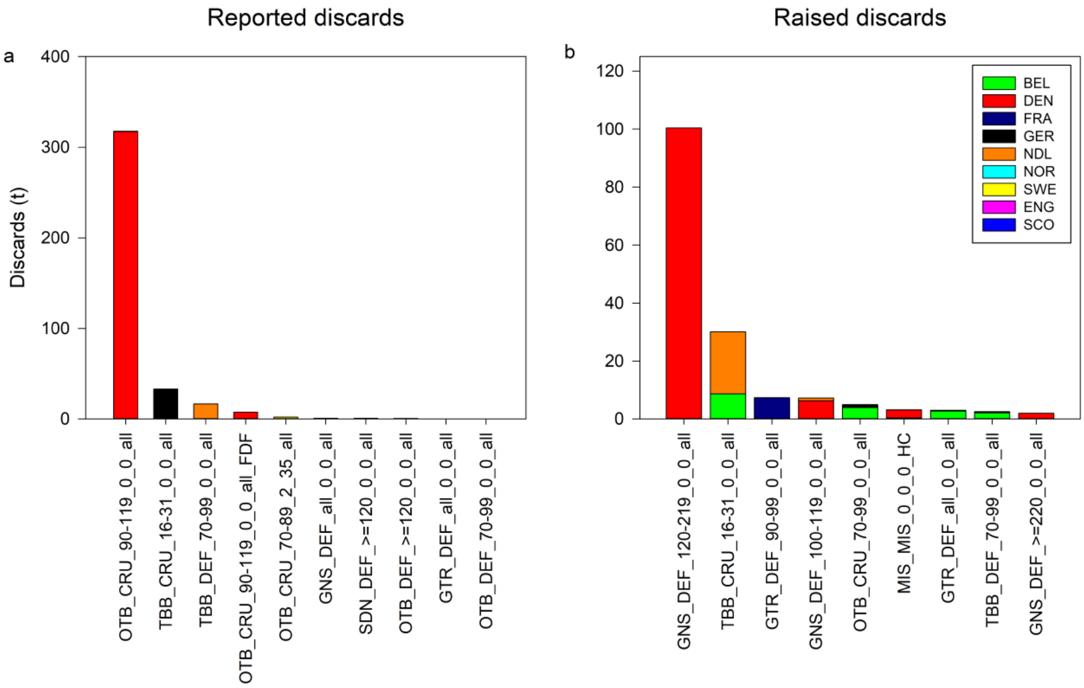

Figure 6.6. Flounder in Subarea 4 and Division 3.a: Flounder discards by métier and country in 2021. Reported discards panel (a), raised discards panel (b).

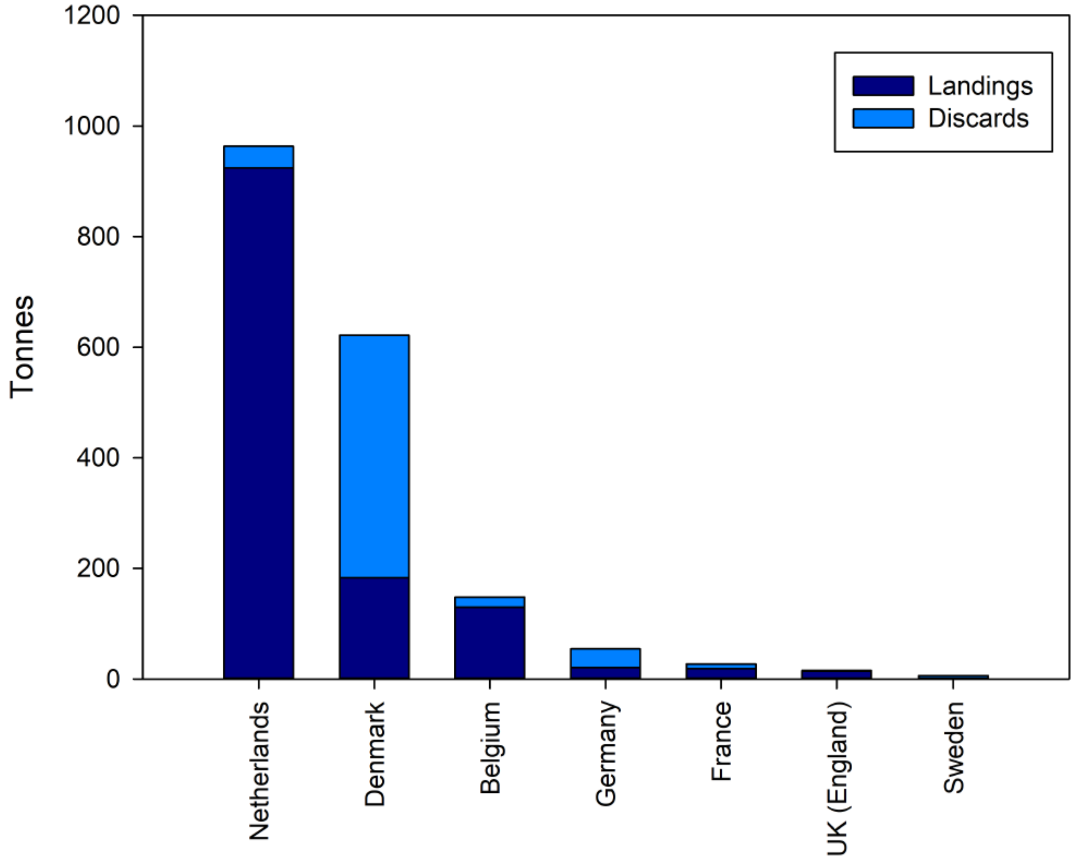

Figure 6.7. Flounder in Subarea 4 and Division 3.a: Flounder landings and discards by country in 2021 estimated with InterCatch.

6.3 Survey data/recruit series

Several surveys in the North Sea, Skagerrak and Kattegat provide information on distribution, abundance and length composition of flounder. The most relevant survey for flounder is probably the North Sea International Bottom Trawl Survey in quarter 1 (NS-IBTSQ1) because it covers the whole distribution area of the stock and shows even a higher catchability compared to the beam trawl surveys conducted in quarter 3 (BTS). However, the NS-IBTSQ1 uses a bottom trawl which is not very well suited to catch demersal flatfishes. Further, it should be noted here that the NS-IBTSQ1 was not fully standardized before 1983. Therefore, index data before this year should be interpreted with caution and are not presented in this report. The beam trawl surveys (BTS) use a beam trawl and are designed for catching flatfish. However, they are carried out in quarter 3, in a time of year in which flounder is distributed in more coastal, shallow and brackish waters in the river estuaries and the wadden sea areas. Biological data available from the NS-IBTSQ1 survey is displayed in Figure 6.9. and Figure 6.10.

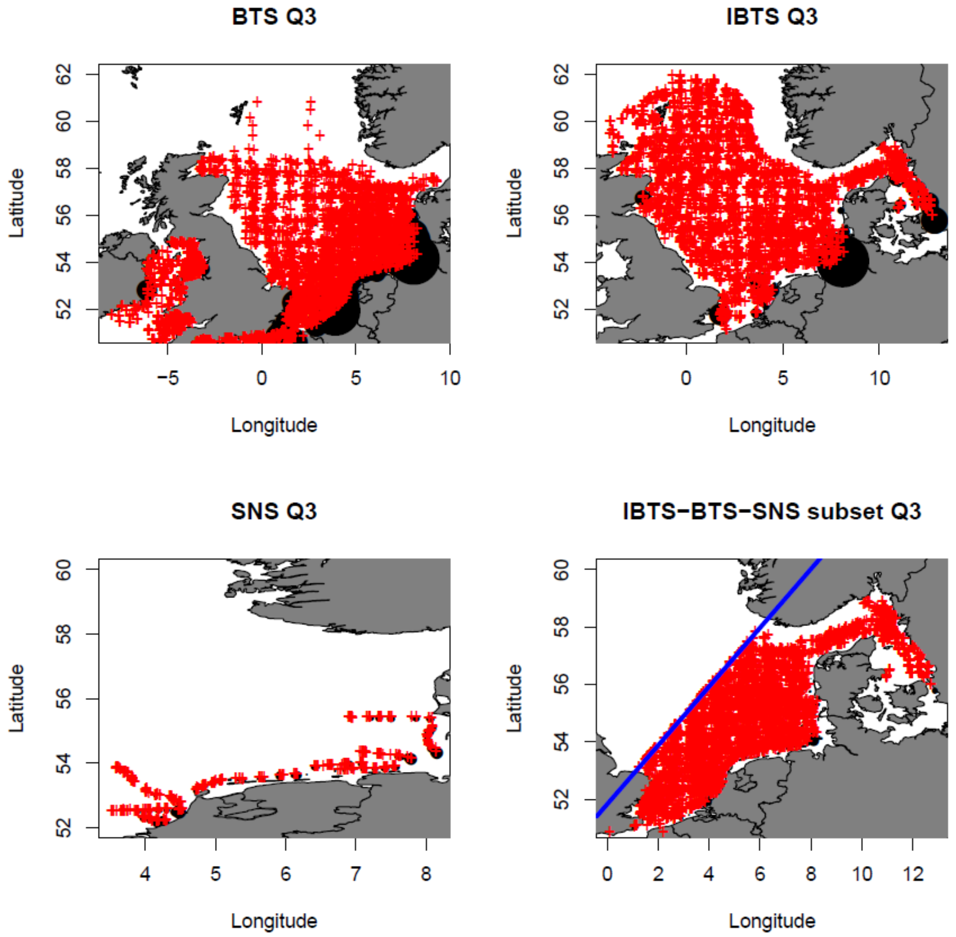

Figure 6.8. Flounder in Subarea 4 and Division 3.a: Distribution of flounder derived from different bottom trawl surveys in Subarea 4 and Division 3.a and the defined index area (lower right panel).

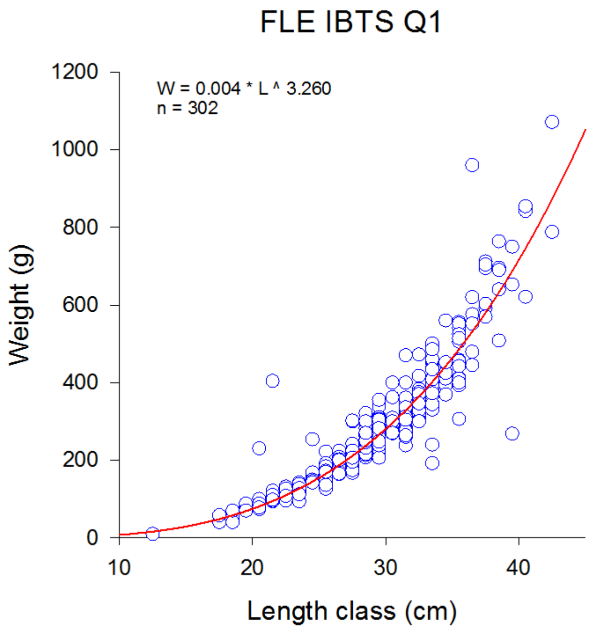

Figure 6.9. Flounder in Subarea 4 and Division 3.a: Length weight relationship of flounder derived from NS-IBTSQ1 data.

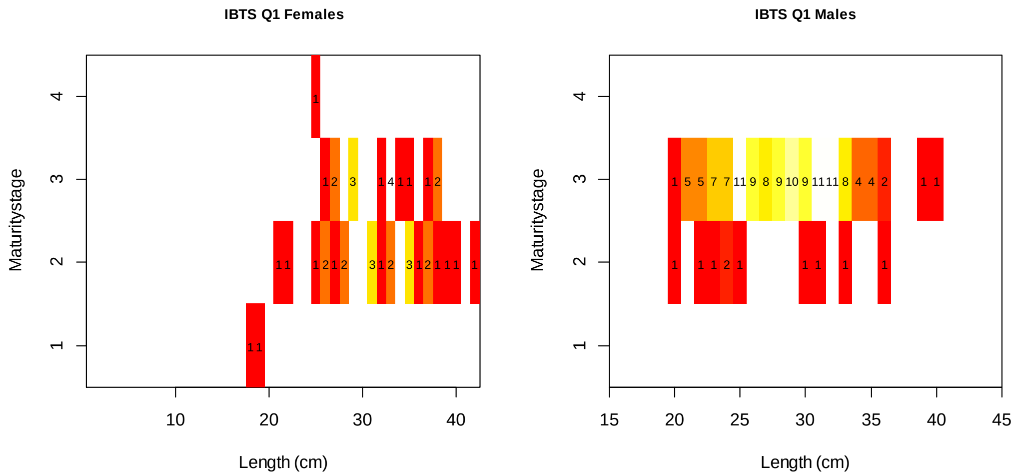

Figure 6.10. Flounder in Subarea 4 and Division 3.a: Maturity at length of female and male flounder derived from IBTS–Q1 data.

Survey indices

The flounder assessment was benchmarked in 2018 and two survey indices were constructed: a NS-IBTSQ1 and a combined quarter 3 index (IBTS, BTS, SNS), both indices modelled with the deltaGAM method (Berg *et al.*, 2014). For both indices the index area was defined, based on the species distribution from the hauls (Figure 6.8 lower right panel) which is restricted to the south-eastern part of the North Sea and Division 3.a. In quarter 3, four gear types were used in the different beam trawl surveys (BT8, BT7, BT6, and BT4) and the GOV in the NS-IBTS survey. Therefore, a gear effect was included to model a combined quarter 3 index for flounder. The following models where formulated:

Quarter 1

$$g(\mu_i) = Year(i) + f_1(lon_i, lat_i) + f_2(depth_i) + \log(HaulDur_i)$$

Quarter 3 – with gear effect

$$g(\mu_i) = Year(i) + Gear(i) + f_1(lon_i + lat_i) + f_2(depth_i) + log(HaulDur_i)$$

The new NS-IBTSQ1 index shows higher values at the beginning of the time series (Figure 6.11 blue line). Since 2000, the index was increasing again until 2008. Since then, the index was in general decreasing, with the lowest observed value in 2022. The combined quarter 3 index (Figure 6.11 red line) does not show any clear trends and in general follows the trend of the NS-IBTSQ1 index. A sharp drop of the combined Q3 index value was observed for 2021, resulting in the lowest observed value for the whole time series. The overall trend of both indices is similar with higher observed values at the beginning of the time series and an overall decreasing trend from 2008 onwards.

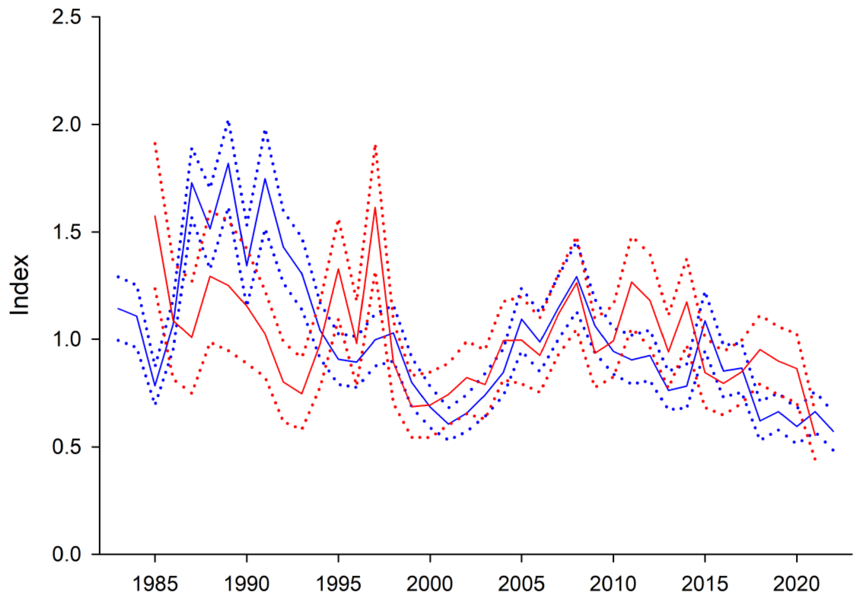

Figure 6.11. Flounder in Subarea 4 and Division 3.a: IBTS Quarter 1 biomass index (blue line) and combined quarter 3 biomass index (red line). Dotted lines display sd.

6.4 MSY Proxy analyses for flounder in Subarea 4 and Division 3.a.

6.4.1 Length based indicators

Flounder length samples (sex combined) from commercial catches were provided in InterCatch format for the years 2014–2020. These data were used for the analyses of MSY proxies applying the Length Based Indicator method (LBI; ICES 2017). The commercial length data show incoming recruitment peaks for some of the years (Figure 6.12). Since the LBI method assumes constant recruitment, the data sets were reduced by length classes below 16 cm (corresponding to ages below 2 years) for the analyses. Further, the length distributions were binned to 20 mm length classes. The method also requires growth parameters, which were taken either from literature (Froese and Sampang, 2013; Table 6.1) or estimated based on the available survey or InterCatch data. The L_{inf} was recalculated this year using InterCatch length distribution and the empirical formula by Garcia *et al*. (2016):

$\log_{10}L_\infty = 0.068260\ (\pm 0.010451) + 0.969112\ (\pm 0.006318)\ \log_{10}L_{max}$,

where L_{max} is defined as the 99% percentile of the commercial length distribution (39.5 cm; Figure 6.13). This resulted in the applied L_{inf} of 41.3 cm. The estimated L_{inf} value did not change, taking into account 2021 data.

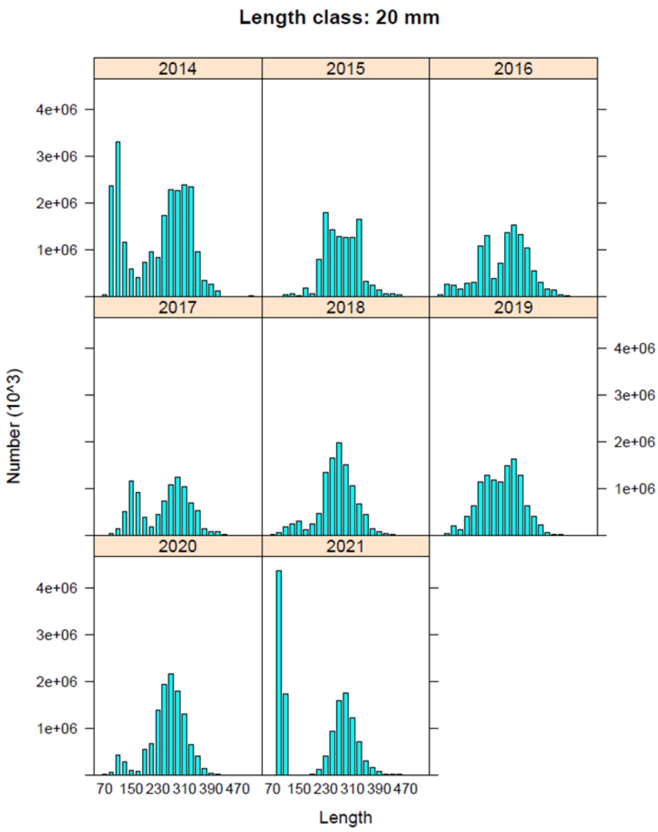

Figure 6.12. Flounder in Subarea 4 and Division 3.a. Length distributions (20 mm length classes) from InterCatch 2014–2021.

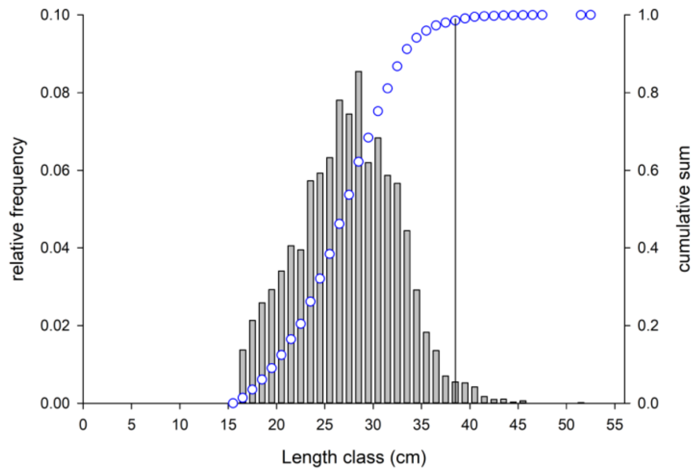

Figure 6.13. Flounder in Subarea 4 and Division 3.a. InterCatch relative length distribution (2014–2021) with the cumulative sum. Vertical line displays the 99% percentile of the distribution (39.5 cm).

The results of the LBI method showed that all of the indicators are above the reference points for 2021 (Table 6.2). The P_{mega} indicator increased to 34% and was above the 30% reference point since for the first time sice 2018. The L_C / L_{mat} ratio fluctuated around 1 but was above in 2020 and in 2021. In terms of the F_{MSY} proxy $L_{mean}/L_{F=M}$ the indicator ratio is above 1 for all the years (Table 6.2; Figure 6.20). From these results it was concluded that flounder is currently exploited below F_{MSY}.

Table 6.1. Flounder in Subarea 4 and Division 3.a. Parameters used as input for the LBI method.

Parameter	Sex combined
von Bertalanffy L_∞ (cm)	41.3
von Bertalanffy k (yr^{-1})	0.36
Length-weight a	0.00867
Length weight b	3.06
Natural mortality M (yr^{-1})	0.2
Length-at-maturity (cm)	21
Natural mortality M	0.2

Table 6.2. Flounder in Subarea 4 and Division 3.a. Length Based Indicator table displaying the reference points and indicators based in InterCatch length sample data 2014–2021.

	Conservation				Optimizing Yield	MSY
	LC/L_{mat}	$L_{25\%}/L_{mat}$	$L_{max5\%}/L_{inf}$	P_{mega}	L_{mean}/L_{opt}	$L_{mean}/L_{F=M}$
Ref	**>1**	**>1**	**>0.8**	**>30%**	**~1(>0.9)**	**≥1**
2014	0.90	1.21	0.93	0.42	1.05	1.18
2015	1.10	1.12	0.94	0.36	1.05	1.05
2016	0.90	1.02	0.96	0.35	1.01	1.13
2017	0.81	1.17	0.93	0.37	1.02	1.22
2018	1.10	1.17	0.91	0.26	1.03	1.03
2019	0.90	1.02	0.89	0.24	0.98	1.10
2020	1.10	1.17	0.87	0.23	1.02	1.02
2021	1.19	1.26	0.90	0.34	1.08	1.02

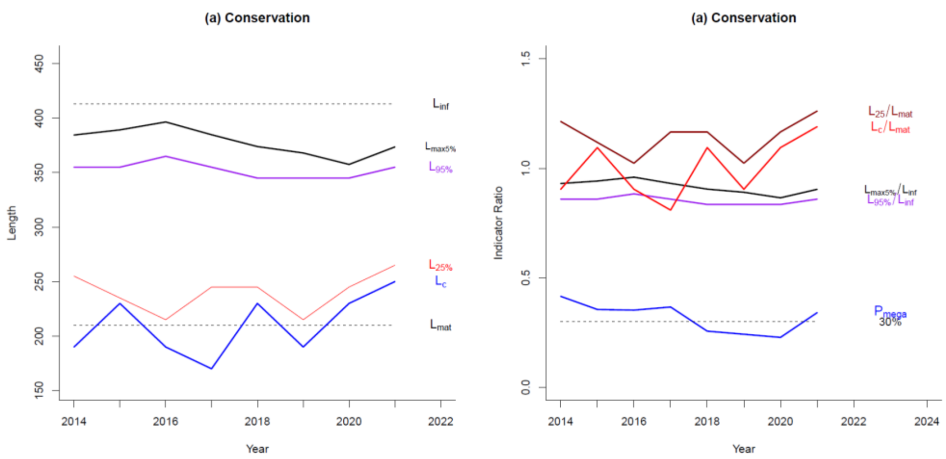

Figure 6.14. Flounder in Subarea 4 and Division 3.a. Conservation indicators (left panel, length in mm) and indicator ratios (right panel).

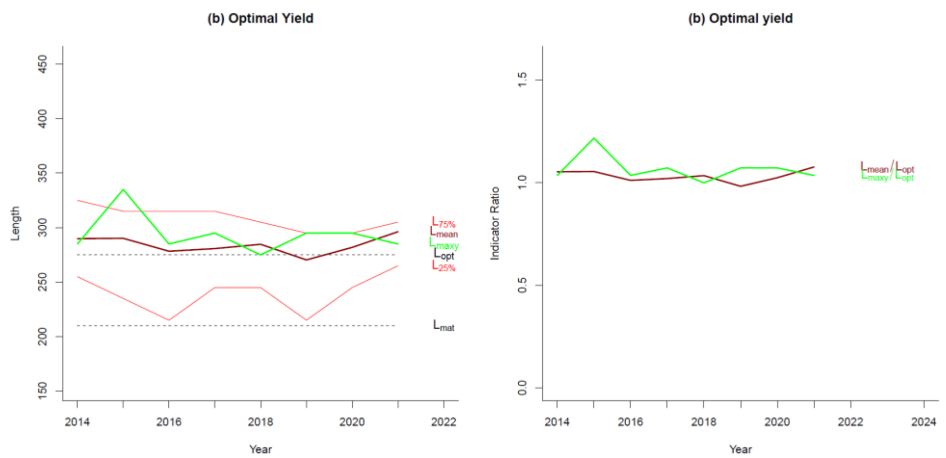

Figure 6.15. Flounder in Subarea 4 and Division 3.a. Optimum yield indicators (left panel, length in mm) and indicator ratios (right panel).

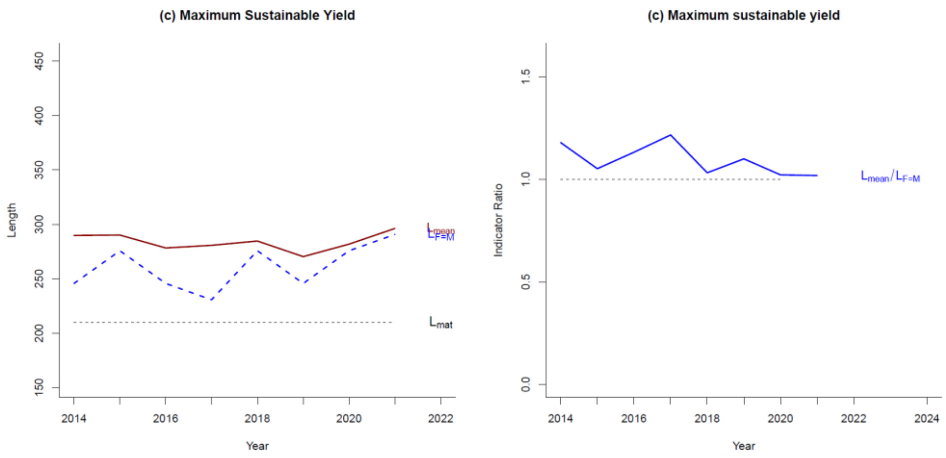

Figure 6.16. Flounder in Subarea 4 and Division 3.a. Maximum sustainable yield indicator (left panel, length in mm) and indicator ratio (right panel).

6.5 Empirical *chr* rule

Flounder in the North Sea (fle.27.3a4) is a category 3 stock for which the 2:3 rule, based on a biomass index, was used as basis for the last catch advice given for the years 2022 and 2023 (ICES, 2017b). Because the 2:3 rule should not be used any longer, the empirical rules developed by WKLIFE X (ICES, 2021b) were tested for this stock. The constant harvest rate (*chr*) rule (ICES, 2021b) was applied in the case of flounder, because the available growth parameter k = 0.36 (Table 6.1).

The *chr* rule applies a constant harvest rate that is considered a proxy for an MSY harvest rate, which is then applied to a biomass index:

$$C_{y+1} = I_{y-1} \times F_{MSYproxy} \times b \times m$$

with C_{y+1} is the catch advice, I_{y-1} the most recent index value, $F_{MSYproxy}$ is the ratio C_y / I_y for which the quantity f >1, where f is the ratio of the mean length L_m in the catch and $L_{F=M}$, b is a biomass safeguard, and m is a multiplier applied to the *chr* rule to maintain the probability of the biomass declining below B_{lim} to less then 5%.

The biomass safeguard b is determined by the relation of the most recent index value to $I_{trigger}$ (with $I_{trigger}$ = 1.4 x I_{loss}; I_{loss} = defined as lowest observed index value). When the most recent index data is greater than $I_{trigger}$, b is set to 1. In the case for flounder b = 0.71 (Table 6.3). The precautionary multiplier m is applied with the *chr* rule to maintain the probability of the biomass declining below B_{lim} to less than 5%. Following the guidelines (ICES, 2022), this precautionary multiplier should be set to 0.5 when applying the *chr* rule. An uncertainty cap (*stability clause*) is applied, which limits the amount the advised catch can change upwards or downwards between years (+20% / -30%). This uncertainty cap was applied in the case of flounder. Based on the latest catch advice (1650 tonnes), the *chr* rule resulted in a catch advice of 1155 tonnes (applying the stability clause), which would correspond to 814 tonnes landings, given the average discard rate of the most recent three years. The summary of the *chr* rule for flounder is displayed in table 6.3.

Table 6.3 Flounder in Subarea 4 and Division 3.a. The basis for the catch scenarios. Catches are in tonnes.*

Previous catch advice A_y		1650 tonnes
Biomass index		
I: most recent biomass index (I_{2022})		16512
MSY proxy harvest rate		
$F_{MSY\ proxy}$: MSY proxy harvest rate (average of the ratio of catch to biomass index for the years for which f>1, where f = $L/L_{F=M}$)		0.11
Biomass safeguard		
$I_{2022} = I_{loss}$		16512
Index trigger value ($I_{trigger}=I_{loss}×1.4$)		23117
Index 2022 (I_{2022})		16512
b: index relative to trigger value, min{$I_{2021}/I_{trigger}$, 1}		0.71
Precautionary multiplier to maintain biomass above B_{lim} with 95% probability		
m: multiplier (generic multiplier based on life history)		0.5
Uncertainty cap (+20%/-30% compared to A_y, only considered if b=1)	Applied	-30%
Discard rate		29%
Catch advice**		1155 tonnes
% advice change***		-30 %
Corresponding landings		814 tonnes

* The figures in the table are rounded. Calculations were done with unrounded inputs, and computed values may not match exactly when calculated using the rounded figures in the table.

** Formula: I × $F_{MSY\ proxy}$ × b × m, limited by uncertainty cap if applicable.

*** Advice value relative to the latest catch advice.

6.6 Issues List

- Métiers with zero landings but no discards reported. No raising possible for these cases. What is the possible impact on catch estimation? Are there other ways to estimate discards for these métiers?
- No suitable data available for the shrimper fleets operating in coastal waters. Raising highly uncertain for these fleets. What is the possible impact on catch estimation? Is there another way to estimate the discards of these fleets?
- Investigate what could be done/changed to improve the SpiCT model.
- Investigate the use of alternative stock indices (DYFS, DFS, others?) which are able to better reflect the stock status.
- Investigate the HCR rules based on life history parameters suggested by WKLIFE X (ICES, 2020)

6.7 References

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Table 6.3. Flounder in Subarea 4 and Division 3.a: Flounder official landings by country in ICES Subarea 4.

Year	Belgium	Denmark	France	Germany	Netherlands	Norway	UK	Other	Total
1950	67	1514	0	641	937	0	67	241	3467
1951	119	1143	0	329	949	0	81	127	2748
1952	91	1210	0	257	841	0	71	186	2656
1953	270	1372	0	397	886	0	92	203	3220
1954	142	1225	0	281	696	0	71	121	2536
1955	145	1244	0	353	871	0	88	109	2810
1956	132	1389	0	277	1097	0	102	2	2999
1957	81	910	0	250	825	0	112	0	2178
1958	99	784	0	257	1088	0	94	0	2322
1959	62	533	0	424	857	0	79	1	1956
1960	82	614	0	540	733	0	49	8	2026
1961	68	776	0	390	579	0	81	13	1907
1962	37	1146	0	313	717	0	53	2	2268
1963	16	501	0	263	467	0	65	0	1312
1964	30	1141	0	305	563	0	48	6	2093
1965	121	1349	0	248	549	0	54	3	2324
1966	32	946	0	229	573	0	71	2	1853
1967	43	540	0	193	331	0	57	25	1189
1968	75	894	0	152	160	0	43	1	1325
1969	54	582	0	158	161	0	33	0	988
1970	50	316	0	135	405	0	57	0	963
1971	60	685	0	173	297	0	70	0	1285
1972	63	991	0	159	275	0	60	0	1548
1973	63	290	0	172	1424	0	53	0	2002
1974	115	766	0	190	2661	0	58	0	3790
1975	68	437	0	155	2191	0	87	1	2939
1976	94	575	0	209	2077	0	70	54	3079
1977	107	320	0	208	1732	0	127	11	2505
1978	122	203	0	198	1519	0	169	0	2211
1979	129	181	31	275	1260	0	201	0	2077
1980	190	300	33	229	806	0	140	0	1698
1981	164	669	14	200	1068	0	133	0	2248
1982	110	630	31	200	1597	0	121	0	2689
1983	88	564	36	197	2059	0	125	0	3069
1984	272	518	15	103	0	0	122	0	1030
1985	163	379	14	128	0	0	109	0	793
1986	155	456	1	91	0	0	111	0	814
1987	132	394	32	106	0	0	90	0	754
1988	160	509	44	105	682	0	98	0	1598

Year	Belgium	Denmark	France	Germany	Netherlands	Norway	UK	Other	Total
1989	200	632	28	95	916	0	80	0	1951
1990	153	467	69	147	0	0	45	0	881
1991	260	377	51	902	0	0	69	0	1659
1992	152	492	35	521	0	0	76	0	1276
1993	194	1812	47	356	0	0	136	0	2545
1994	196	642	57	921	0	0	247	0	2063
1995	301	628	103	843	0	0	250	0	2125
1996	262	1439	68	43	0	0	193	0	2005
1997	110	988	10	25	0	0	157	0	1290
1998	283	154	40	13	4938	0	132	0	5560
1999	326	123	0	11	3158	0	54	0	3672
2000	289	100	46	17	2656	5	52	0	3165
2001	241	92	42	4	2608	3	32	0	3022
2002	165	83	51	2	3531	3	55	0	3890
2003	206	94	33	3	3172	9	120	0	3637
2004	335	96	46	5	3720	18	74	0	4294
2005	241	171	17	5	3363	38	111	0	3946
2006	168	152	19	2	4020	39	216	0	4616
2007	298	166	56	45	2925	11	119	0	3620
2008	306	228	30	39	2231	3	57	0	2894
2009	272	273	38	46	2124	3	59	0	2815
2010	251	126	20	58	2612	6	87	0	3160
2011	262	112	17	25	2566	1	65	0	3048
2012	348	100	11	23	1672	0	38	0	2192
2013	346	93	13	28	1199	0	24	0	1703
2014	376	107	15	30	1314	0	31	0	1873
2015	277	97	19	19	1409	0	15	0	1836
2016	193	87	20	27	1277	0	25	0	1629
2017	97	101	0	28	943	1	14	0	1184
2018	102	114	0	24	1139	1	18	0	1398
2019	94	133	9	48	1186	19	15	0	1507
2020*	154	114	7	48	1280	30	18	0	1651
2021*	536	93	19	21	947	2	19	1	1638

***Preliminary catch statistics**

Table 6.4. Flounder in Subarea 4 and Division 3.a: Flounder official landings by country in ICES Division 3.a.

Year	Denmark	Germany	Netherlands	Norway	Sweden	Total
1950	1632	92	0	0	657	2381
1951	1548	88	0	0	759	2395
1952	1161	48	0	0	683	1892
1953	1135	17	0	0	724	1876
1954	1138	13	0	0	528	1679
1955	1265	11	0	0	667	1943
1956	1229	6	0	0	0	1235
1957	1331	12	0	0	0	1343
1958	1099	12	0	0	0	1111
1959	1003	3	0	0	0	1006
1960	875	10	0	0	566	1451
1961	821	9	0	0	442	1272
1962	812	3	0	0	0	815
1963	554	0	0	0	0	554
1964	822	1	0	0	0	823
1965	1016	0	0	0	0	1016
1966	1027	0	0	0	0	1027
1967	811	3	0	0	0	814
1968	808	2	0	0	0	810
1969	721	0	0	0	0	721
1970	667	0	0	0	0	667
1971	611	1	0	0	0	612
1972	365	0	0	0	0	365
1973	346	0	0	0	0	346
1974	1656	2	0	0	0	1658
1975	1377	1	0	0	89	1467
1976	949	2	4	0	144	1099
1977	1036	0	19	0	64	1119
1978	1560	10	14	0	64	1648
1979	1219	0	0	0	100	1319
1980	426	0	0	0	135	561
1981	1831	0	0	0	74	1905
1982	1236	0	0	0	75	1311
1983	2352	0	0	0	160	2512
1984	2463	0	0	0	283	2746
1985	1203	0	0	0	102	1305
1986	1585	0	0	0	166	1751
1987	1050	0	0	0	119	1169
1988	1164	0	0	0	149	1313

Year	Denmark	Germany	Netherlands	Norway	Sweden	Total
1989	996	0	0	0	133	1129
1990	650	1	0	0	57	708
1991	574	0	0	0	50	624
1992	455	0	0	0	52	507
1993	673	3	0	0	67	743
1994	865	1	0	0	77	943
1995	403	19	0	0	76	498
1996	429	9	0	0	104	542
1997	367	2	0	0	68	437
1998	637	5	0	0	83	725
1999	558	6	0	0	24	588
2000	609	17	0	0	30	656
2001	672	2	0	1	30	705
2002	493	0	0	1	30	524
2003	452	3	0	0	18	473
2004	462	2	0	0	14	478
2005	467	0	0	0	15	482
2006	380	0	0	0	13	393
2007	419	3	1	0	22	445
2008	326	4	0	0	16	346
2009	238	2	0	0	33	273
2010	188	0	0	0	17	205
2011	129	0	0	0	16	145
2012	110	0	0	0	8	118
2013	162	0	0	0	11	173
2014	190	0	0	0	4	194
2015	74	0	0	0	3	77
2016	106	0	0	0	3	109
2017	153	0	0	1	5	159
2018	189	0	0	0	3	192
2019	156	0	2	0	3	161
2020*	111	0	0	0	5	116
2021*	90	0	0	0	2	92

*** preliminary catch statistics**

Table 6.5. Flounder in Subarea 4 and Division 3.a: Flounder total official landings by ICES areas.

Year	Division 3.a	Subarea 4	Total
1950	2381	3467	5848
1951	2395	2748	5143
1952	1892	2656	4548
1953	1876	3220	5096
1954	1679	2536	4215
1955	1943	2810	4753
1956	1235	2999	4234
1957	1343	2178	3521
1958	1111	2322	3433
1959	1006	1956	2962
1960	1451	2026	3477
1961	1272	1907	3179
1962	815	2268	3083
1963	554	1312	1866
1964	823	2093	2916
1965	1016	2324	3340
1966	1027	1853	2880
1967	814	1189	2003
1968	810	1325	2135
1969	721	988	1709
1970	667	963	1630
1971	612	1285	1897
1972	365	1548	1913
1973	346	2002	2348
1974	1658	3790	5448
1975	1467	2939	4406
1976	1099	3079	4178
1977	1119	2505	3624
1978	1648	2211	3859
1979	1319	2077	3396
1980	561	1698	2259
1981	1905	2248	4153
1982	1311	2689	4000
1983	2512	3069	5581
1984	2746	1030	3776
1985	1305	793	2098
1986	1751	814	2565
1987	1169	754	1923
1988	1313	1598	2911

Year	Division 3.a	Subarea 4	Total
1989	1129	1951	3080
1990	708	881	1589
1991	624	1659	2283
1992	507	1276	1783
1993	743	2545	3288
1994	943	2063	3006
1995	498	2125	2623
1996	542	2005	2547
1997	437	1290	1727
1998	725	5560	6285
1999	588	3672	4260
2000	656	3165	3821
2001	705	3022	3727
2002	524	3890	4414
2003	473	3637	4110
2004	478	4294	4772
2005	482	3946	4428
2006	393	4616	5009
2007	445	3620	4065
2008	346	2894	3240
2009	273	2815	3088
2010	205	3160	3365
2011	145	3048	3193
2012	118	2192	2310
2013	173	1703	1876
2014	194	1873	2067
2015	77	1836	1913
2016	109	1628	1737
2017	159	1184	1343
2018	192	1398	1590
2019	161	1507	1668
2020*	116	1651	1767
2021*	92	1638	1730

*** preliminary catch statistics**

Table 6.6. Flounder in Subarea 4 and Division 3.a: Total official landings, InterCatch landings, discards and total catch.

Year	Official landings	IC landings	IC discards	IC total catch	Discard rate
2002	4414	4217	2084	6301	33.07%
2003	4110	3922	1370	5292	25.89%
2004	4772	4601	637	5238	12.16%
2005	4428	4214	1265	5479	23.09%
2006	5009	4837	1026	5863	17.50%
2007	4065	3908	2082	5990	34.76%
2008	3240	3067	1376	4443	30.97%
2009	3088	2804	1342	4146	32.38%
2010	3365	3166	3087	6253	49.37%
2011	3193	3041	1694	4735	35.77%
2012	2310	2189	1205	3394	35.49%
2013	1876	1750	1415	3165	44.71%
2014	2062	1907	1127	3034	37.15%
2015	1883	1762	1228	2990	41.07%
2016	1738	1750	628	2378	26.41%
2017	1262	1244	588	1832	32.10%
2018	1582	1587	657	2244	29.28%
2019	1668	1653	727	2380	33.55%
2020*	1767	1715	679	2395	28.35%
2021*	1730	1293	543	1836	29.58%

***preliminary catch statistics**

7 Grey gurnard (*Eutrigla gurnardus*) in Subarea 4, Divisions 7.d and 3.a (North Sea, Eastern English Channel, Skagerrak and Kattegat)

7.1 General

Grey gurnard (*Eutrigla gurnardus*) was assessed in the Working Group on the Assessment of New MoU Species (ICES, 2014) until 2014. Since 2015, the stock was assessed by the Working Group on the Assessment of Demersal Stocks in the North Sea and Skagerrak (WGNSSK), and defined as a category DLS 3.2 stock (ICES, 2015). For this stock, only survey data and limited catch data (InterCatch data 2012–2021) are available. Official landings data are incomplete or were not reported specifically for grey gurnard in the past. Grey gurnard in Subarea 4, Divisions 7.d and 3.a is a non-target stock with no TAC, and has a biennial advice. ICES has not been requested to provide advice on fishing opportunities for this stock for the years 2019 - 2022. However, a new catch advice was requested for the years 2023 and 2024. During the WGNSSK 2022, new available discard and landings data and the current assessment were updated. The empirical *rb* rule (ICES, 2020b) was applied for the first time as the basis of the catch advice. The *rb* rule resulted in a catch advice of 5846 tonnes for the years 2023 and 2024. Taking into account the average discard rate of the most recent three years, this implies landings of no more than 1120 tonnes.

7.1.1 Biology and ecosystem aspects

Grey gurnard (*Eutrigla gurnardus*) occurs in the Eastern Atlantic from Iceland, Norway, southern Baltic, and North Sea to southern Morocco and Madeira. It is also found in the Mediterranean and Black Seas. In the North Sea and in the Skagerrak/Kattegat, grey gurnard is an abundant demersal species. In the North Sea, the species may form dense semi-pelagic aggregations in winter to the northwest of the Dogger Bank, whereas in summer it is more widely distributed. The species is less abundant in the Channel, the Celtic Sea and in the Bay of Biscay. Spawning takes place in spring and summer. There do not seem to be clear nursery areas.

Grey gurnard is considered a predator on young age groups of a number of commercially important demersal stocks (cod, whiting, haddock, sandeel, and Norway pout) in the North Sea (de Gee and Kikkert, 1993). Therefore, an increase in abundance of grey gurnard can lead to an increase in mortality especially of North Sea cod (age-0) and whiting (age-0 and age-1) (ICES, 2017). The multispecies model SMS estimated that grey gurnard can cause up to 50% of the predation mortality on 0-group cod and whiting. Therefore, the abundance and distribution pattern of grey gurnard and its prey size preferences are highly relevant from an ecological point of view (Floeter and Temming, 2005; Kempf *et al.*, 2013).

7.1.2 Stock ID and possible assessment areas

No studies are known of the stock ID of grey gurnard. In a pragmatic approach for advisory purposes and in order to facilitate addressing ecosystem considerations, the population is currently split among three ecoregions: North Sea including Division 7.d, Celtic Seas and South European Atlantic. This proposal should be discussed considering the low levels of catches reported in recent years in Celtic Seas and South European Atlantic (ICES, 2011; ICES, 2012).

7.1.3 Management regulations

There is no minimum landing size for this species and there is no TAC.

7.2 Fisheries data

7.2.1 Historical landings

Historically, grey gurnard is taken as a by-catch species in mixed demersal fisheries for flatfish and roundfish. Grey gurnard from the North Sea is mainly landed for human consumption purposes. However, the market is limited and the largest part of the catch is discarded. Owing to the low commercial value of this species and the high observed discard rates, landings data do not reflect the actual catches.

In the past, gurnards were often not sorted by species when landed and were reported as one generic category of "gurnards". Further, catch statistics are incomplete for some years, e.g. the Netherlands did not report gurnards during the years 1984–1999. In recent years, the official statistics seem to improve gradually. However, some countries continue to report "gurnards" landings and do not provide information on grey gurnard separately (e.g. Germany) or the data imported into InterCatch are based on a gurnard mix, raised by survey information on the proportion of the specific gurnard species. The latter approach is highly questionable, because tub gurnard is a much more valuable bycatch species and a larger proportion of that species is landed compared to grey gurnard.

Since the early 1980s, specific landings data for grey gurnard are available from the official catch statistics. Before that, these data occurred only sporadically in the statistics. Most of grey gurnard catches are taken in Subarea 4 and to a much lesser extent in divisions 7.d and 3.a (Figure 7.1–7.3; Table 7.5–7.7). Exceptionally high annual landings were reported during the late 1980s to early 1990s with a maximum of 46 598 tonnes in 1987 (Figure 7.2; Table 7.6) because of Danish landings for reduction purposes. After this peak, the Danish landings dropped again to low levels. Compared to 2020 the official landings in 2021 with 1106 tonnes were on a rather low level (1756 tonnes in 2020; Table 7.8), and were the lowest since 2015. The average official landings for the last ten years (2012–2021) was 1485 tonnes. Official landings data from 1950 to 2005 were taken from the "ICES catch statistics 1950 to 2010" (https://www.ices.dk/data/Documents/CatchStats/HistoricalLandings1950-2010.zip). Data from 2006 to 2019 were taken from the "ICES catch statistics 2006 to 2019" (https://www.ices.dk/data/Documents/CatchStats/OfficialNominalCatches.zip). Data for 2020 and 2021 were taken from the preliminary catch statistics provided by ICES (http://data.ices.dk/rec12/login.aspx).

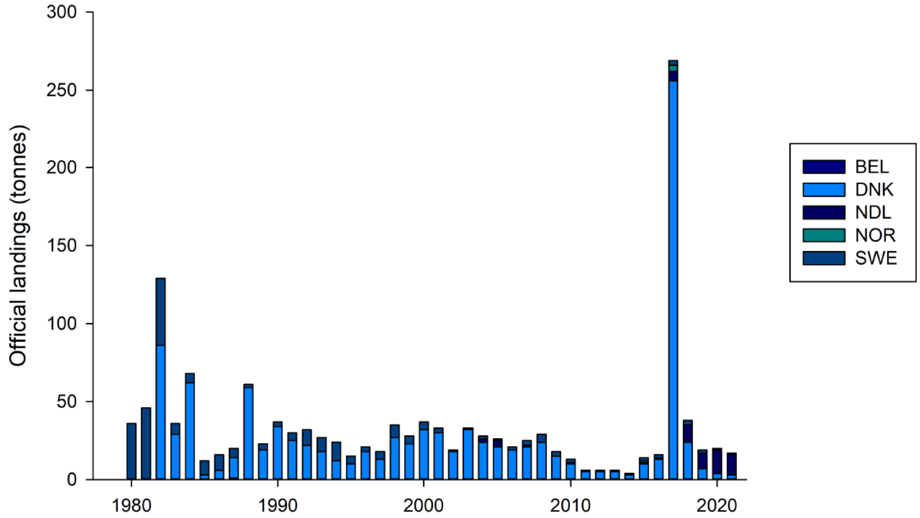

Figure 7.1. Grey gurnard in Subarea 4, Division 3.a and Division 7.d: Official landings of grey gurnard in Division 3.a 1980–2021.

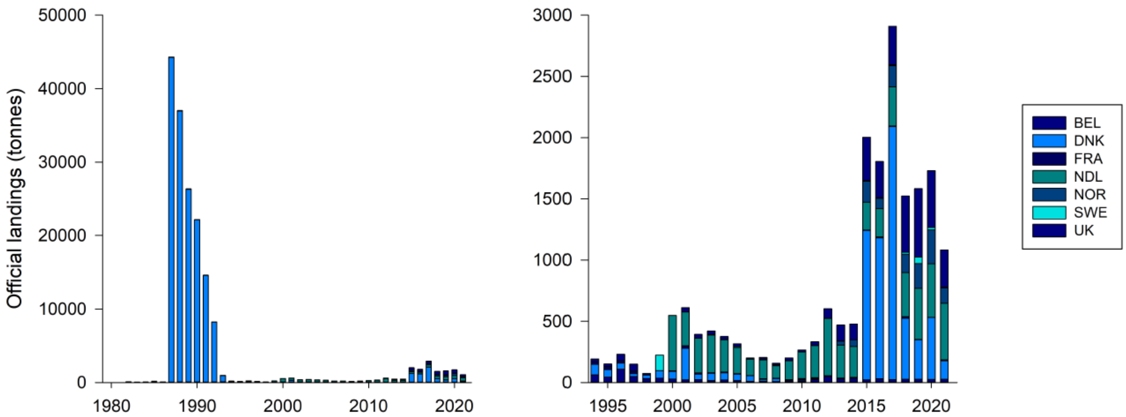

Figure 7.2. Grey gurnard in Subarea 4, Division 3.a. and Division 7.d: Official landings of grey gurnard in Subarea 4 by country for the years 1980 - 2021 (a), and official landings of grey gurnard by country in Subarea 4 for the years 1994 - 2021 (b).

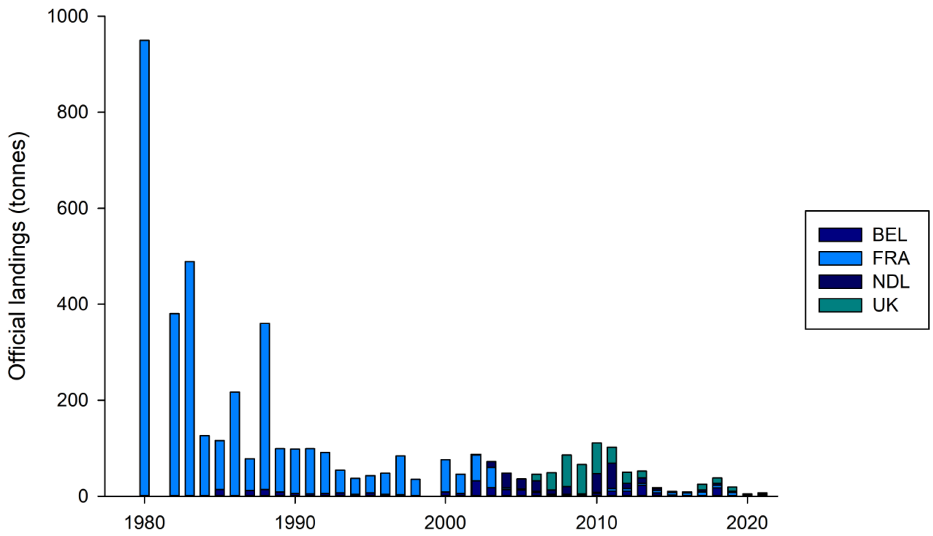

Figure 7.3. Grey gurnard in Subarea 4, Division 3.a. and Division 7.d: Official landings by country of grey gurnard in Division 7.d for the years 1980–2021.

7.2.2 InterCatch data

InterCatch contains now data for the years 2012–2021. The largest amount of landings in 2021 was reported by Scotland (212 tonnes, OTB_DEF_>=120_0_0_all; Figure 7.4). Considerable amounts of landings were also reported by Denmark as industrial bycatch (MIS_MIS_0_0_0_IBC, 152 tonnes), and by several Dutch fleets (e.g. SSC_DEF_70-99_0_0_all, 235 tonnes). For all countries, the amount of discards exceeded the amount of landings (Figure 7.7 and 7.8). The largest amounts of discards were reported for the Dutch beam trawl fleet (TBB_DEF_70-99_0_0_all, 661 tonnes), the Dutch OTB_CRU_70-99_0_0_all fleet (299 tonnes), and the Scottish OTB_DEF_>=120_0_0_all fleet (235 tonnes).

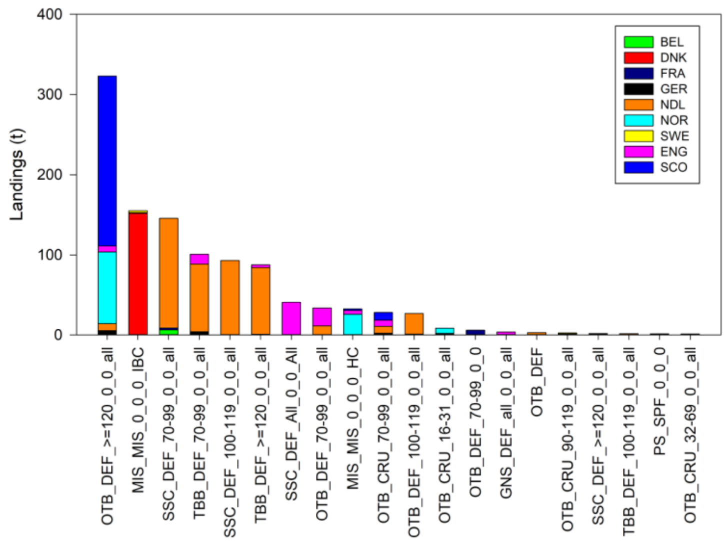

Figure 7.4. Grey gurnard in Subarea 4, Division 3.a. and Division 7.d. Grey gurnard landings in 2021 by métier and country as uploaded into InterCatch.

In total, 34% of landings were reported with discards (Figure 7.5). For all other métiers with landings, discards were raised within InterCatch. Some métiers reported zero landings (82 métiers) for which no discard raisings were possible. Some of these métiers are negligible or also reported zero discards (e.g. FPO_CRU_0_0_0_all). But it has to be noted, that grey gurnard is probably a considerable part of unwanted bycatch in some of the zero landing métiers, e.g. OTB_DEF_>=120_0_0_all, SDN_DEF_>=120_0_0_all, and OTB_CRU_90-119_0_0_all.

For the discard raising, it was attempted to use the same groupings as for the previous data years. However, this was not possible for all cases and compared to the previous year slight changes had to be made. The grouping is based on gear type and mesh size over areas and season. For the length sampling allocation, only one landings-group and one discard-group was set up, because data availability did not allow for a higher resolution. Length samples for landings were provided only by one fleet for 2021 data, the SCO OTB_DEF_>=120_0_0_all fleet, and this was used subsequently for all other landing métiers (Figure 7.6).

The following groupings were used for the 2021 data discard raising:

Group 1: all passive gears -> raised with all other passive métiers.

Group 2: MIS_MIS_0_0_0_HC -> no discard data available for this métier. Raised with all other métiers.

Group 3: TBB_DEF métiers (>=70) -> raised with TBB_DEF métiers (>=70)

Group 4: OTB_CRU_70-99_0_0_all -> raised with OTB_CRU_70-99_0_0_all

Group 5: OTB_DEF_120_0_0_all -> raised with OTB_DEF_120_0_0_all

Group 6: OTB_DEF_100-119_0_0_all, SSC_DEF_100-119_0_0_all -> raised with OTB_DEF_100-119_0_0_all (only one métier available, NDL)

Group 7: OTB_DEF_70-99_0_0, SSC_DEF_70-99_0_0_all, SDN_DEF_70-99_0_0_all, OTM_SPF and OTB_SPF_70-99_0_0_all -> raised with OTB_DEF_70-99_0_0_all

Group 8: 9 SSC and SDN_DEF_>=120_0_0_all -> raised with SSC and SDN_DEF_>=120_0_0_all

Group 9: OTB_CRU_90-119_0_0_all -> raised with OTB_CRU_90-119_0_0_all

Group 10: OTB_CRU_32-69_0_0_all -> raised with OTB_CRU_32-69_0_0_all (no discards)

Group 11: OTB_CRU_70-89_2_35_all -> raised with OTB_CRU_70-89_2_35_all métiers

Group 12: SSC_DEF_32-69_0_0_all, OTB_SPF_32-69_0_0_all, and PS_SPF_0_0_0 -> raised with all other métiers

Some métiers were not raised because no suitable data were available or they were negligible:

- MIS_MIS_0_0_0_IBC (16 métiers)
- OTB_CRU_16-31_0_0_all (3 métiers)
- TBB_CRU_16-31_0_0_all (3 métiers)

The largest amount of discards were raised for the Dutch SSC_DEF_70-99_0_0_all fleet (678 tonnes), the Dutch TBB_DEF_>=120_0_0_all fleet (657 tonnes), and the Dutch SSC_DEF_100-119_0_0_all fleet (350 tonnes; Figure 7.7). The total catch estimated with InterCatch for the year 2021 was 5541 tonnes from which 1099 tonnes were landings (20% of total catch) and 4442 tonnes estimated discards (80% of total catch). The Netherlands took the largest proportion of the total catch in 2021, followed by UK England, and UK Scotland (Figure 7.8).

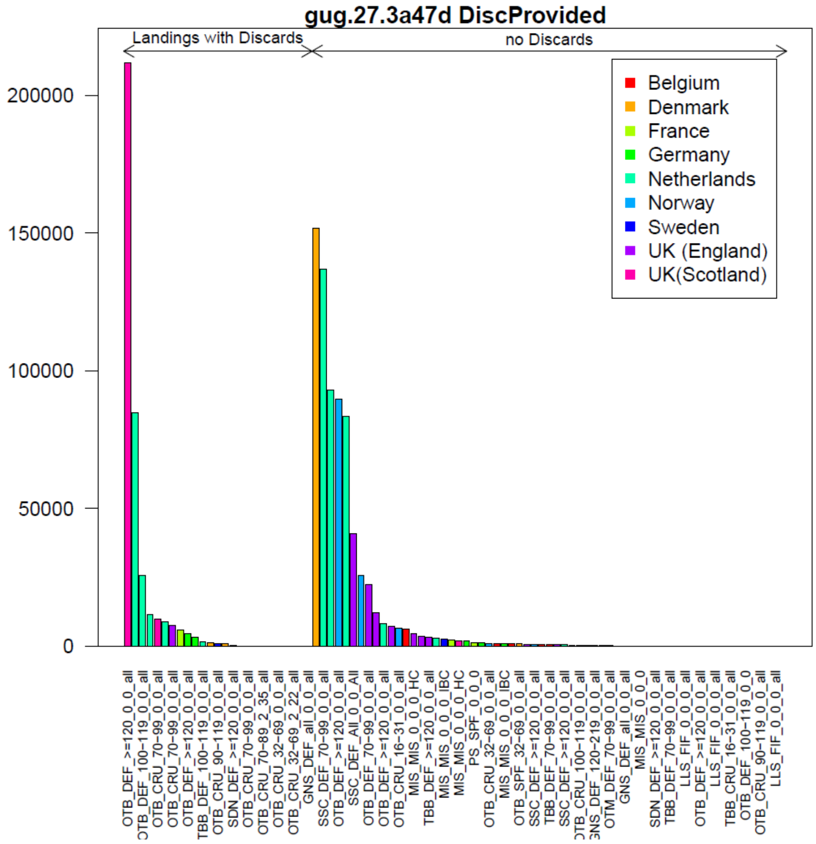

Figure 7.5. Grey gurnard in Subarea 4, Division 3.a. and Division 7.d. Provision of landings with and without discards (kg) in InterCatch by fleet and country (2021 data).

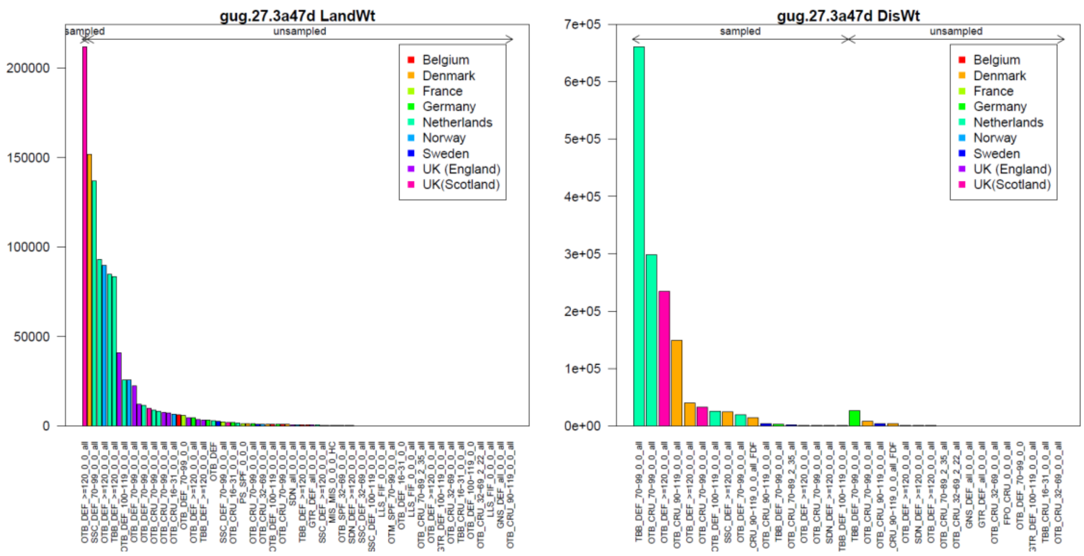

Figure 7.6. Grey gurnard in Subarea 4, Division 3.a. and Division 7.d. Provision of length samplings in weight (kg) for landings (left panel) and discards (right panel) in InterCatch by fleet and country (2021 data).

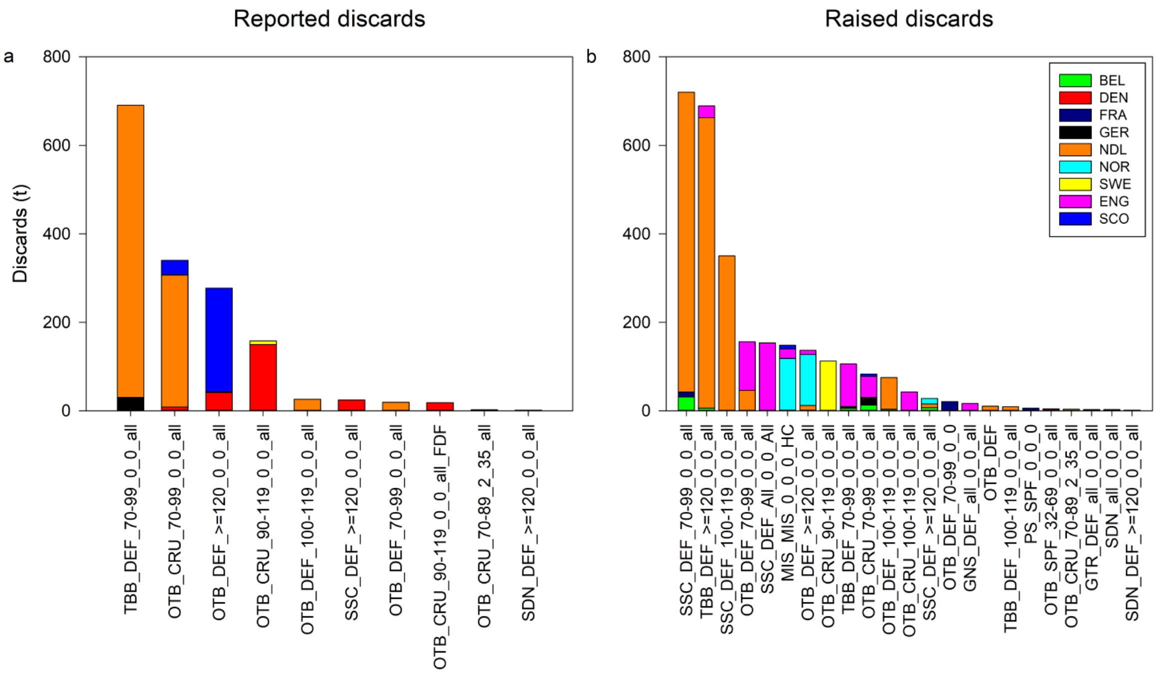

Figure 7.7. Grey gurnard in Subarea 4, Division 3.a. and Division 7.d. Grey gurnard discards in 2020 by métier and country. Reported discards panel (a), raised discards panel (b). Legend valid for both panels.

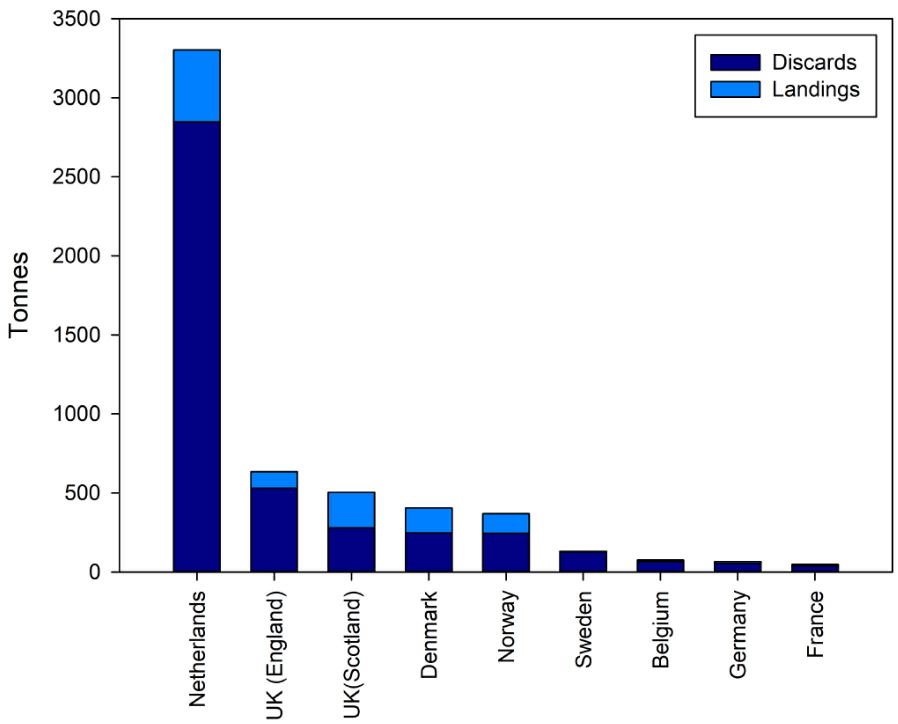

Figure 7.8. Grey gurnard in Subarea 4, Division 3.a. and Division 7.d. Grey gurnard total landings and discards in 2021 by country.

7.2.3 Other information on Discards

In Table 7.1 the numbers per hour of discarded grey gurnard in Dutch bottom-trawl fisheries in North Sea and Eastern Channel are shown for 2006–2012 (Uhlmann *et al.*, 2013). The rates are highly variable depending on the specific métiers, with highest values observed for the SSC_DEF métiers. German discard data from an observer programme indicate that the proportion of discarded gurnard in German demersal trawl fisheries ranges between 76.6% and 93.0% (Ulleweit *et al.*, 2010).

Table 7.1 Grey gurnard in Subarea 4, Division 3.a. and Division 7.d: Discards in number per hour of grey gurnard by different métiers in the Netherlands 2006–2012.

Métier	TBB_DEF	TBB_DEF*	TBB_DEF	SSC_DEF	SSC_DEF	OTB_MCD	OTB_DEF	OTB_DEF
Mesh	70-99	70-99	100-119	100-119	>120	70-99	70-99	100-119
2006	68.3							
2007	60.2							
2008	34.3							
2009	55	17	37			111	77	15
2010	81	10	109			47	52	110
2011	61	27	10	NA	119	27	55	70
2012	41	24	30	317	307	110	75	12

*≤300 hp segment

7.3 Survey data/recruit series

For the North Sea and Skagerrak/Kattegat, data are available from the International Bottom Trawl Survey in the North Sea (NS-IBTS; ICES, 2021a). The NS-IBTS Q1 and NS-IBTS Q3 can provide information on distribution and the length composition of the stock. Grey gurnard occurs throughout the North Sea and Skagerrak/Kattegat. During winter, grey gurnards are concentrated to the northwest of the Dogger Bank at depths of 50–100 m, while densities are lower off the Danish coast, in the German Bight and eastern part of the Southern Bight (Figure 7.9). The distribution pattern changes substantially in spring, when the whole area south of 56°N becomes more densely populated and the high concentrations in the central North Sea disappear until the next winter (Daan *et al*., 1990; Figure 7.10).

The nearly absence of grey gurnard in the southern North Sea during winter and the marked shift in the centre of distribution between winter and summer suggests a preference for higher water temperatures (Hertling, 1924; Daan *et al*., 1990).

During winter, grey gurnard occasionally form dense aggregations just above the sea bed (or even in midwater, especially during night time) which may result in extremely large catches. Within one survey, these large hauls may account for 70% or more of the total catch of all species. Bottom temperatures in high density areas usually range from 8 to 13°C (Sahrhage, 1964).

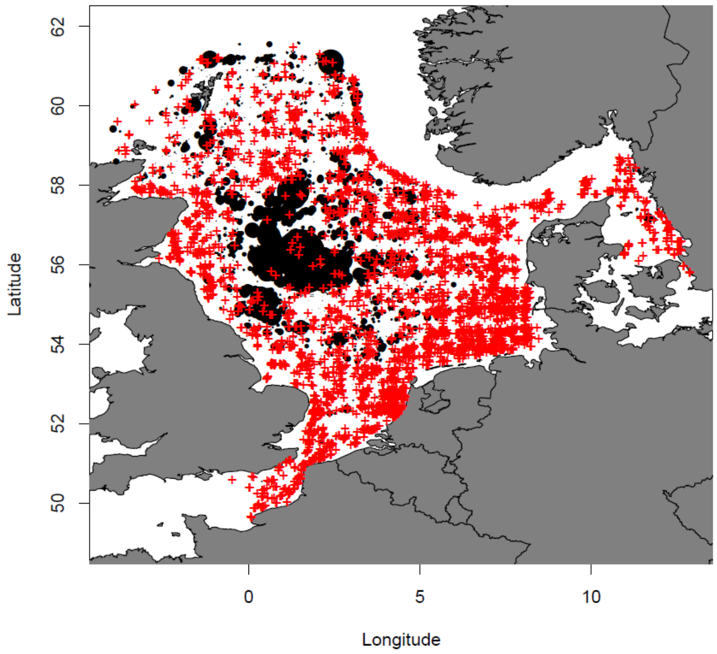

Figure 7.9. Grey gurnard in Subarea 4, Division 3.a. and Division 7.d. Spatial distribution of grey gurnard from NS-IBTS Q1 survey (all years) in Subarea 4 and Division 3.a. Red crosses display zero hauls.

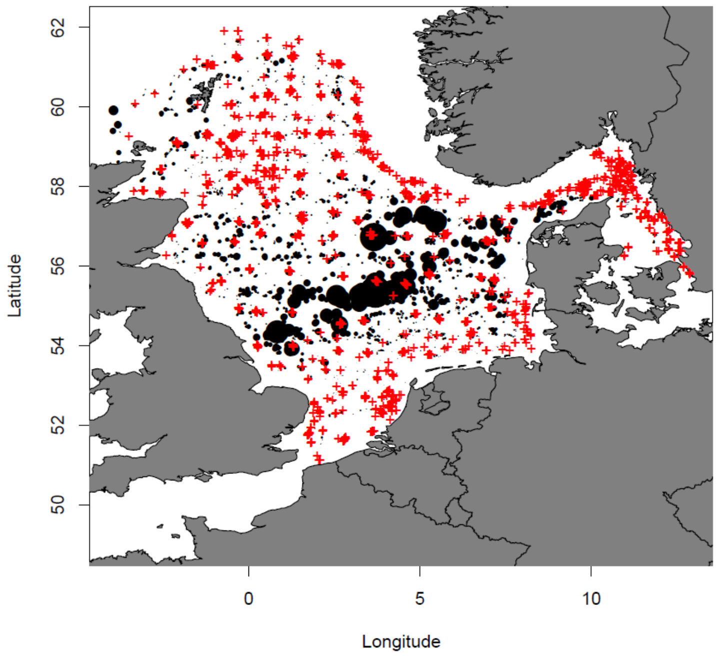

Figure 7.10. Grey gurnard in Subarea 4, Division 3.a. and Division 7.d: Spatial distribution of grey gurnard from NS-IBTS Q3 survey (all years) in Subarea 4 and Division 3.a. Red crosses display zero hauls.

7.4 Biological sampling

Individual biological data for this species are scarce (see also the stock annex). In the North Sea, individual data have been collected sporadically during some years of the NS-IBTS Q1 and NS-IBTS Q3 survey. The age readings done on collected otoliths from NS-IBTS Q1 resulted in an age range from 2 to 14 years, but not that many individuals were aged (n = 469, years 2010 and 2014).

Available data on grey gurnard individual weights and maturity were analysed in order to estimate a mature biomass index. The obtained weight–length relation was:

Weight = 0.006 * LngtClass ^ 3.082 (NS-IBTS Q1 and Q3 2010-2014; 2016-2018 data; Figure 7.11a).

A maturity ogive based on all available grey gurnard maturity data from NS-IBTS Q1 was used to calculate this mature biomass index. The obtained maturity ogive shows that above 21.1 cm more than 95% of all the individuals can be considered mature (Figure 7.11b; DATRAS CA maturity data were available for the years 1992, 2010, 2014, 2016). The corresponding Lmat50% value was 16.3 cm. Proportion mature at length was calculated by the model:

Prop-Mat = 0.991 / (1 + exp (-1 * (LngtClass - 16.273) / 2.105)).

The available age and maturity data suggest that grey gurnard is early maturing in the North Sea and a certain proportion of fish at age 1 are mature.

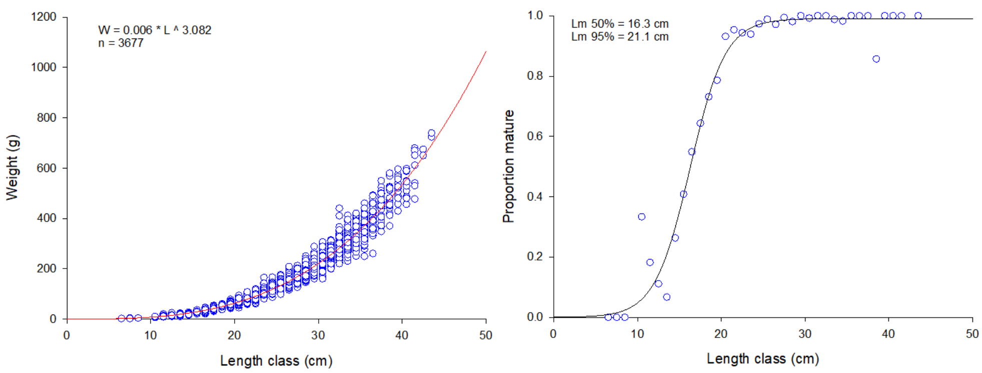

Figure 7.11 Grey gurnard in Subarea 4, Division 3.a. and Division 7.d: Length-weight relationship from NS-IBTS Q1 and IBTS Q3 CA data (left panel); maturity ogive obtained from NS-IBTS Q1 CA data (right panel).

7.5 Analysis of stock trends/assessment

Information from landings is poor, due to poor reporting (gurnard species were not always identified in the data, and probably also misreporting has occurred), and also because the low value of this species leads to massive discarding.

To analyse stock trends, a mature biomass index was calculated applying a length weight relationship and a maturity ogive which were obtained from available NS-IBTS CA (DATRAS) records (see Section 7.4 above).

According to van Heesen and Daan (1996), outliers were excluded from previous NS-IBTS Q1 time series, since grey gurnards tend to form dense concentrations during winter. Outliers were defined as hauls which accounted for more than 90% of the total gurnard weight caught in the respective year. However, such extreme outliers were only identified in the time period before

1983 which is not displayed here. The start of the time series chosen here is 1983, since full standardization of the NS-IBTS was reached then. The time series of mature biomass index of grey gurnard of the NS-IBTS Q1 survey has shown a strong increase pattern from the beginning of 1990s (Figure 7.12; Table 7.7). Since then it was fluctuating on a high level until 2017. A strong decline of the index was observed for the year 2018, in 2019 the index value was only slightly higher. The NS-IBTS Q1 index then decreased further until 2022. The mature biomass index for the NS-IBTS Q3 does not show the same pronounced increasing trend compared to the quarter 1 index. The 2014 value was the highest observed in this time series. Since then, the NS- IBTS Q3 index showed an overall decreasing trend until 2021. In general, lower biomass and abundance values were observed for the NS-IBTS Q3 survey time series. Compared to the North Sea/Skagerrak (Subarea 4/Division 3.a) the mature biomass values recorded by the Channel Ground Fish Survey (CGFS) in the Eastern Channel (Division 7.d) were extremely low (not shown in this report). No trend could be detected in the CGFS index. Therefore, the advice for grey gurnard in area 4, 3.a and 7.d should be based on the NS-IBTS survey, which covers by far the largest part of the stock distribution area.

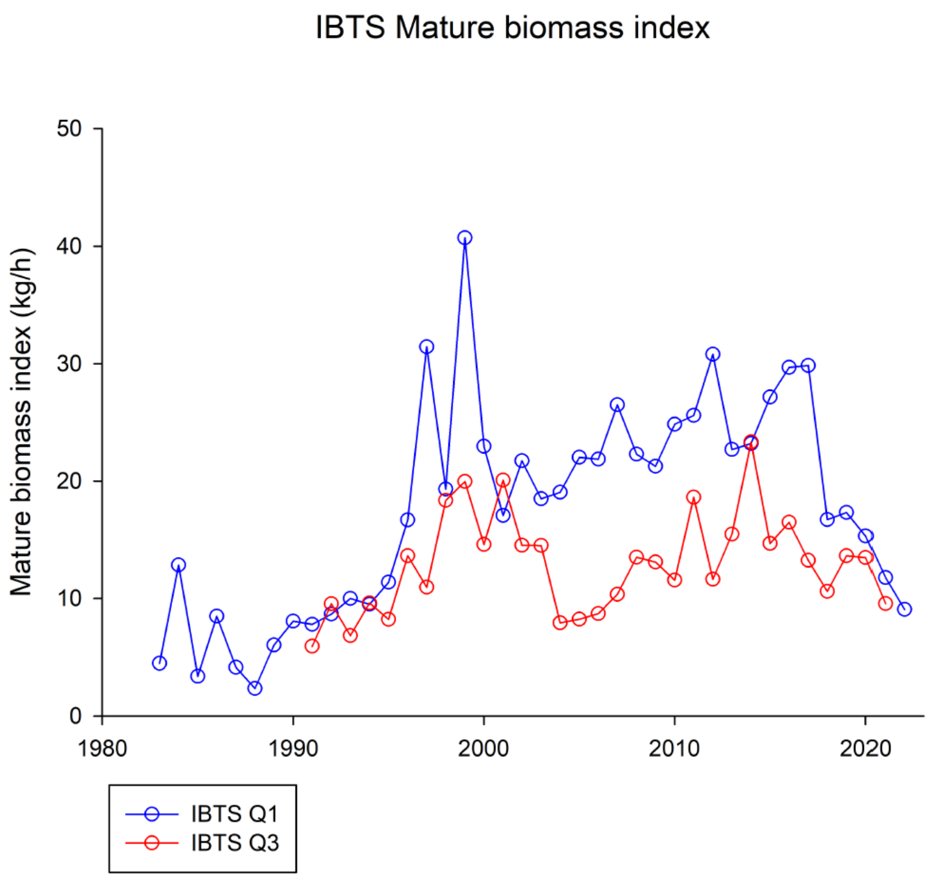

Figure 7.12. Grey gurnard in Subarea 4, Division 3.a. and Division 7.d: IBTS–Q1 and IBTS–Q3 grey gurnard mature biomass index.

7.6 MSY Proxies

7.6.1 Length Based Indicators (LBI) - update

Results of the length based indicator method are sensitive to the assumed values of L_{inf} and L_{mat} (16.3 cm). During the WGNSSK 2022, the estimation of L_{inf} was updated taking into account the new imported length data from commercial samplings (ICES, 2022). The new estimated L_{inf} of 38.2 cm was the same as estimated one year before. How these values were estimated is described in detail in the WGNSSK 2018 report (ICES, 2018) and in the stock annex. The available length frequency distributions from InterCatch were binned into 20 mm size classes and all show a unimodal distribution (Figure 7.13). The results of the LBI method showed, that with respect to conservation, the indicators are above the reference points for L_C / L_{mat} and $L_{25\%}$ / L_{mat} for all the data years (Figure 7.14 and Table 7.2 and Table 7.3). For the $L_{max5\%}$ / L_{inf} reference point the indicator is above the reference point for the last five years. The P_{mega} was for all years below the reference of 30%. With respect to the MSY_{proxy}, the indicator is above the reference points for the years 2017 – 2020 (Figure 7.16), but it dropped below in 2021. Thus, it was concluded, that the exploitation for this stock might be above F_{MSY} in the year 2021.

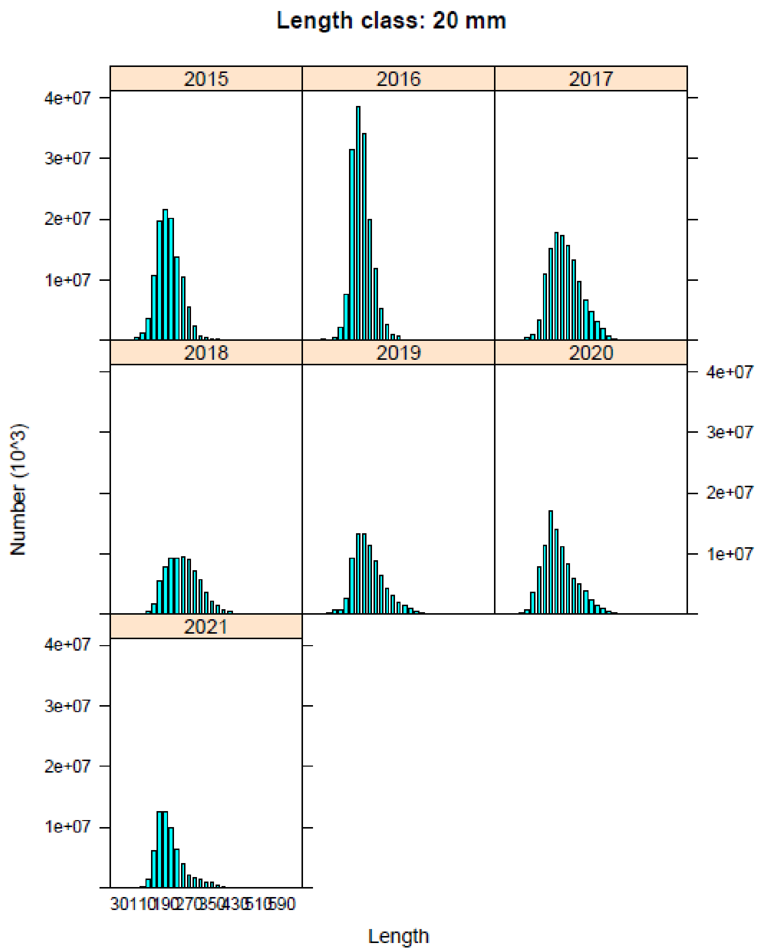

Figure 7.13 Grey gurnard in Subarea 4, Division 3.a. and Division 7.d: Obtained length frequency distributions binned into 20 mm size classes.

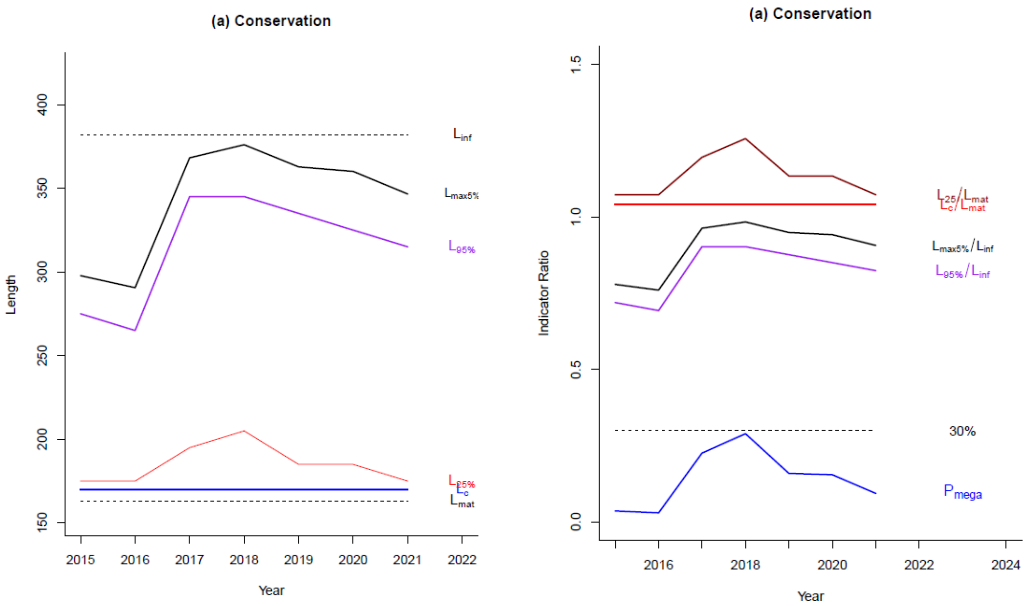

Figure 7.14 Grey gurnard in Subarea 4, Division 3.a. and Division 7.d: Conservation indicators (left panel) and indicator ratios (right panel).

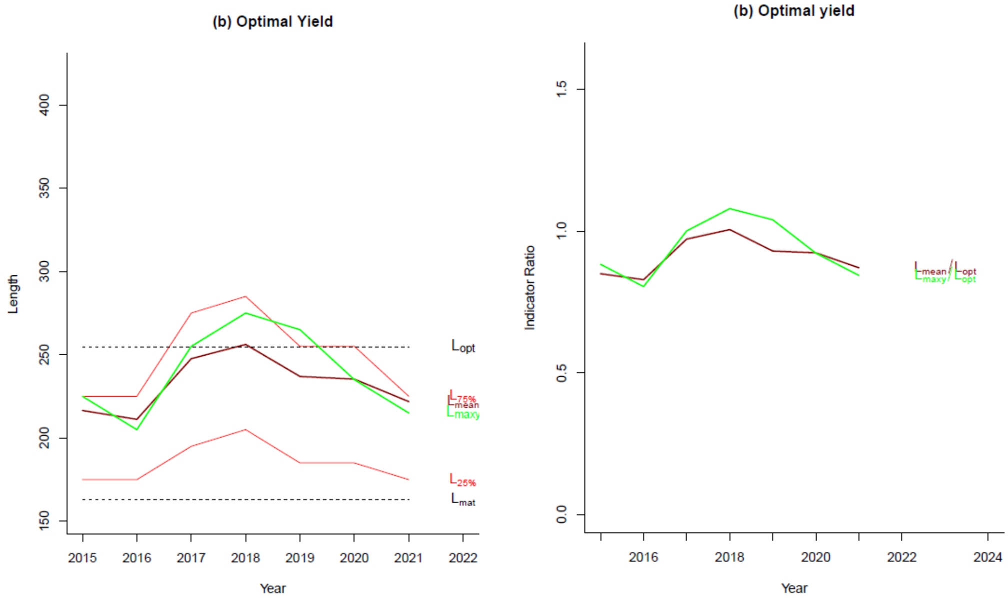

Figure 7.15 Grey gurnard in Subarea 4, Division 3.a. and Division 7.d: Optimum yield indicators (left panel) and indicator ratios (right panel).

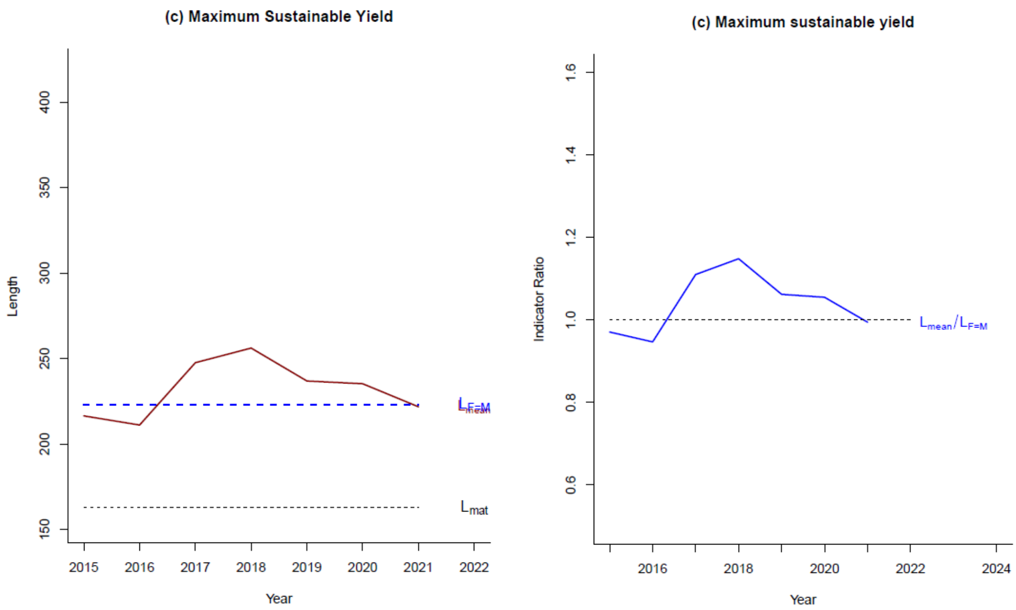

Figure 7.16 Grey gurnard in Subarea 4, Division 3.a. and Division 7.d: Maximum sustainable yield indicator (left panel) and indicator ratio (right panel).

Table 7.2 Grey gurnard in Subarea 4, Division 3.a. and Division 7.d: Length-based reference points (cm).

Year	L75	L25	Lmed	L90	L95	Lmean	Lc	LFeM	Lmaxy	Lmat	Lopt	Linf	Lmax5
2015	22.5	17.5	19.5	25.5	27.5	21.7	17.0	22.3	22.5	16.3	25.5	38.2	29.8
2016	22.5	17.5	19.5	24.5	26.5	21.1	17.0	22.3	20.5	16.3	25.5	38.2	29.1
2017	27.5	19.5	23.5	31.5	34.5	24.8	17.0	22.3	25.5	16.3	25.5	38.2	36.8
2018	28.5	20.5	24.5	32.5	34.5	25.6	17.0	22.3	27.5	16.3	25.5	38.2	37.6
2019	25.5	18.5	21.5	30.5	33.5	23.7	17.0	22.3	26.5	16.3	25.5	38.2	36.3
2020	25.5	18.5	20.5	30.5	32.5	23.5	17.0	22.3	23.5	16.3	25.5	38.2	36.0
2021	22.5	17.5	19.5	27.5	31.5	22.2	17.0	22.3	21.5	16.3	25.5	38.2	34.7

Table 7.3 Grey gurnard in Subarea 4, Division 3.a. and Division 7.d: Length-based indicators. Green colour indicate that the observed value is above the respective reference point, red colour indicates that it is below.

	Conservation				Optimizing Yield	MSY
	L_C/L_{mat}	$L_{25\%}/L_{mat}$	$L_{max5\%}/L_{inf}$	P_{mega}	L_{mean}/L_{opt}	$L_{mean}/L_{F=M}$
Ref	**>1**	**>1**	**>0.8**	**>30%**	**~1(>0.9)**	**≥1**
2015	**1.04**	**1.07**	0.78	0.04	0.85	0.97
2016	**1.04**	**1.07**	0.76	0.03	0.83	0.95
2017	**1.04**	**1.20**	**0.96**	0.23	**0.97**	**1.11**
2018	**1.04**	**1.26**	**0.98**	0.29	**1.01**	**1.15**
2019	**1.04**	**1.13**	**0.95**	0.16	**0.93**	**1.06**
2020	**1.04**	**1.13**	**0.94**	0.16	**0.92**	**1.06**
2021	**1.04**	**1.07**	**0.91**	0.09	**0.87**	0.99

7.7 Empirical *rb* rule

Grey gurnard (gug.27.3a47d) is a category 3 stock for which the 2:3 rule, based on a mature biomass IBTS-Q1 index, was used as basis for the advice given in 2020 (ICES, 2020a). However, since 2022 the 2:3 rule should not be used any longer, and instead the empirical rules tested by WKLIFE X (ICES, 2021b) should be applied. Since no reliable von Bertalanffy growth parameters (especially the growth parameter k) exist for grey gurnard, and grey gurnard is no short-lived species, the *rb* rule was applied this year as the basis of the catch advice. The *rb* rule is, as the 2:3 rule was, based on the ratio (*r*) of the mean of the last two index values (index A) and the mean of the three preceding values (index B), multiplied by recent catches or previous advised catches (A_y), and additionally a biomass safeguard (*b*), and a precautionary multiplier (*m*):

$$C_{y+1} = A_y \times r \times b \times m$$

In case of grey gurnard the average of the most recent catches was applied, because the last catch advice was given in 2016. Since then, no new catch advice was requested for this stock. The biomass safeguard *b* is determined by the relation of the most recent index value to $I_{trigger}$ (with $I_{trigger}$ = 1.4 x I_{loss}; I_{loss} = defined as lowest observed index value). When the most recent index value, I_{2022} in the case of NS-IBTS Q1, is greater than $I_{trigger}$, *b* is set to 1. This was the case for grey gurnard. The precautionary multiplier *m* is applied with the *rb* rule to maintain the probability of the biomass declining below B_{lim} to less than 5%. Following the guidelines (ICES, 2022), this precautionary multiplier should be set to 0.5 when applying the *rb* rule. An uncertainty cap (*stability clause*) is applied, which limits the amount the advised catch can change upwards or downwards between years (+20% / -30%).

Applying the *rb* rule to this grey gurnard stock resulted in a catch advice of no more than 5846 tonnes. This corresponds to 1120 tonnes landings, if the average discard rate of 81% does not change. Due to the low index ratio the uncertainty cap was applied (Table 7.4).

Table 7.4 Grey gurnard in Subarea 4, Division 3.a. and Division 7.d: The basis for the catch scenarios applying the *rb* rule. Catches are in tonnes.*

Previous catch advice A_y (average catch of last three years 2019, 2020, and 2021)		8352 tonnes
Stock biomass trend		
Index A (2021, 2022)		10.4 kg/hour
Index B (2018, 2019, 2020)		16.5 kg/hour
r: Stock biomass trend (index ratio A/B)		0.63
Biomass safeguard		
Last index value (I_{2022})		9.1 kg/hour
$I_{loss} = I_{1988}$		2.4 kg/hour
Index trigger value ($I_{trigger}=I_{loss}\times 1.4$)		3.3 kg/hour
b: index relative to trigger value, min{ $I_{2022}/I_{trigger}$, 1}		1
Precautionary multiplier to maintain biomass above B_{lim} with 95% probability		
m: multiplier (generic multiplier based on life history)		0.5
Uncertainty cap (+20%/-30% compared to A_y, only considered if b=1)	Applied	-30%
Discard rate		81%
Catch advice for 2023 and 2024**		5846 tonnes
% advice change^		-30%
Corresponding landings		1120 tonnes

* The figures in the table are rounded. Calculations were done with unrounded inputs, and computed values may not match exactly when calculated using the rounded figures in the table.

** Formula rb rule: Ay × r × b × m, limited by uncertainty cap if applicable.

^ Advice value for 2023 and 2024 relative to the average catch of the most recent three years (8252 tonnes).

7.8 Data requirements

For management purposes, information should be available on catches and landings. Traditionally the quality of landings data has been poor for this species because in the past often only landings of "gurnards" were reported which is still the case for some countries today (e.g. Germany, UK England). Further, this species is highly discarded and discard data are only available for the recent years (2012–2021).

Given the high level of discarding, observation at sea under DCF is the main source of information to better estimate total catches.

For a better understanding of this species an increase in our knowledge of biological parameters is required, especially of growth parameters with respect to the application of the *rb* rule or other empirical rules developed for data limited stocks (ICES, 2021b). In the context of ecosystem considerations, it would be useful to obtain more information on age composition of the stock and its diet composition.

From the information presented here, it can be concluded that grey gurnard is currently of very limited commercial interest.

7.9 Issues list

The available data (landings, discards, length samples) were uploaded into InterCatch for the years 2012-2021 and are used for the assessment. It should be investigated if this data series could possibly be extended to cover more years in the past.

The used survey indices are well suitable for this stock as the NS-IBTS covers most of the stock distribution area and shows a good catchability for this species. However, the use of a combined NS-IBTS Q1 and NS-IBTS Q3 index as well as other survey data should be investigated, e.g. applying the deltaGAM method (Berg et al., 2014).

Although catch data are incomplete for some years, it should be investigated if SPiCT (Pedersen and Berg, 2017) could serve as model to assess the grey gurnard stock.

There are some issues with the reporting of grey gurnard for some nations, e.g. Germany does not officially report grey gurnard but only a generic gurnard group in which also other gurnard species are included. This is usually not corrected for when uploading data to InterCatch. This is similar to the UK data for which a ratio from survey data was used to correct for the proportion of other gurnard species. However, also this method will introduce a bias in the final estimates because the survey abundance does not necessarily reflect what is landed or discarded in the fishery.

For some fleets zero landings are reported, but at the same time no discards are reported. For these cases it is not possible to raise any discards in InterCatch, although high discards may occur in these fleets. It is not known how this affects the estimation of the total catch within InterCatch.

Biological data are not collected on a routine basis for grey gurnard on the IBTS. However, from time to time new data are available via DATRAS and the availability of these data, and possibly also other data sources, should be checked and compiled during a benchmark assessment.

7.10 References

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7.11 Catch and index tables

Table 7.5. Grey gurnard in Subarea 4, Division 3.a. and Division 7.d: Official grey gurnard landings in Division 3.a (tonnes).

Year	BE	DK	NL	NO	SE	Total
1980	0	0	0	0	36	36
1981	0	0	0	0	46	46
1982	0	86	0	0	43	129
1983	0	29	0	0	7	36
1984	0	62	0	0	6	68
1985	0	3	0	0	9	12
1986	0	6	0	0	10	16
1987	1	13	0	0	6	20
1988	0	59	0	0	2	61
1989	0	19	0	0	4	23
1990	0	34	0	0	3	37
1991	0	25	0	0	5	30
1992	0	22	0	0	10	32
1993	0	18	0	0	9	27
1994	0	12	0	0	12	24
1995	0	10	0	0	5	15
1996	0	18	0	0	3	21
1997	0	13	0	0	5	18
1998	0	27	0	0	8	35
1999	0	23	0	0	5	28
2000	0	32	0	0	5	37
2001	0	30	0	0	3	33
2002	0	18	0	0	1	19
2003	0	32	0	0	1	33
2004	0	24	2	0	2	28
2005	0	21	4	0	1	26
2006	0	19	0	0	2	21
2007	0	21	1	0	3	25
2008	0	24	0	0	5	29
2009	0	15	0	0	3	18
2010	0	10	1	0	2	13
2011	0	5	0	0	1	6
2012	0	5	0	0	1	6
2013	0	5	0	0	1	6
2014	0	3	0	0	1	4
2015	0	10	1	1	2	14
2016	0	13	1	0	2	16
2017	0	257	6	4	3	270

Year	BE	DK	NL	NO	SE	Total
2018	0	24	11	0	3	38
2019	0	7	10	0	2	19
2020*	0	4	15	0	1	20
2021*	0	3	13	0	1	17

* preliminary data

Table 7.6. Grey gurnard in Subarea 4, Division 3.a. and Division 7.d: Official grey gurnard landings in Subarea 4 (tonnes).

Year	BE	DK	FR	NL	NO	SE	UK	Total
1980	0	0	43	0	0	0	0	43
1981	0	0	0	0	0	0	0	0
1982	0	0	100	0	0	0	0	100
1983	0	0	64	0	0	0	0	64
1984	0	0	71	0	0	0	0	71
1985	88	0	85	0	0	0	0	173
1986	0	27	66	0	0	0	0	93
1987	63	44205	56	0	0	0	0	44324
1988	72	36887	43	0	0	0	22	37024
1989	73	26230	45	0	0	0	0	26348
1990	85	22041	42	0	0	0	0	22168
1991	70	14514	28	0	0	0	0	14612
1992	98	8113	21	0	0	0	10	8242
1993	106	822	27	0	0	0	24	979
1994	63	87	21	0	0	0	22	193
1995	43	63	26	0	0	0	21	153
1996	108	52	18	0	0	0	54	232
1997	49	23	22	0	0	0	57	151
1998	33	29	13	0	0	0	0	75
1999	35	63	0	0	0	127	0	225
2000	28	63	5	452	0	0	0	548
2001	22	258	20	277	0	1	33	611
2002	23	45	10	285	0	1	29	393
2003	16	60	5	307	0	6	26	420
2004	21	59	6	264	0	3	23	376
2005	16	52	5	213	0	8	22	316
2006	10	46	2	133	2	0	7	200
2007	11	16	3	155	5	0	14	204
2008	8	24	2	104	5	3	12	158
2009	15	6	2	154	1	1	22	201
2010	14	8	10	218	2	0	14	266
2011	26	6	7	263	1	0	31	334
2012	49	3	4	467	2	0	77	602

Year	BE	DK	FR	NL	NO	SE	UK	Total
2013	30	5	2	268	33	1	131	470
2014	35	4	3	252	56	0	128	478
2015	22	1220	2	229	172	5	354	2004
2016	31	1151	6	232	83	6	297	1806
2017	24	2068	4	329	172	8	320	2925
2018	27	497	14	364	149	16	463	1530
2019	26	301	3	425	203	51	567	1576
2020*	25	506	1	438	276	20	465	1731
2021*	27	151	7	462	125	6	304	1082

* preliminary data

Table 7.7. Grey gurnard in Subarea 4, Division 3.a. and Division 7.d: Official grey gurnard landings in Division 7.d (tonnes).

Year	BE	FR	NL	UK	Total
1980	0	950	0	0	950
1981	0	0	0	0	0
1982	0	380	0	0	380
1983	0	489	0	0	489
1984	0	126	0	0	126
1985	14	102	0	0	116
1986	0	217	0	0	217
1987	12	66	0	0	78
1988	14	346	0	0	360
1989	9	90	0	0	99
1990	6	92	0	0	98
1991	5	94	0	0	99
1992	6	85	0	0	91
1993	7	47	0	0	54
1994	4	33	0	0	37
1995	7	36	0	0	43
1996	4	44	0	0	48
1997	3	81	0	0	84
1998	1	34	0	0	35
1999	1	0	0	0	1
2000	9	67	0	0	76
2001	6	40	0	0	46
2002	32	54	1	0	87
2003	18	42	12	0	72
2004	14	3	31	0	48
2005	13	2	21	0	36
2006	8	2	22	14	46
2007	3	1	9	36	49

Year	BE	FR	NL	UK	Total
2008	1	3	16	66	86
2009	1	1	3	61	66
2010	6	2	39	64	111
2011	11	5	53	33	102
2012	11	5	11	23	50
2013	23	4	11	14	52
2014	7	5	4	2	18
2015	2	6	2	0	10
2016	1	6	2	0	9
2017	1	8	4	12	25
2018	17	7	4	11	39
2019	1	7	3	8	19
2020*	1	2	1	1	5
2021*	1	3	2	1	7

* preliminary data

Table 7.8. Grey gurnard in Subarea 4, Division 3.a. and Division 7.d: Mature biomass indices (kg/hour) from IBTS–Q1 and IBTS–Q3.

Year	IBTS–Q1	IBTS–Q3
1983	4.48	
1984	12.85	
1985	3.38	
1986	8.49	
1987	4.15	
1988	2.35	
1989	6.03	
1990	8.07	
1991	7.80	5.93
1992	8.67	9.55
1993	10.01	6.84
1994	9.51	9.62
1995	11.38	8.22
1996	16.68	13.63
1997	31.44	10.96
1998	19.31	18.35
1999	40.72	19.96
2000	22.97	14.59
2001	17.06	20.08
2002	21.72	14.53
2003	18.49	14.52
2004	19.05	7.93

Year	IBTS–Q1	IBTS–Q3
2005	22.02	8.23
2006	21.87	8.71
2007	26.49	10.35
2008	22.29	13.52
2009	21.26	13.10
2010	24.85	11.56
2011	25.59	18.63
2012	30.81	11.64
2013	22.70	15.47
2014	23.20	23.33
2015	27.16	14.68
2016	29.69	16.49
2017	29.84	13.24
2018	16.71	10.61
2019	17.32	13.64
2020	15.32	13.49
2021	11.78	9.56
2022	9.07	

Table 7.9. Grey gurnard in Subarea 4, Division 3.a. and Division 7.d: Summary of the assessment done during the WGNSSK 2021 with updated values (Official BMS landings, ICES landings (incl. IBC), discards (incl. BMS), and catches in tonnes).

Year	Official landings	Official BMS landings	ICES Landings	ICES catches	ICES discards	Discard rate
1983	589					
1984	265					
1985	301					
1986	326					
1987	44422					
1988	37445					
1989	26470					
1990	22303					
1991	14741					
1992	8365					
1993	1060					
1994	254					
1995	211					
1996	301					
1997	253					
1998	145					
1999	254					
2000	661					

Year	Official landings	Official BMS landings	ICES Landings	ICES catches	ICES discards	Discard rate
2001	690					
2002	499					
2003	525					
2004	452					
2005	378					
2006	267					
2007	278					
2008	273					
2009	285					
2010	390					
2011	442					
2012	658		689	8345	7656	0.92
2013	528		1180	10230	9050	0.88
2014	500		1892	8596	6704	0.78
2015	2028		2141	8452	6311	0.75
2016	1831		2156	12058	9902	0.82
2017	3220		3451	16940	13489	0.80
2018	1607		1137	11418	10281	0.90
2019	1614	13	1709	9295	7586	0.82
2020	1756	6	1966	10221	8255	0.81
2021	1106	0	1099	5541	4442	0.80

8 Haddock in Subarea 4, Division 6.a and Subdivision 20 (North Sea, West of Scotland and Skagerrak)

Until 2014, haddock in Subarea 4, Division 6.a and Subdivision 20 (referred to hereafter as Northern Shelf haddock) were assessed as two separate stocks: Subarea 4 and Subdivision 20 by WGNSSK, and Division 6.a by WGCSE. The 2014 Benchmark Workshop for Northern Haddock Stocks (ICES, 2014) concluded that the two notional haddock stocks should be assessed as one stock.

This stock was benchmarked in early 2022 at the Benchmark Workshop on North Sea and Celtic Sea Stocks (WKNSCS; ICES, 2022). The primary reason for this benchmark was that support for the assessment model, TSA, would soon be unavailable due to the imminent retirement of the model developer. Additionally, several updates were made to the input datasets, new reference points were calculated and the inputs to the short term forecast were updated in line with the new assessment model software.

Minor revisions were made to the catch time series back to 2008 and new natural mortality estimates were available from WGSAM (ICES, 2021). Previously, the mean weights-at-age in the stock were assumed to be equal to mean weights-at-age in the catch. Mean weight correction factors for each age class were derived for the benchmark by comparing mean weights-at-age in the survey data to those in the catch data. These correction factors were then applied to the catch time series to obtain estimates for mean weight-at-age in the stock. Maturity-at-age estimates were also updated from an assumed ogive that was knife-edged at age 3 to annually varying maturity estimates derived from survey data. Finally, new methods for generating abundance indices from survey data were explored. This enabled the inclusion of survey data collected on the West Coast of Scotland to produce two modelled survey indices for Q1 and Q3+Q4 (combined quarters) that cover the entirety of the stock area.

The assessment model was changed to SAM (Nielsen and Berg, 2014) since SAM and TSA are both state space model and therefore have similar underlying assumptions. Additionally, a SAM assessment was presented alongside the main TSA assessment at previous WGNSSK meetings and gave similar results. The updated SAM assessment showed similar results to the previous TSA assessment though the spawning stock biomass (SSB) was estimated to be lower in the new assessment from 2000 onwards. The fishing mortality was correspondingly estimated to be higher whereas the more recent peaks in recruitment were estimated to be lower. These changes were primarily driven by the new abundance indices.

New reference points were derived from the new assessment and in general, were seen to scale with the changes in the assessment. This resulted in a new stock perception where the SSB has been below B_{lim} for the last 15-20 years. This new perception is consistent with the existing view of poor recruitment over that same period. However, SSB in 2022 was estimated to be above MSY $B_{trigger}$ due to two large incoming years classes (2019 and 2020).

The short-term forecast inputs were updated to enable a stochastic forecast to be performed in SAM. This also allowed for a better recruitment assumption to be made for the forecast. Previously, the model point estimate of recruitment in the intermediate year was used which generally did not give a realistic recruitment value or include any information on the frequency of larger year classes commonly seen for this stock. However, the new settings resample recent recruitments to obtain a more realistic recruitment estimate as well as information on the frequency of larger year classes. This resampling is restricted to the years since 2000 because levels of recruitment are seen to be lower over the last 2 decades compared to the historic time series.

8.1 General

8.1.1 Ecosystem aspects

Ecosystem aspects are summarised in the Stock Annex.

8.1.2 Fisheries

A general description of the fishery (along with its historical development) is presented in the Stock Annex. Most of the information presented below and in the Stock Annex pertains to the Scottish fleet, which takes the largest proportion of the haddock stock. This fleet is not just confined to the Northern Shelf area, as vessels will sometimes operate in Divisions 6.b (Rockall) and 5.b (Faroes).

8.1.2.1 Changes in fleet dynamics

Specific information on changes in the Scottish fleet during 2011–2021 was not provided to WGNSSK in 2022, and it is difficult to reach a firm conclusion on the likely effect of recent fishery changes on haddock mortality.

The EU landings obligation was implemented for the majority of fleets catching Northern Shelf haddock in January 2016 and catches of this stock have been fully under the landings obligation since 2019. It is unclear what changes in fleet dynamics and fishing behaviour this has caused.

Fish from the 2019 and 2020 year-classes formed the bulk of haddock catches in 2021. The entry of the large 2019 and 2020 year-classes into the fishery has led to an increase in the discarding rate for 2021.

8.1.2.2 Additional information provided by the fishing industry

No specific additional information on haddock was provided by the relevant fishing industries in 2022.

8.1.3 ICES advice

8.1.3.1 ICES advice for 2022

Subarea 4, Division 6.a and Subdivision 20

The advice for 2022:

ICES advises that when the MSY approach is applied, total catches in 2022 should be no more than 128 708 tonnes.

ICES notes the existence of a precautionary management plan, developed and adopted by one of the relevant management authorities for this stock.

8.1.4 Management

Annual management of the fishery operates through TACs for three discrete areas. The first is Subarea 4 (and EU Waters of 2.a). The 2021 and 2022 TACs for haddock in this area were 42 785 tonnes and 44 924 tonnes respectively. The second is Division 3.a (EU waters), for which the TACs for 2021 and 2022 were 2630 tonnes and 2761 tonnes respectively. The third is Division 6.a, for which the TACs in 2021 and 2022 were 4767 tonnes and 5006 tonnes respectively.

The stock is managed according to advice based on the ICES MSY approach. The details of management plans relevant to North Sea haddock (Subarea 4 and Subdivision 20) and haddock in Division 6.a are provided in the Stock Annex. However, these management plans have not been evaluated by ICES for the wider Northern Shelf area. In 2018, EU-Norway requested an evaluation of multiple management strategies (WKNSMSE: ICES, 2019a) however, these are no longer applicable following the revisions to the assessment and reference points at the benchmark in 2022 (WKNSCS; ICES, 2022). In July 2018, the European Union agreed to a multiannual management plan for demersal fisheries in the North Sea (MAP). However, the plan was not adopted by Norway or the UK and is therefore not used as the basis of advice for this shared stock. Details of the plan are given in EC 2018/973.

Fleets catching Northern Shelf haddock have previously been subject to several management schemes both aimed at reducing catches of cod. These were the Scottish Conservation Credits scheme which utilised Real Time Closures and the use of species-selective gears and the Fully documented Fisheries scheme which utilised on board monitoring cameras. Further details of these schemes are given in the Stock Annex.

The EU landings obligation was initially implemented from 1 January 2016 for directed haddock fisheries and was fully implemented in the North Sea and North Western Waters from 1 January 2019. A small number of exemptions exist for catches of haddock in ICES division 3.a. These include *de minimis* exemptions for catches of haddock from creels and some bottom trawls targeting *Nephrops* or Northern prawn. A survivability exemption exists for haddock caught using pots and fyke nets.

8.2 Data available

8.2.1 Catch

Official landings data for each country participating in the fishery are presented in Table 8.2.1, together with the corresponding ICES estimates and the agreed international quota (listed as "total allowable catch" or TAC). International data on landings, discards, below minimum size (BMS) landings and logbook registered discards (LRD) from 2008 onwards are collated through the InterCatch system (see Section 1.2). The sampling coverage of haddock catch is usually quite high with the majority of the catch data being provided by Scotland.

Figure 8.2.1 and Tables 8.2.2 to 8.2.4 summarise the proportion of landings in the combined Northern Shelf area for which samples have been provided for 2021. While there are a large number of fleets for which landings have not been sampled, the overall contribution of these fleets to total landings is small. However, the proportion of landings that have been sampled (81%) continues to be less than in previous years due to the ongoing impact of the covid-19 pandemic in 2021.

Industrial bycatch (IBC) has declined considerably from the high levels observed until the late 1970s and has rarely exceed 100 tonnes in recent years. However, estimates for 2020 and 2021 both exceed 1000 tonnes. This increase is being partly driven by the large size of the 2019 and 2020 year classes and may also be due to an increase in effort in the Norway pout fishery.

Subarea 4 discard estimates are derived from data submitted by Denmark, Germany, the Netherlands, England and Scotland. As Scotland is the principal haddock fishing nation in that area, Scottish discard practices dominate the overall estimates. DCF regulations oblige only the UK (Scotland and England) and Denmark to submit discard age-composition data for Subarea 4. Subdivision 20 discard estimates are derived from data submitted by Denmark. Division 6.a discard estimates are provided by UK (Scotland) and Ireland. Where landings are provided without a corresponding discard estimate, discards are raised using a discard rate inferred using simple averaging weighted by landings weight without consideration of quarter, country or gear. In 2021, discard observations are available for the fleets landing the majority of haddock landings (provided for 86% of the landings; see Figure 8.2.2), and 66% of the reported discards were sampled (see Figure 8.2.3). However, these sampling levels continue to be lower than those seen before the covid-19 pandemic. In particular, there was no sampling at all of Scottish discards during Q1 of 2021.

The collation of BMS landings and LRD in InterCatch was introduced in 2016 in accordance with the implementation of the EU landing obligation and are sampling information is solely provided by Scotland. However, the provision of BMS landings data was low before 2019. In 2021, the sampling coverage of BMS landings was low (13%) (see Figure 8.2.4) since estimates for Subarea 4 were not considered reliable enough for submission to InterCatch. Logbook registered discard observations have not been submitted by any country for haddock since 2016.

The full time series of landings, discards, BMS landings and industrial by-catch (IBC) is presented in Table 8.2.5 and Figure 8.2.5. The total landed yield of the international fishery has been relatively stable since 2007. The ICES estimates (Table 8.2.5) suggest that haddock discarding (as a proportion of the total catch) decreased significantly during 2013, and the discard rate for that year was the lowest in the time series at 7.2% by weight. This may have been due in part to fleet behaviour changes related to cod avoidance measures, but also to the weak year-classes since 2009 (implying that the bulk of the catch was large, mature fish that are less likely to be discarded). The discard rate increased year on year to 18% in 2016 before dropping again in 2017 and 2018 (see Figure 8.2.5). Since then, the discard rate has increased again, year on year, reaching 37% in 2021. This increase is being driven by the two large incoming year-classes of 2019 and 2020. The recent changes in discarding are not consistent across ages (Figure 8.2.6).

It would be expected that under the EU Landing Obligation fish caught under the MCRS would be landed and recorded as BMS landings in log books rather than. The log book records of BMS landings would then be reported to ICES. However, low BMS values may be seen if the fish caught below MCRS are either not landed, not recorded in log books, not reported to ICES or a mixture of the three. BMS landings reported to ICES in 2021 are 0.41% of the total catch which is significantly lower than the discard estimate of 37% of total catch. This suggests that fish caught below MCRS are not being reported as BMS landings.

Previously, estimated discard rates could be calculated using video data from Scottish vessels carrying cameras (as part of the FDF scheme described in the Stock Annex). Neither fish ages nor weights can be measured directly using video, but a method has been developed in Scotland for estimating discard rates by measuring numbers and lengths of discarded fish and applying existing weight-length relationships to obtain a discarded weight, which can then be compared with the total landed weight (see Needle *et al.*, 2015). The lack of age information currently impedes the use of these estimates in the ICES assessment process, but work is underway in Scotland and elsewhere to address this.

8.2.2 Age compositions

Age compositions for un-sampled landings (including IBC), discards, and BMS landings are generated from the age compositions from all sampled landings, discards and BMS landings, respectively, without consideration of quarter, country or gear. Total catch-at-age data are given in Table 8.2.6, while catch-at-age data for each catch component are given in Tables 8.2.7 to 8.2.10. The increase in discards since 2019 is thought to be due to the entry of the large 2019- and 2020-year classes to the fishery. In the past, vessels have only very seldom exhausted their quota in this fishery, and previous discarding behaviour is thought to have been driven by a complicated mix of economic and other market-driven factors.

8.2.3 Weight-at-age

Weight-at-age for the total catch in the North Sea is given in Table 8.2.11. Weight-at-age in the total catch is a number-weighted average of weight-at-age in the human consumption landings, discards, BMS landings and industrial bycatch components. Weights-at-age in the stock are derived by applying correction factors (calculated from comparing mean weights-at-age in the catch data to survey data from NS-IBTS Q1 and UK-SCOWCGFS Q1) to the mean weights-at-age in the catch. The mean weights-at-age for the separate catch components and for the stock are given in Tables 8.2.12 to 8.2.16 and are illustrated in Figure 8.2.7 and Figure 8.2.8: this shows the declining trend in weights-at–age for older ages in total catch and landings. However, in recent years there has been a slight increase in mean weight-at-age.

The mean weights-at-age in the last data year (2021) are used in the intermediate year (2022) in the assessment. However, there is some evidence for reduced growth rates for large year classes. Jaworski (2011) concluded that linear cohort-based growth models are the most appropriate method for characterising haddock growth. Therefore, these modelled weights are used in the short-term forecast (Section 8.6).

8.2.4 Maturity and natural mortality

The general basis for estimates of maturity and natural mortality are described in the Stock Annex. Natural mortality varies with age and year as shown in Figure 8.2.9 and Table 8.2.17. These values shown here are derived from the WGSAM 2020 key run (ICES, 2021). Annually varying maturity ogives are estimated from Q1 survey data following WGMOG guidelines (ICES, 2008) and are shown in Figure 8.2.10 and Table 8.2.18. The method for producing the maturity ogives involves a re-calculation of the entire time series whenever new data are added. Therefore, a retrospective analysis was conducted to check the robustness of the historic values to the addition of new data. The Mohn’s rho values for ages 1 to 4 were 6%, 9%, 1% and 0.1% respectively, indicating a high level of robustness (Figure 8.2.11).

At WGNSSK 2022 an update was made to the maturity ogive calculation made at the recent benchmark. This was needed as a new maturity scale was introduced by WKASMSF (ICES, 2018) which was used by several countries submitting survey data in 2021. As we were unaware of this new maturity scale, the data reported using the new scale, representing 31% of available samples in 2021, were omitted from the maturity analysis. The maturity ogives derived at the benchmark were updated to include the missing data and where then used to update the benchmark assessment results. More details of this comparison can be found in Working Document 1 (Annex 8). Overall, very little difference was seen compared to the benchmark assessment results and so the conclusions of the benchmark remain unaffected.

Maturity data for haddock is derived from Q1 survey data (NS IBTS and UK-SCOWCGFS) which were affected by severe weather and vessel issues in 2022. Several data checks were performed to ensure that the reduced sampling did not result in questionable maturity estimates. The number of available maturity samples in 2022 were approximately half of that usually available each year. The raw maturity estimates from the processing of the survey data were considered to be slightly lower than might be expected from the time series. However, the final step in generating the maturity ogives uses a GAM smoother. This step is included to reduce the effect of interannual variability and bring stability to the maturity time series. This smoothing step resulted in final maturity estimates for 2022 that were considered suitably representative for use in the assessment. The use of the smoother also means that the impact of the reduced sampling in 2022 should be reduced further in subsequent years assuming the survey sampling coverage returns to normal levels.

8.2.5 Catch, effort and research vessel data

The available survey data are summarised in the following table: data used to generate indices for use in the final assessment are highlighted in bold.

Area	Country	Quarter	Code	Year range	Age range
Subarea 4	Scotland	Q3	ScoGFS Aberdeen Q3	1982-1997	0+
Subarea 4	Scotland	Q3	ScoGFS Q3 GOV	1998-present	0+
Subarea 4	England	Q3	EngGFS Q3 GRT	1977-1991	0+
Subarea 4	England	Q3	EngGFS Q3 GOV	1992-present	0+
Subarea 4 and Division 3.a	**International**	**Q1**	**IBTS Q1**	**1983-present**	**1+**
Subarea 4 and Division 3.a	**International**	**Q3**	**IBTS Q3**	**1991-present**	**0+**
Subarea 6.a	**Scotland**	**Q1**	**ScoGFS-WIBTS Q1**	**1985-2010**	**1+**
Subarea 6.a	**Scotland**	**Q1**	**UK-SCOWCGFS-Q1**	**2011-present**	**1+**
Subarea 6.a	**Scotland**	**Q4**	**ScoGFS-WIBTS Q4**	**1996-2009**	**0+**
Subarea 6.a	**Scotland**	**Q4**	**UK-SCOWCGFS-Q4**	**2011-present**	**0+**
Subarea 6.a	**Ireland**	**Q4**	**IGFS-WIBTS-Q4**	**1993-2002**	**0+**
Subarea 6.a	**Ireland**	**Q4**	**New IGFS-WIBTS-Q4**	**2003-present**	**0+**

The 2022 benchmark meeting (WKNSCS; ICES, 2022) developed combined North Sea-West Coast of Scotland (NS-WC) indices for Q1 and Q3+Q4 (combined quarters) for use in the assessment using the delta-GAM modelling approach. The general methodology is described in Berg et al. (2014) and full methodological details are available in the report of the last benchmark (WKNSCS; ICES, 2022). For the NS-WC Q1 survey indices the model is fit to ages 1-8+ and all are used in the assessment model. For the NS-WC Q3+Q4 survey indices the model is fit to ages 0-8+ all of which are used in the assessment model. A summary is given in the table below:

Modelled survey name	Input survey data	Quarter	Area	Years	Ages
Modelled NS-WC Q1 survey indices	ScoGFS-WIBTS-Q1; UK-SCOWCGFS-Q1; NS-IBTS-Q1	Q1	North Sea (27.4), Skagerrak (27.3.a) and West Coast of Scotland (27.6.a)	1983-2022	1-8+
Modelled NS-WC Q3+Q4 survey indices	NS-IBTS-Q3; ScoGFS-WIBTS-Q4; IGFS-WIBTS-Q4; UK-SCOWCGFS-Q4	Q3+Q4	North Sea (27.4), Skagerrak (27.3.a) and West Coast of Scotland (27.6.a)	1991-2021	0-8+

The modelled survey indices used for the calibration of the assessment are presented in Table 8.2.19. Survey-based abundance distributions by age and year are given in Figures 8.2.12 (North Sea IBTS Q1), 8.2.13 (North Sea IBTS Q3) which clearly show the large incoming 2019 and 2020 year-classes. Abundance trends in survey indices are shown in Figure 8.2.14. These indicate reasonably good consistency in stock signals from the two North Sea surveys, and support the perception of large 2019- and 2020-year-classes.

In 2022, a combination of several storms and mechanical issues with some vessels during Q1 resulted in a reduction in the sampling coverage of the NS-IBTS Q1 survey and the cancellation of the UK-SCOWCGFS Q1 survey. Both of these surveys are used to produce the Q1 modelled indices. A sensitivity analysis was conducted by replicating the reduced sampling coverage in previous years to evaluate the impact on the resulting indices. The results of this are presented in Working Document 1 (Annex 8). The solution recommended and followed at WGNSSK 2022 was to use the coefficients of variation associated with the modelled indices as an additional input to the assessment model. This represents a permanent change to the assessment model inputs as agreed at WKNSCS (ICES, 2022) and the Stock Annex has been updated accordingly.

8.3 Data analyses

The assessment has been carried out using SAM (Nielsen and Berg, 2014) as the main assessment method. The results of a SURBAR analysis are also shown, to corroborate (or otherwise) the main assessment.

8.3.1 Exploratory catch-at-age-based analyses

The catch-at-age data, in the form of log-catch curves linked by cohort (Figure 8.3.1), indicate partial recruitment to the fishery for most cohorts up to age 2 (shown by hooks towards the top of the catch curves). Gradients between consecutive values within a cohort have reduced considerably for some recent cohorts, reflecting a reduction in fishing mortality, although catch curves are considerably more variable in recent years suggesting less consistent catch data (which may reflect the lower sample size available from reduced landings, or covid-19 impacts on sampling). Figure 8.3.2 plots the negative gradient of straight lines fitted to each cohort over the age range 2–4, which can be viewed as a rough proxy for average total mortality for ages 2–4 in the cohort. These negative gradients are also lower in most recent cohorts

Cohort correlations in the catch-at-age matrix (plotted as log-numbers) are shown in Figure 8.3.3. These correlations show good consistency within cohorts up to the plus-group, verifying the ability of the catch-at-age data over the full time-series to track relative cohort strengths.

8.3.2 Exploratory survey-based analyses

The two survey derived indices (delta-GAM NS-WC Q1 and delta-GAM NS-WC Q3+Q4) show a high level of consistency between the indices in the plot of survey catch curves (Figure 8.3.4). Although there are indications of reduced catchability for cohorts in delta-GAM NS-WC Q1 from the 2010. The plots of mean-standardised log survey indices by age and cohort (Figure 8.3.5) and the pairwise within-survey correlations (Figure 8.3.6) show that both surveys track year-class strength well through the population overall.

A SURBAR run (ICES, 2010; Needle, 2015) was carried out using the same combination of tuning indices as the SAM assessment, although with excluding the plus group (8+). The summary plot from this run is given is Figure 8.3.7, which indicates good precision in estimates for total mortality, and relative estimates for biomass and recruitment. The SURBAR residual plot in Figure 8.3.8 shows that there remains an indication of some conflict (mostly positive residuals for Q1 and negative residuals for Q3+Q4).

Mean-standardising SSB and recruitment estimates (using a common year-range for the mean) and generating SAM estimates of Z by adding F and M enables the comparison between SAM and SURBAR shown in Figure 8.3.19. SSB and recruitment estimates are very similar from the two models, although it is noticeable that the swings between high and low SURBAR SSB estimates are more pronounced than for SAM. The mean Z time-series from SURBAR are consistent for the most part with those from SAM, although there is some offset in years of higher mean Z. Overall, the SURBAR assessment concurs with and support the final SAM assessment, with some relatively minor variations.

8.3.3 Final assessment

Table 8.3.1 and Table 8.3.2 give the final SAM assessment inputs and settings, while Table 8.3.2 gives the corresponding parameter estimates from the completed run. A full description of the SAM method, inputs and settings are given in the Stock Annex, and the ICES WKNSCS (2022) report. Note that, for assessment purposes, total catch is divided into human consumption landings (referred to as "landings") and a composite of discards, BMS landings and industrial bycatch (referred to as "discards" or "discards+bycatch+BMS").

In 2022, coefficients of variation (CVs) associated with the delta-GAM NS-WC Q1 indices were added as an input to the assessment model to address uncertainties arising from reduced sampling coverage of the Q1 surveys. More details are given in Working Document 1 (Annex 8).

The stock summary is given in Figure 8.3.10. The spawning stock biomass in 2022 is seen to be at almost a historically high value while fishing mortality is seen to be at its historical minimum. Recruitment in 2021 is seen to be lower than the previous 2 years and is similar in size to the majority of year classes since 2000 (see also Figure 8.3.11).

The one-observation-ahead (Figure 8.3.12) and process error (Figure 8.3.13) residuals are relatively small and, although some patterns are seen the residuals, these are similar to those seen at the last benchmark meeting (WKNSCS; ICES, 2022). Investigation of these patterns is listed as an issue in section 8.12.

The fit to the commercial catch data, delta-GAM NS-WC Q1 indices and delta-GAM NS-WC Q3+Q4 indices are shown in figures 8.3.14-8.3.16. Overall these indicate reasonably good fits to data, although the model tends to underestimate the largest peaks and drops in abundance in the data.

The results of the leave-one-out analysis are shown in Figure 8.3.17. These results show similar trends when either of the survey indices are removed from the analysis indicating that the signals from each survey are consistent with each other. The leave-one-out runs are all mostly within the pointwise 95% confidence intervals of the full assessment results except for some more recent years in the SSB estimate when the delta-GAM NS-WC Q1 survey is removed.

Figure 8.3.18 summarizes the results of SAM retrospective analyses for Northern Shelf haddock. There is very little retrospective noise or bias: none of the retrospective run falls outside of the pointwise 95% confidence intervals of the full time-series assessment for any of the summaries. It may be hypothesized that the strong population signals from occasional large year-classes provide sufficient data contrast to obviate against retrospective noise.

Mohn's rho values (average relative bias of retrospective estimates) were calculated for SSB, F and recruitment estimates from SAM and were -4%, 5% and -9% respectively and all lie well within the ±20% limits specified by WKFORBIAS (ICES, 2020).

Fishing mortality estimates for the final SAM assessment are presented in Table 8.3.4, the stock numbers in Table 8.3.5, and the assessment summary in Table 8.3.6.

8.4 Historical Stock Trends

The historical stock and fishery trends are presented in Figure 8.3.10.

Landings yields stabilised between 2005 and 2014, partly due to the limitation of inter-annual TAC variation to ±15% in the EU-Norway management plan for the North Sea. Discards have fluctuated in the same period due to the appearance and subsequent growth of the 1999, 2005, 2009, 2014, 2019 and 2020 year-classes, while industrial bycatch (IBC) is now at a very low level for haddock (see Figure 8.2.5).

Estimated fishing mortality for 2008 to 2020 fluctuates between 0.2 and 0.4 and is now just below the F_{MSY} value of 0.24 in 2021. Fluctuations around the previous F(target) rate (0.3) of the management plan are an expected consequence of the lag between data collection and management action, and should not be taken to indicate that the plan did not work.

The underlying mean level of recruitment has declined from the early seventies until today, and recruitment remains lower in general. Over the last two decades, recruitment has been characterised by stretches of poor recruitment (e.g. 2006–2008 and 2010–2013) with occasional modestly sized year-classes (e.g. 2005, 2009, 2014) which have sustained the fishery in recent years. However, the 2019 and 2020 year-classes are estimated to be the largest since the 1999 year-class, and are very unusual for a haddock stock in that they occur consecutively. These recruitment events have increased the estimated SSB in 2021 and 2022, and will impact significantly on the short-term forecast for 2023 and 2024 (see Section 8.6).

8.5 Recruitment estimates

Following the Stock Annex, recruits in the intermediate year (IY = 2022) and in the quota year (IY + 1 = 2023) were sampled, with replacement, from recent (2000-2021) recruitment estimates from SAM. This method ensures that information about the frequency of the occasional larger year classes are included in the forecast. The geometric mean of the resampled recruitments is 1 623 040 thousand.

This stock is subject to the reopening process later in the year, following the completion of the IBTS Q3 survey, where the recruitment assumption may be updated with a recruitment estimate resulting from an RCT3 analysis (according to the standard ICES update protocol).

The following table summarises the recruitment, age 1 and age 2 assumptions for the short-term forecast.

Year class	Age in 2022	SAM estimate (millions)	SAM forecast (millions)
2020	2	1268	
2021	1	1045	
2022	0		1623
2023	Age 0 in 2023		1623
2024	Age 0 in 2024		1623

8.6 Short-term forecasts

The short-term forecast is a stochastic forecast conducted in SAM. The inputs to the short-term forecast are presented in Table 8.6.1. The forecast is conducted for a single fleet (as opposed to two fleets: human consumption catch and industrial bycatch) and industrial bycatches are included with the projected discards.

Initial stock size

The initial stock sizes are simulated from the estimated distribution at the start of the intermediate year (including covariances).

Maturity and natural mortality

Both the natural mortality and maturity estimates used in the forecast are set equal to the mean of the final 3 data years (2019-2021).

Weights-at-age

Mean weights-at-age are forecast using the method proposed by Jaworski (2011) which was discussed by WKHAD (ICES, 2014) and modified at WKNSCS (ICES, 2022). The method is summarized in the Stock Annex, and involves fitting straight lines to cohort-based weight estimates and extrapolating forward in time.

The mean weights-at-age resulting from this method for the landings are summarised in Figure 8.6.1. The weights-at-age for discards, IBC and BMS were combined using the relative contribution of each component to the total catch. These combined weights were used in the extrapolation to calculate the forecast weights and are shown in Figure 8.6.2. Where there is insufficient data (i.e. less than 3 data points) to allow for cohort-based modelling of weights-at-age a simple three-year (2019–2021) means by age are used for all forecast years. The mean weights-at-age for the total catch are derived by combining the forecast weights-at-age for the landings and discards (including IBC and BMS) using the relative contribution of each component to the total catch. Survey-derived correction factors (see Section 8.2.3 for more details) were applied to the mean weights-at-age for the catch to derive mean weight-at-age for the stock. The resulting forecast weights for the stock and all catch components are shown in Figure 8.6.3.

In 2022, the cohort-based growth modelling method resulted in erroneous results for the landings weights for the 2018 cohort. This was caused by an unusually high mean weight for age 1 fish landed from this cohort in the catch data. An investigation revealed that this likely arose from a combination of relatively low sample numbers generally seen for this age class and the split of those samples across countries. Specifically, a larger than usual number of samples for this cohort at age 1 came from Norway which generally reports greater mean weights compared to other countries. A straight 3-year mean (2019-2021) was used instead of the cohort-based growth method to generate the mean weights for this cohort for the forecast.

Fishing mortality

WKNSCS (ICES, 2022) concluded that fishing mortality estimates for the intermediate year should be a mean of the final 3 data years (2019-2021), rescaled to the final year (2021) F. When this approach results in a total catch that overshoot the TAC, a TAC constraint should be considered. A TAC constraint was needed for the intermediate year to avoid a TAC overshoot of 43 186 t (given that quota uptake for this stock very seldom exceeds 90%). The combined-area human consumption TAC for 2022 is 52 691 tonnes.

The catches obtained with the fishing mortality rates discussed above are split into landings and discards (including IBC and BMS) by using the relative contribution (averaged over 2019–2021) of each component to the total catch.

Splitting catch forecasts between management units

The haddock assessment presented in this section is for the combined Northern Shelf stock, following the conclusion from ICES WKHAD (2014) that this was biologically appropriate. However, catch advice is still required for the extant management units. ICES WKHAD (2014) proposed a survey-based method for splitting forecast catch into sub-units on the basis of a time-smoothed survey-based estimate of the proportion of the fishable stock in each area in each year.

However, the survey-based proportions were not accepted by ACOM (in June 2014) as the basis for advice, due to concerns over the comparability of survey catchability between the three management areas covered by the assessment area. As a consequence, the catch forecasts provided in Table 8.6.2 are provided for the full stock area only (Subarea 4, Division 6.a and Subdivision 20).

Forecast results

Results for the short-term forecasts are presented in Table 8.6.2. Assuming a TAC-constrained F of 0.111 in 2022, SSB is expected to be 396 233 tonnes in 2022, before increasing in 2023 to 494 778 tonnes (the increase in SSB is due to the 2020-year class becoming mostly mature). In this case, projected landings in 2022 would be 40 425 tonnes with associated projected unwanted catch (discards +IBC + BMS) of 12 267 t.

Several alternative options for 2023 have been highlighted in Table 8.6.2. These are based on various reference points including F_{MSY}, F_{pa}, F_{lim}, B_{pa}, B_{lim}, $B_{trigger}$ as well as F_{2022}, $F_{MSY\text{-}upper}$, and $F_{MSY\text{-}lower}$. Under the assumption of F_{MSY}, the 2023 total catch is forecast to be 137 058 tonnes, which corresponds (if 2022 discard+IBC+BMS rates remain unchanged) to a landings yield of 118 373 tonnes and discards (including IBC and BMS) of 18 685 tonnes. This advised catch represents a 6.5% increase on the 2022 TAC. This exploitation is forecast to lead in turn to an SSB in 2024 of 438 042 tonnes, a decrease of 11.5% on the value forecast above for 2023.

8.7 Medium-term forecasts

No specific medium-term forecasts have been carried out for this stock. Management simulations over the medium-term period were previously performed for North Sea haddock (Needle, 2008a, b) and West of Scotland haddock (Needle, 2010), while management strategy evaluations for Northern Shelf haddock were conducted in 2019 in response to a request for advice on a proposed EU-Norway management plan (ICES 2019a, b).

8.8 Biological reference points

Biological reference points were calculated at WKNSCS (ICES, 2022) using EqSim following the acceptance of the benchmark assessment. The EqSim settings and assumptions are detailed in the WKNSCS report (ICES, 2022). The calculations are based on a recruitment time-series from 2000–2021, rather than the full time series. This is because the recruitment during this more recent period has been poor compared to the full time series and it would be unwise to assume that a very large recruitment is likely in the near future.

Using the ICES guidelines for sporadic spawners, B_{lim} was set to 136 541 tonnes (the estimated SSB for 1999, the smallest stock size to produce a good recruitment), and B_{pa} was revised to 1.645*sigmaSSB x B_{lim} = 189 734 tonnes (where sigmaSSB = 0.2). An EqSim analysis run without assessment or advice error or the advice rule gave a value of 0.43 for F_{lim} (the F that leads, on average, leads to B_{lim}).

An EqSim analysis run with assessment and advice error (using default values) but without the advice rule gave a value of 0.27 for the unconstrained F_{MSY}. The value of F_{pa} is set equal to the F that provides a 95% probability for SSB to remain above B_{lim} in the long term ($F_{p.05}$; run with assessment and advice error and advice rule) by the ICES guidelines. The value of $F_{p.05}/F_{pa}$ was calculated as 0.24 at WKNSCS 2022. Since the value of the unconstrained F_{MSY} (0.27) was estimated to be above $F_{p.05}/F_{pa}$, the final value of F_{MSY} was capped at $F_{p.05}/F_{pa}$ (0.24) to ensure consistency between the precautionary and MSY frameworks (see Figure 8.8.1). The F_{MSY} ranges were adjusted accordingly to be consistent with the capped value of F_{MSY} ($F_{MSY\ lower} = F_{p.05\ lower}$ = 0.186; $F_{MSY\ upper} = F_{p.05}$ = 0.24).

Finally, the value of MSY $B_{trigger}$ was set equal to B_{pa} (189 734 tonnes) since the stock has been fished at a value above the unconstrained F_{MSY} for the past 5 years.

The reference points in full from these analyses are given below:

Variable	WGNSSK 2021	WKNSCS 2022
B_{lim}	94 000 tonnes	136 541 tonnes
B_{pa}	132 000 tonnes	189 734 tonnes
MSY $B_{trigger}$	132 000 tonnes	189 734 tonnes
F_{lim}	0.384	0.43
$F_{p.05}/F_{pa}$	0.194	0.24
F_{MSY}	0.194	0.24
$F_{MSY\ lower}$	0.167	0.186
$F_{MSYupper}$	0.194	0.24

8.9 Quality of the assessment

Survey data are consistent both within and between surveys, and the catch data are internally consistent. Trends in mortality from catch data and survey indices are similar. Retrospective bias in the SAM model is low, and well within the WKFORBIAS guidelines.

The covid-19 pandemic affected catch sampling in 2020 and also, to a lesser extent, in 2021. In 2020, both observer and market sampling were not possible during Q2 but continues at a reduced level in Q3 and Q4. In 2021, Scottish observer sampling was not possible during Q1 though sampling proceeded at similar levels to the latter half of 2020 for the rest of the year. This reduced coverage is not thought to have had a significant impact on the quality of catch data for Scotland (which has the main fleets catching haddock).

In 2022, a combination of several major storms and mechanical issues with some vessels resulted in a reduction in the sampling coverage across the NS-IBTS and SCOWCGFS Q1 surveys. This increased the uncertainty on the Q1 survey indices used in the assessment. Relative weightings (CVs) for the Q1 survey indices were added as an input to the assessment model to minimise the impact of this increased uncertainty on the assessment results.

8.10 Status of the Stock

Fishing mortality is now estimated to be at a historically low level in 2021 is just below the estimate of F_{MSY} (0.24). Discard rates have increased above the historical minimum observed in 2013. The 2010–2013 year-classes were estimated to be weak, following the relatively strong 2009 year-class, but the 2014 year-class was slightly larger than the recent average and the incoming 2019- and 2020-year classes appear to be the largest since 1999. Spawning stock biomass has recovered from levels below B_{lim} to levels well above MSY $B_{trigger}$/B_{pa} (189 734 tonnes) and is predicted to increase further next year as the 2019- and 2020-year-classes mature.

8.11 Management Considerations

The previous EU-Norway management plan for North Sea haddock, and the EU management plan for Division 6.a haddock, are not appropriate for the Northern Shelf stock, as they each relate to only a part of the full stock area. Discussions took place during 2019–20 between the EU and Norway to try and establish a new management strategy on the basis of the Northern Shelf stock, but no agreement has yet been reached, and further work would also need to include the UK. In the meantime, the principal basis for management of this haddock stock is the ICES MSY approach. The survey-based proposal for splitting catch advice into management subunits, which was proposed by WGNSSK in 2014, has not been agreed by ACOM, and the split of quota into management units remains based on historical landings. It is unlikely, therefore, to follow any future changes in stock distribution across the Northern Shelf.

Considering the Northern Shelf as a whole, fishing mortality declined significantly in the early 2000s and has fluctuated around a relatively low level since. The current estimate is just below F_{MSY}. Spawning stock biomass is estimated to have reached a historical peak in 2002 with the growth of the large 1999 year-class, but declined again rapidly and is now driven strongly by occasional, moderately-sized year-classes. The most recent of these occurred in 2005, 2009 and 2014 with two substantial year classes occurring in 2019 and 2020. Other recent cohorts have been very weak. SSB is expected to continue to increase over the next year as the 2019 and 2020 year-classes mature and its impact on SSB is expected to be the most significant in the available time-series.

Keeping fishing mortality close to the target MSY level would be preferable to encourage the sustainable exploitation of the recent larger year-classes. Estimated discard rates are now increasing as large numbers of small fish enter the population, and this needs to be monitored and mitigated. In particular, discard rates remain high in certain small-mesh fisheries (such as the TR2 *Nephrops* fleets in Division 6.a). Further improvements to gear selectivity measures, allowing for the release of small fish, would be highly beneficial not only for the haddock stock, but also for the survival of juveniles of other species that occur in mixed fisheries along with haddock. Similar considerations also apply to spatial management approaches (such as real-time closures), and other measures intended to reduce unwanted bycatch and discarding of various species (such as the previous Scottish Conservation Credits scheme; see Stock Annex). Haddock was included in the EU Landings Obligation regulation from 2016, though the impacts on fishing and on the stock are as yet unknown.

Haddock is a specific target for some fleets, but is also caught as part of a mixed fishery catching cod, whiting and *Nephrops*. It is important to consider both the species-specific assessments of these species for effective management, as well as the latest developments in the mixed fisheries approach. This is not straightforward when stocks are managed via a series of single-species, single-area management plans that do not incorporate mixed-stocks considerations. However, a reduction in effort on one stock may lead to a reduction or an increase in effort on another and the implications of any change need to be considered carefully.

8.12 “Living issues” benchmark list

Below is a list of issues which were either left unresolved from the last benchmark or have arisen during subsequent WGNSSK meetings. A scoring system has been developed to aid Working

Groups in prioritising stocks to be put forward for benchmark (see Annex 6 for further details). The current scoring for this stock is:

1. Assessment quality	2. Opportunity to improve	3. Management importance	4. Perceived stock status	5. Time since last benchmark	Total Score
2	0	5	2	1	1.6

8.12.1 Stock ID and other issues

Explore stock ID and structure, using otolith micro-chemistry, tagging data, and the spatial range of genetic data. Investigate ecosystem drivers for long term forecasts/MSE with consideration for climate change.

8.12.2 Data

Investigate indices of reproductive potential and methods to use them in management advice. Address spatial residual patterns in the modelled survey indices. Consider adding CVs as weighting for the Q3+Q4 survey indices as well as the Q1 indices.

8.12.3 Assessment

Investigate poor fit/residual patterns in plus group in view of increasing relative importance of this age class. Explore further model settings to address patterns within the assessment residuals.

8.12.4 Forecast

Review forecast settings in view of the settings recommended by the model developer.

8.13 References

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Table 8.2.1. Haddock in Subarea 4, Division 6.a and Subdivision 20. Nominal landings (000 t) during 2011–2021, as officially reported to, and estimated by, ICES, along with WG estimates of catch components, and corresponding TACs. Landings estimates for 2020 and 2021 are preliminary. Quota uptake estimates are also given, calculated as the ICES estimates of landings divided by available quota before 2018. Quota uptake from 2018 onwards is calculated as the ICES estimates of total catch divided by available quota (following the implementation of the Landing Obligation). Reporting of BMS landings started in 2016.

Subdivision 20											
Country	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
DE	102	120	90	114	103	125	56	31	30	12	21
DK	1661	1916	1456	1764	1059	908	852	542	457	448	1841
NL	0	0	5	6	4	2	20	4	4	1	11
NO	125	303	223	86	63	70	0	0	0	0	8
PT	0	0	0	0	0	0	0	0	0	15	0
SE	198	210	217	219	203	110	104	140	93	56	124
UK	0	0	3	0	0	0	0	0	0	0	0
BMS landings							< 1	< 1	0	1	74
Subarea 4											
Country	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
BE	106	78	78	98	47	53	30	29	29	40	150
DE	575	548	677	677	599	554	609	348	313	331	369
DK	697	947	1283	1079	1442	1244	1185	1117	1174	1683	1892
FO	0	0	0	0	0	0	0	0	0	0	0
FR	0	0	0	0	0	0	0	0	1	2	0
NL	71	191	172	99	44	146	75	102	166	175	291
NO	1195	1006	1662	2743	2003	1499	2164	1428	1516	3171	2215
SE	128	103	113	154	136	118	181	100	111	114	142
UK	23343	27378	33013	29851	25905	26427	25667	26091	22044	20452	17123
BMS landings							< 1	15	160	287	208
Division 6.a											
Country	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
DE	0	0	0	0	0	0	0	0	0	0	0
DK	0	0	0	0	0	2	2	1	9	4	18
ES	36	15	14	19	9	33	28	28	64	26	24
FO	0	0	0	0	0	0	0	0	0	0	0
FR	73	32	51	67	41	62	68	66	57	86	92
IE	290	845	746	667	768	1034	641	758	562	441	587
NL	0	0	0	0	11	28	31	17	54	13	0
NO	4	0	6	2	7	5	1	7	10	2	0
UK	1364	4123	3878	3261	3052	3101	2480	3441	2755	2081	2838
BMS landings							0	2	15	26	30
	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Official landings	30288	37990	43864	41115	35596	35642	34334	34451	29637	29427	27965
ICES landings	30273	37839	43230	40589	35215	35111	33799	34441	30747	28942	26457
ICES discards	12609	5054	3305	5271	6241	7582	6960	5055	5337	8693	16129
ICES IBC	0	19	168	65	21	37	8	30	186	1077	1357
ICES BMS	-	-	-	-	-	-	201	93	160	180	217
ICES total catch	42882	42912	46703	45926	41477	42930	40860	39687	36449	38928	44122
TAC 4	34057	39000	45041	38284	40711	61933	33643	41767	28950	35653	44924
TAC 3.a	2100	2095	2770	2355	2504	3926	2069	2569	1780	2193	2630
TAC 6.a	2005	6015	4211	3988	4536	6462	3697	4654	3226	3973	4767
Total TAC	38162	47110	52022	44627	47751	72321	39409	48990	33956	41819	50182
ICES quota uptake	79%	80%	83%	91%	74%	49%	86%	70%	107%	93%	88%

Table 8.2.2. Haddock in Subarea 4, Division 6.a and Subdivision 20. Proportion of sampling strata for discards imported into InterCatch and proportion of discards raised from averaged discard rates for 2021.

Catch category	Raised or imported	Weight (tonnes)	Proportion
BMS landings	Imported	176	100
Discards	Imported	11926	73
Discards	Raised	4340	27
Landings	Imported	28129	100
Logbook registered discards	Imported	0	NA

Table 8.2.3. Haddock in Subarea 4, Division 6.a and Subdivision 20. Proportion of age distributions for landings, BMS landings and discards either imported or raised in InterCatch and either sampled or estimated for 2021.

Catch category	Raised or imported	Sampled or estimated	Weight (tonnes)	Proportion
Logbook registered discards	Imported	Estimated	0	NA
Landings	Imported	Sampled	22792	81
Landings	Imported	Estimated	5337	19
Discards	Imported	Sampled	10802	66
Discards	Raised	Estimated	4340	27
Discards	Imported	Estimated	1125	7
BMS landings	Imported	Estimated	154	87
BMS landings	Imported	Sampled	22	13

Table 8.2.4. Haddock in Subarea 4, Division 6.a and Subdivision 20. Proportion by area of distributions for landings, BMS landings and discards either imported or raised in InterCatch and either sampled or estimated for 2021.

Catch category	Raised or imported	Sampled or estimated	Area	Weight (tonnes)	Proportion
Logbook registered discards	Imported	Estimated		0	NA
Landings	Imported	Sampled	27.6.a	3341	92
Landings	Imported	Estimated	27.6.a	302	8
Discards	Imported	Sampled	27.6.a	4161	96
Discards	Raised	Estimated	27.6.a	183	4
BMS landings	Imported	Sampled	27.6.a	22	98
BMS landings	Imported	Estimated	27.6.a	<1	2
Logbook registered discards	Imported	Estimated		0	NA
Landings	Imported	Sampled	27.4	17670	79
Landings	Imported	Estimated	27.4	4794	21
Discards	Imported	Sampled	27.4	6308	56
Discards	Raised	Estimated	27.4	3895	34
Discards	Imported	Estimated	27.4	1105	10
BMS landings	Imported	Estimated	27.4	153	100
Logbook registered discards	Imported	Estimated		0	NA
Landings	Imported	Sampled	27.3.a.20	1781	88
Landings	Imported	Estimated	27.3.a.20	240	12
Discards	Raised	Estimated	27.3.a.20	332	54
Discards	Imported	Sampled	27.3.a.20	262	43
Discards	Imported	Estimated	27.3.a.20	20	3
BMS landings	Imported	Estimated	27.3.a.20	0	NA

Table 8.2.5. Haddock in Subarea 4, Division 6.a and Subdivision 20. ICES estimates of catch components by weight (000 tonnes).

Year	Subarea 4					Subdivision 20					Division 6.a				Combined				
	Landings	Discards	BMS landings	IBC	Total	Landings	Discards	BMS landings	IBC	Total	Landings	Discards	BMS landings	Total	Landings	Discards	BMS landings	IBC	Total
1965	161.7	62.3		74.6	298.6	0.7				0.7	32.5	3.4		35.9	194.9	65.7		74.6	335.2
1966	225.6	73.5		46.7	345.8	0.6				0.6	29.9	0.7		30.6	256.1	74.2		46.7	377.0
1967	147.4	78.2		20.7	246.3	0.4				0.4	20.3	7.4		27.7	168.1	85.6		20.7	274.4
1968	105.4	161.8		34.2	301.4	0.4				0.4	20.5	25.3		45.8	126.3	187.1		34.2	347.6
1969	331.1	260.1		338.4	929.5	0.5				0.5	26.3	25.2		51.5	357.9	285.3		338.4	981.6
1970	524.1	101.3		179.7	805.1	0.7				0.7	34.1	6.2		40.3	558.9	107.5		179.7	846.1
1971	235.5	177.8		31.5	444.8	2				2	46.3	12.2		58.5	283.8	190.0		31.5	505.3
1972	193	128		29.6	350.5	2.6				2.6	41.1	16.4		57.5	236.7	144.4		29.6	410.7
1973	178.7	114.7		11.3	304.7	2.9				2.9	28.8	11.4		40.2	210.4	126.1		11.3	347.8
1974	149.6	166.4		47.5	363.5	3.5				3.5	18.0	15.4		33.3	171.1	181.8		47.5	400.3
1975	146.6	260.4		41.5	448.4	4.8				4.8	13.7	33.0		46.6	165.1	293.4		41.5	499.9
1976	165.7	154.5		48.2	368.3	7				7	18.8	15.3		34.1	191.5	169.8		48.2	409.5
1977	137.3	44.4		35	216.7	7.8				7.8	19.3	4.4		23.7	164.4	48.8		35	248.2
1978	85.8	76.8		10.9	173.5	5.9				5.9	17.2	1.1		18.3	108.9	77.9		10.9	197.7
1979	83.1	41.7		16.2	141	4				4	14.8	6.5		21.3	101.9	48.2		16.2	166.3
1980	98.6	94.6		22.5	215.7	6.4				6.4	12.8	4.8		17.5	117.8	99.4		22.5	239.6
1981	129.6	60.1		17	206.7	6.6				6.6	18.2	7.1		25.3	154.4	67.2		17	238.6
1982	165.8	40.6		19.4	225.8	7.5				7.5	29.6	7.7		37.3	202.9	48.3		19.4	270.6
1983	159.3	66		12.9	238.2	6				6	29.4	3.4		32.8	194.7	69.4		12.9	277.0
1984	128.2	75.3		10.1	213.6	5.4				5.4	30.0	8.1		38.1	163.6	83.4		10.1	257.1
1985	158.6	85.2		6	249.8	5.6				5.6	24.4	10.7		35.1	188.6	95.9		6	290.5
1986	165.6	52.2		2.6	220.4	2.7				2.7	19.6	5.2		24.7	187.9	57.4		2.6	247.8
1987	108	59.1		4.4	171.6	2.3				2.3	27.0	11.1		38.1	137.3	70.2		4.4	211.9
1988	105.1	62.1		4	171.2	1.9				1.9	21.1	5.0		26.1	128.1	67.1		4	199.2
1989	76.2	25.7		2.4	104.2	2.3				2.3	16.7	2.5		19.2	95.2	28.2		2.4	125.8
1990	51.5	32.6		2.6	86.6	2.3				2.3	10.1	0.8		11.0	63.9	33.4		2.6	100.0
1991	44.7	40.2		5.4	90.2	3.1				3.1	10.6	4.8		15.3	58.4	45.0		5.4	108.7
1992	70.2	47.9		10.9	129.1	2.6				2.6	11.3	3.5		14.9	84.1	51.4		10.9	146.5
1993	79.6	79.6		10.8	169.9	2.6				2.6	19.1	7.0		26.1	101.3	86.6		10.8	198.7
1994	80.9	65.4		3.6	149.8	1.2				1.2	14.2	5.0		19.2	96.3	70.4		3.6	170.3
1995	75.3	57.4		7.7	140.4	2.2				2.2	12.4	7.7		20.0	89.9	65.1		7.7	162.6
1996	76	72.5		5	153.5	3.1				3.1	13.5	7.8		21.3	92.6	80.3		5	177.9
1997	79.1	52.1		6.7	137.9	3.4				3.4	12.9	7.5		20.4	95.4	59.6		6.7	161.7
1998	77.3	45.2		5.1	127.6	3.8				3.8	14.4	7.0		21.4	95.5	52.2		5.1	152.8
1999	64.2	42.6		3.8	110.7	1.4				1.4	10.4	3.9		14.3	76.0	46.5		3.8	126.3
2000	46.1	48.8		8.1	103	1.5				1.5	7.0	6.3		13.2	54.6	55.1		8.1	117.7
2001	39	118.3		7.9	165.2	1.9				1.9	6.7	8.5		15.2	47.6	126.8		7.9	182.3

Year	Subarea 4					Subdivision 20					Division 6.a				Combined				
	Landings	Discards	BMS landings	IBC	Total	Landings	Discards	BMS landings	IBC	Total	Landings	Discards	BMS landings	Total	Landings	Discards	BMS landings	IBC	Total
2002	54.2	45.9		3.7	103.8	4.1				4.1	7.1	9.4		16.5	65.4	55.3		3.7	124.4
2003	40.1	23.5		1.1	64.8	1.8	0.2			2	5.3	4.5		9.8	47.2	28.2		1.1	76.5
2004	47.3	15.4		0.6	63.2	1.4	0.1			1.6	3.2	4.5		7.7	51.9	20.0		0.6	72.5
2005	47.6	8.4		0.2	56.2	0.8	0.2			1	3.1	3.8		6.9	51.5	12.4		0.2	64.1
2006	36.1	16.9		0.5	53.6	1.5	1			2.5	5.7	5.2		10.9	43.3	23.1		0.5	66.9
2007	29.4	27.8			57.3	1.5	0.8			2.3	3.7	4.0		7.8	34.6	32.6			67.3
2008	29.1	15.5		0.0	44.5	1.3	0.4			1.8	2.8	1.6		4.4	33.2	17.5		0.0	50.7
2009	30.1	10.0			40.1	1.5	0.4			1.9	2.8	1.8		4.6	34.4	12.2		0.0	46.6
2010	28.0	7.3			35.3	1.4	0.6			2.0	2.9	1.6		4.5	32.3	9.5		0.0	41.8
2011	26.8	10.1			36.8	2.1	1.3			3.4	1.8	1.3		3.1	30.7	12.7		0.0	43.4
2012	30.5	3.8		0.0	34.4	2.6	0.8			3.4	5.1	0.5		5.6	38.2	5.1		0.0	43.4
2013	36.9	2.1		0.0	39.0	2.2	0.2		0.2	2.5	4.8	1.0		5.8	43.8	3.3		0.2	47.3
2014	34.7	4.3		0.1	39.1	2.3	0.2			2.4	4.1	0.8		4.9	41.1	5.3		0.1	46.5
2015	30.0	4.7		0.0	34.7	1.4	0.2		0.0	1.6	4.0	1.4		5.4	35.4	6.3		0.0	41.7
2016	29.7	5.9	0.2	0.0	35.8	1.2	0.1		0.0	1.3	4.3	1.6	0.0	6.0	35.3	7.6	0.2	0.0	43.1
2017	29.3	5.2	0.1	0.0	34.6	1.1	0.1			1.2	3.5	1.6		5.1	33.9	7.0	0.1	0.0	41.0
2018	29.3	3.6	0.1	0.0	33.1	0.8	0.1			0.9	4.4	1.4	0.0	5.8	34.5	5.1	0.2	0.0	39.8
2019	26.7	3.4	0.2	0.2	30.5	0.6	0.1		0.0	0.7	3.6	2.1	0.0	5.7	30.9	5.6	0.2	0.2	36.8
2020	26.0	7.9	0.2	0.9	35.1	0.4	0.2		0.1	0.8	2.7	0.6	0.0	3.3	29.1	8.7	0.2	1.1	39.2
2021	21.0	11.3	0.2	1.3	33.7	2.0	0.6		0.1	2.7	3.7	4.3	0.0	8.0	26.7	16.3	0.2	1.4	44.5

Table 8.2.6. Haddock in Subarea 4, Division 6.a and Subdivision 20. Numbers at age data (thousands) for total catch. Ages 0–7 and 8+ and years 1972–2021 are used in the assessment.

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	8+
1965	650218	368560	16491	721514	36301	4954	2245	626	118	97	47	0	0	0	0	0	262
1966	1672925	1007517	26186	7536	459941	11903	1109	633	222	90	23	2	0	0	0	0	337
1967	345371	856339	108401	5814	3850	202830	2843	223	231	61	34	0	0	0	0	0	326
1968	11133	1226448	477603	22671	2303	3210	60034	1052	84	22	5	0	0	0	0	0	111
1969	75301	20554	3736629	313593	9029	2678	2894	23704	392	32	7	0	0	0	0	0	431
1970	941790	272467	218881	2003201	60200	1350	1285	401	6539	81	13	19	0	0	0	0	6652
1971	337277	1881729	74866	50845	480381	10916	589	201	167	1767	176	3	5	0	0	0	2119
1972	255110	696714	671965	43309	23547	211817	4067	241	53	27	475	11	0	0	0	0	566
1973	79461	412305	587335	260080	6450	5689	72652	1406	140	34	234	49	5	0	0	0	462
1974	665110	1283252	187149	342628	60523	1956	1795	22380	345	57	63	4	7	4	0	0	480
1975	51796	2276937	673960	62175	112242	17691	1078	718	6168	339	70	11	0	8	0	0	6596
1976	171400	192030	1127520	225532	11538	32677	5864	228	84	1863	64	3	5	0	0	0	2019
1977	119506	263702	109480	426291	45756	4984	6757	1608	163	40	460	8	0	1	0	0	672
1978	281785	223294	130963	31141	144703	11791	1582	2322	740	122	33	275	16	2	0	0	1188
1979	844410	261156	220200	45487	7978	38097	3069	377	629	181	57	13	52	3	0	0	935
1980	374573	439674	374310	80225	11364	2040	11143	827	143	168	96	34	9	7	1	0	457
1981	645352	116229	430149	180553	17044	2225	497	3320	164	78	26	32	5	1	4	0	311
1982	275508	217834	89989	390347	49835	4275	820	551	1072	60	28	8	2	2	0	0	1172
1983	513034	148158	222772	83199	166812	20055	2365	338	255	385	93	21	4	4	0	0	763
1984	95862	483045	139887	143821	29321	56077	6238	967	127	84	185	19	5	1	1	0	423
1985	127003	161400	441785	80605	41508	7082	18393	1929	296	56	29	144	9	0	0	1	535
1986	45703	137091	144075	328016	29497	10595	1686	4421	581	156	56	47	37	16	4	1	898
1987	10249	253236	259369	56407	92705	6214	3993	1187	2596	462	56	65	35	32	17	8	3271
1988	16679	33092	424014	96795	17161	27728	2030	874	368	1076	95	21	12	13	17	1	1603
1989	19587	51743	43162	216359	21015	4189	7671	763	285	170	469	69	8	3	2	1	1007
1990	19286	82571	78881	17811	60888	4373	1104	1839	254	100	54	13	12	1	4	2	439
1991	128703	188087	101425	24822	4706	17618	1388	684	1024	171	65	11	11	1	2	2	1287
1992	277933	166550	255051	43257	7162	1486	6376	611	337	401	149	22	6	2	0	0	918
1993	136841	302610	269220	123469	11822	1986	669	2050	215	210	188	84	4	4	0	0	706
1994	89104	91674	339428	106673	35056	3381	601	366	746	132	48	36	26	5	0	0	992
1995	200151	336460	119210	182969	33802	9237	898	161	155	151	21	8	6	2	1	0	345
1996	167032	46797	505401	73987	66245	11159	4058	1080	75	72	37	9	8	3	1	0	205
1997	36954	162449	107657	251339	18037	18288	2762	937	121	16	18	5	4	4	2	0	170
1998	21919	88387	224037	60861	128348	7110	4590	850	263	60	7	8	3	2	1	1	345
1999	90634	69455	119094	110046	28510	45221	2700	2047	438	53	8	3	3	2	0	0	507
2000	12630	397390	110381	61263	33137	7254	9935	765	367	53	13	2	1	1	0	0	438
2001	3518	95086	633162	34548	12078	5573	2094	1611	257	89	28	3	4	0	0	0	382
2002	50927	36063	99685	372036	7812	2801	1615	729	603	283	25	8	5	0	0	0	923
2003	7082	13136	15234	48729	127241	2166	786	339	144	100	48	5	1	0	0	0	299

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	8+
2004	3758	25698	24627	8958	38784	97827	1010	248	82	42	37	12	1	0	0	0	174
2005	8779	17695	24596	15085	5446	27745	61457	371	132	38	11	8	4	1	0	0	193
2006	3229	122537	30995	20657	11284	6078	16415	32978	156	56	20	7	4	1	0	0	243
2007	2046	20565	171600	16796	8187	4782	2237	6876	7254	75	8	14	3	1	0	0	7355
2008	2550	25087	35038	80164	4156	2093	1354	552	1577	2473	6	4	1	1	0	0	4061
2009	27313	11967	13754	18495	77722	1904	759	563	133	242	545	8	2	0	0	0	930
2010	2508	49728	14174	17429	11677	37295	833	379	142	78	81	162	10	0	0	3	475
2011	5024	4342	64649	12999	7402	5791	20830	450	119	70	25	12	70	0	0	0	295
2012	1377	3879	5072	66385	5431	3697	2414	8051	137	176	50	28	32	22	2	0	447
2013	1303	12258	4251	4651	68803	2216	1532	840	3919	36	7	7	2	2	2	0	3976
2014	3504	7593	20031	4690	7647	46684	1080	962	371	1694	13	6	1	1	0	2	2089
2015	3776	27610	15630	17723	1719	5013	21935	1062	434	437	785	108	0	0	0	0	1765
2016	1701	9374	61656	8846	5556	655	451	10138	253	151	9	149	9	0	0	1	573
2017	2615	12732	23207	54472	3228	1498	144	367	1442	502	6	20	3	1	0	1	1974
2018	3632	5556	24263	17121	35201	925	522	210	100	970	20	0	3	3	1	1	1099
2019	3555	17935	11790	25744	7145	21202	432	369	23	46	143	5	1	4	1	10	232
2020	1540	45286	27157	11930	14636	3281	7953	178	164	62	61	20	0	0	0	0	307
2021	6813	24198	72275	13536	5768	8346	767	4727	45	31	2	2	0	1	0	0	81

Table 8.2.7. Haddock in Subarea 4, Division 6.a and Subdivision 20. Numbers at age data (thousands) for landings. Ages 0–7 and 8+ and years 1972–2021 are used in the assessment.

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	8+
1965	0	2670	3908	396363	30232	4358	2126	620	118	97	47	0	0	0	0	0	262
1966	0	13034	6899	5332	419437	11113	1082	631	222	90	23	2	0	0	0	0	337
1967	0	55548	40030	4627	3607	198991	2821	223	231	61	34	0	0	0	0	0	326
1968	0	22108	151474	17130	2160	3176	59110	1051	84	22	5	0	0	0	0	0	111
1969	0	143	759680	175763	7965	2282	2760	23452	392	32	7	0	0	0	0	0	431
1970	0	2428	52031	1211535	53570	1184	1220	398	6539	81	13	19	0	0	0	0	6652
1971	0	35945	27011	37832	448352	10551	582	201	167	1767	176	3	5	0	0	0	2119
1972	0	13354	233966	35440	22165	210167	4054	241	53	27	475	11	0	0	0	0	566
1973	0	7277	211018	209961	6085	5459	72528	1406	140	34	234	49	5	0	0	0	462
1974	0	25699	55734	236624	53054	1868	1679	22156	345	57	63	4	7	4	0	0	480
1975	0	28773	211495	41030	93617	17406	1073	718	6163	339	70	11	0	8	0	0	6591
1976	0	3045	246027	155162	11292	29594	5846	228	84	1863	64	3	5	0	0	0	2019
1977	0	8934	33058	278741	42737	4737	6516	1608	163	40	460	8	0	1	0	0	672
1978	0	13913	55636	26119	123655	11479	1496	2317	740	122	33	275	16	2	0	0	1187
1979	0	16077	120456	38247	7752	37353	3052	377	629	181	57	13	52	3	0	0	935
1980	0	11487	154765	67241	9978	1985	11057	820	143	166	96	34	9	7	1	0	456
1981	0	1959	174018	128102	16447	2219	494	3320	164	78	26	32	5	1	4	0	311
1982	0	7623	40161	282492	45732	3811	820	551	1072	60	28	8	2	2	0	0	1172
1983	0	7669	114118	57151	152477	19147	2201	338	255	385	93	21	4	4	0	0	763

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	8+
1984	0	22842	80349	115405	27331	52226	6238	967	127	84	185	19	5	1	1	0	423
1985	0	3059	267559	75242	40846	6858	18360	1929	296	56	29	144	9	0	0	1	535
1986	0	12735	67173	287995	29371	10587	1685	4421	581	156	56	47	37	16	4	1	898
1987	0	11150	120584	46970	89772	6212	3993	1187	2596	462	56	65	35	32	17	8	3271
1988	0	2371	167090	83798	16114	27515	2030	874	344	1076	95	21	12	13	17	1	1579
1989	0	5446	17801	146467	19506	4130	7549	752	283	170	467	69	8	3	2	1	1003
1990	0	6279	46366	15680	54465	4117	1054	1761	250	100	54	13	12	1	4	2	435
1991	0	21627	57480	23058	4646	17468	1388	684	1024	171	65	11	11	1	2	2	1287
1992	0	3544	128147	38838	7038	1483	6354	611	337	401	149	22	6	2	0	0	918
1993	0	3232	92828	102781	11570	1976	669	2028	215	210	188	84	4	4	0	0	706
1994	0	1484	75783	85391	32827	3345	600	366	746	132	48	36	26	5	0	0	992
1995	0	2410	32846	114437	31198	9038	898	161	155	151	21	8	6	2	1	0	345
1996	0	1179	84349	41653	55794	11123	4058	1080	75	72	37	9	8	3	1	0	205
1997	0	2292	26774	140099	16153	17846	2762	937	121	16	18	5	4	4	2	0	170
1998	0	2167	45449	42411	106125	6959	4579	850	263	60	7	8	3	2	1	1	345
1999	0	1340	31357	60351	26260	42494	2648	2047	438	53	8	3	3	2	0	0	507
2000	0	5508	32823	34517	27247	6927	9734	765	367	53	13	2	1	1	0	0	438
2001	0	855	75731	17938	10929	5321	2094	1609	256	89	28	3	4	0	0	0	381
2002	0	816	14893	124903	6330	2710	1615	618	603	283	25	8	5	0	0	0	923
2003	0	53	2119	16076	81868	2141	777	339	144	100	48	5	1	0	0	0	299
2004	0	495	3142	4906	23978	77262	996	239	82	42	37	12	1	0	0	0	174
2005	0	788	5777	8878	4178	22915	56760	370	131	38	11	8	4	1	0	0	192
2006	0	2129	10416	11780	8602	5209	14745	30350	149	54	20	7	3	1	0	0	234
2007	0	1146	28873	11204	7361	4684	2199	6773	7183	75	8	14	3	1	0	0	7284
2008	0	327	6945	53012	3944	2063	1285	544	1576	2468	6	4	1	1	0	0	4055
2009	0	438	4589	9317	62331	1837	725	532	133	242	541	8	2	0	0	0	925
2010	0	1036	4695	12884	10496	35690	803	379	131	78	81	161	10	0	0	3	463
2011	0	57	15441	11014	6571	5687	20609	450	119	70	24	11	70	0	0	0	294
2012	0	209	3191	52623	4927	3685	2408	8032	137	176	50	28	32	22	2	0	447
2013	0	983	2369	4165	65909	2183	1522	825	3880	36	6	7	2	2	2	0	3935
2014	0	207	12576	3684	7471	42241	1076	948	364	1690	13	6	1	1	0	2	2077
2015	0	599	10558	16192	1631	4983	20943	1061	434	437	785	108	0	0	0	0	1764
2016	0	155	36387	8648	5532	652	443	10119	253	151	9	149	9	0	0	1	572
2017	0	148	11248	47244	3123	1482	136	366	1430	502	6	20	3	1	0	1	1962
2018	0	108	12032	15031	33277	922	521	206	100	966	20	0	3	3	1	1	1095
2019	0	282	5060	21797	6935	20372	429	366	23	45	142	5	1	4	1	10	230
2020	0	972	15876	9846	13642	2892	7555	172	158	60	59	19	0	0	0	0	296
2021	0	518	27082	10794	5138	7915	718	4456	43	29	2	1	0	1	0	0	77

Table 8.2.8. Haddock in Subarea 4, Division 6.a and Subdivision 20. Numbers-at-age data (thousands) for discards. Ages 0–7 and 8+ and years 1972–2021 are used in the assessment.

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	8+
1965	5757	111654	4897	141863	3704	4	1	0	0	0	0	0	0	0	0	0	0
1966	13832	445648	12742	1197	24643	35	2	0	0	0	0	0	0	0	0	0	0
1967	46372	408281	62831	1032	219	1576	9	0	0	0	0	0	0	0	0	0	0
1968	67	741402	244976	3512	97	15	186	0	0	0	0	0	0	0	0	0	0
1969	4475	5234	1273332	39179	432	16	8	0	0	0	0	0	0	0	0	0	0
1970	68905	99125	78340	306391	2663	13	4	0	0	0	0	0	0	0	0	0	0
1971	14189	1275394	37883	9623	25648	66	2	0	0	0	0	0	0	0	0	0	0
1972	18446	444794	380988	6846	1236	1212	13	0	0	0	0	0	0	0	0	0	0
1973	38129	287558	363916	50108	354	33	123	0	0	0	0	0	0	0	0	0	0
1974	88456	982287	99148	59143	2869	6	4	0	0	0	0	0	0	0	0	0	0
1975	7479	1653311	377845	16385	13423	143	0	0	0	0	0	0	0	0	0	0	0
1976	6418	122012	698428	41183	200	137	0	0	0	0	0	0	0	0	0	0	0
1977	16364	107748	47070	79922	664	9	0	0	0	0	0	0	0	0	0	0	0
1978	1193	83683	63997	4214	19568	248	80	0	0	0	0	0	0	0	0	0	0
1979	4795	119245	82074	5734	142	365	0	0	0	0	0	0	0	0	0	0	0
1980	258	146751	197725	4726	96	0	0	0	0	0	0	0	0	0	0	0	0
1981	442	15023	225773	47838	157	1	0	0	0	0	0	0	0	0	0	0	0
1982	505	36063	35089	94315	2293	0	0	0	0	0	0	0	0	0	0	0	0
1983	24327	76672	94323	20914	12092	905	164	0	0	0	0	0	0	0	0	0	0
1984	3275	361946	48893	23714	1623	3317	0	0	0	0	0	0	0	0	0	0	0
1985	4924	146668	156400	3624	115	1	16	0	0	0	0	0	0	0	0	0	0
1986	13007	84333	75071	39219	23	1	0	0	0	0	0	0	0	0	0	0	0
1987	1996	159860	134988	9142	2795	2	0	0	0	0	0	0	0	0	0	0	0
1988	7399	27412	244105	10535	427	10	0	0	24	0	0	0	0	0	0	0	24
1989	10673	43756	23611	67102	1048	23	35	0	2	0	2	0	0	0	0	0	4
1990	16290	69073	30530	1772	4932	28	25	0	0	0	0	0	0	0	0	0	0
1991	11794	143967	40697	1163	17	107	0	0	0	0	0	0	0	0	0	0	0
1992	36231	82605	115933	4063	97	0	6	0	0	0	0	0	0	0	0	0	0
1993	12346	191714	163172	17474	170	1	0	3	0	0	0	0	0	0	0	0	0
1994	19197	75840	254112	20271	2069	30	0	0	0	0	0	0	0	0	0	0	0
1995	2118	231490	84163	67644	2539	199	0	0	0	0	0	0	0	0	0	0	0
1996	22563	35010	413599	28996	10344	36	0	0	0	0	0	0	0	0	0	0	0
1997	15260	114893	69948	106789	1700	425	0	0	0	0	0	0	0	0	0	0	0
1998	2936	77065	162251	15801	20732	88	11	0	0	0	0	0	0	0	0	0	0
1999	20814	57336	83205	46764	1905	2561	49	0	0	0	0	0	0	0	0	0	0
2000	8472	320463	55818	24661	5703	321	201	0	0	0	0	0	0	0	0	0	0
2001	1531	71284	521655	6483	1115	244	0	2	1	0	0	0	0	0	0	0	1
2002	1120	21358	80304	243495	978	64	0	111	0	0	0	0	0	0	0	0	0
2003	2937	7101	11014	31369	43849	13	9	0	0	0	0	0	0	0	0	0	0

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	8+
2004	3758	24613	21221	3967	14548	19811	5	4	0	0	0	0	0	0	0	0	0
2005	8779	16730	18722	6181	1258	4826	4496	1	1	0	0	0	0	0	0	0	1
2006	3229	118636	19862	8636	2634	823	1596	2520	6	1	1	0	0	0	0	0	8
2007	2045	19393	142509	5585	826	97	38	103	71	0	0	0	0	0	0	0	71
2008	2550	24760	28093	27151	212	30	69	8	2	4	0	0	0	0	0	0	6
2009	27313	11529	9165	9178	15390	67	34	31	0	0	4	0	0	0	0	0	4
2010	2508	48691	9479	4545	1181	1605	30	0	11	0	0	1	0	0	0	0	12
2011	5024	4285	49207	1985	831	104	222	0	0	0	1	1	0	0	0	0	2
2012	1377	3670	1880	13735	502	10	5	15	0	0	0	0	0	0	0	0	0
2013	1303	11271	1873	470	2638	25	5	12	24	0	1	0	0	0	0	0	25
2014	3504	7386	7435	999	164	4375	2	13	7	1	0	0	0	0	0	0	8
2015	3776	27011	5065	1522	87	27	980	0	0	0	0	0	0	0	0	0	0
2016	1700	9029	24507	188	17	2	7	8	0	0	0	0	0	0	0	0	0
2017	2580	12418	11798	7122	103	16	7	2	12	0	0	0	0	0	0	0	12
2018	3632	5440	11654	2063	1818	3	0	4	0	3	0	0	0	0	0	0	3
2019	3555	17456	6412	3596	168	705	1	0	0	0	0	0	0	0	0	0	0
2020	1540	43835	10427	1593	441	280	116	0	0	0	0	0	0	0	0	0	0
2021	6813	23588	43021	2071	366	25	11	43	0	0	0	0	0	0	0	0	0

Table 8.2.9. Haddock in Subarea 4, Division 6.a and Subdivision 20. Numbers-at-age data (thousands) for BMS landings. Ages 0–7 and 8+ and years 2016–2021 are used in the assessment.

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	8+
2016	0	189	725	2	1	0	0	0	0	0	0	0	0	0	0	0	0
2017	35	166	158	95	1	0	0	0	0	0	0	0	0	0	0	0	0
2018	0	8	566	13	77	0	0	0	0	0	0	0	0	0	0	0	0
2019	0	195	287	219	0	2	0	0	0	0	0	0	0	0	0	0	0
2020	0	443	263	124	46	1	0	0	0	0	0	0	0	0	0	0	0
2021	0	66	782	117	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 8.2.10. Haddock in Subarea 4, Division 6.a and Subdivision 20. Numbers-at-age data (thousands) for IBC. Ages 0–7 and 8+ and years 1972–2021 are used in the assessment.

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	8+
1965	644461	254237	7686	183288	2365	592	118	6	0	0	0	0	0	0	0	0	0
1966	1659093	548835	6546	1007	15861	755	25	2	0	0	0	0	0	0	0	0	0
1967	298999	392510	5539	155	24	2264	12	0	0	0	0	0	0	0	0	0	0
1968	11066	462938	81153	2029	46	19	738	1	0	0	0	0	0	0	0	0	0
1969	70826	15178	1703617	98650	632	380	126	252	0	0	0	0	0	0	0	0	0
1970	872884	170914	88509	485275	3967	153	61	2	0	0	0	0	0	0	0	0	0
1971	323088	570391	9972	3390	6381	299	6	0	0	0	0	0	0	0	0	0	0
1972	236664	238566	57010	1023	146	439	0	0	0	0	0	0	0	0	0	0	0
1973	41332	117470	12402	11	11	196	0	0	0	0	0	0	0	0	0	0	0
1974	576654	275266	32267	46862	4600	82	112	224	0	0	0	0	0	0	0	0	0
1975	44317	594854	84620	4761	5203	141	5	0	5	0	0	0	0	0	0	0	5
1976	164982	66973	183064	29188	46	2946	17	0	0	0	0	0	0	0	0	0	0
1977	103142	147019	29352	67628	2355	238	240	0	0	0	0	0	0	0	0	0	0
1978	280592	125698	11330	809	1480	64	6	5	0	0	0	0	0	0	0	0	0
1979	839615	125834	17671	1507	84	379	16	0	0	0	0	0	0	0	0	0	0
1980	374315	281436	21820	8258	1291	54	86	7	0	1	0	0	0	0	0	0	1
1981	644910	99247	30358	4613	440	6	2	0	0	0	0	0	0	0	0	0	0
1982	275003	174147	14740	13540	1810	464	0	0	0	0	0	0	0	0	0	0	0
1983	488707	63818	14331	5134	2242	3	0	0	0	0	0	0	0	0	0	0	0
1984	92587	98257	10644	4702	368	535	0	0	0	0	0	0	0	0	0	0	0
1985	122079	11672	17826	1739	547	223	17	0	0	0	0	0	0	0	0	0	0
1986	32696	40023	1831	802	103	7	0	0	0	0	0	0	0	0	0	0	0
1987	8253	82226	3797	295	138	0	0	0	0	0	0	0	0	0	0	0	0
1988	9280	3309	12819	2462	620	202	0	0	0	0	0	0	0	0	0	0	0
1989	8914	2541	1751	2789	460	37	86	10	0	0	0	0	0	0	0	0	0
1990	2996	7218	1986	359	1491	227	25	78	4	0	0	0	0	0	0	0	4
1991	116909	22493	3248	601	43	43	0	0	0	0	0	0	0	0	0	0	0
1992	241702	80402	10971	356	27	3	17	0	0	0	0	0	0	0	0	0	0
1993	124495	107664	13220	3214	82	9	0	18	0	0	0	0	0	0	0	0	0
1994	69907	14349	9534	1011	160	7	1	0	0	0	0	0	0	0	0	0	0
1995	198033	102560	2201	888	65	0	0	0	0	0	0	0	0	0	0	0	0
1996	144469	10608	7453	3338	107	0	0	0	0	0	0	0	0	0	0	0	0
1997	21694	45264	10935	4451	184	17	0	0	0	0	0	0	0	0	0	0	0
1998	18983	9155	16337	2649	1490	63	0	0	0	0	0	0	0	0	0	0	0
1999	69820	10780	4531	2932	344	166	3	0	0	0	0	0	0	0	0	0	0
2000	4158	71419	21740	2085	186	5	0	0	0	0	0	0	0	0	0	0	0
2001	1987	22946	35776	10127	35	8	0	0	0	0	0	0	0	0	0	0	0
2002	49807	13889	4489	3638	504	27	0	0	0	0	0	0	0	0	0	0	0
2003	4145	5983	2101	1285	1524	12	0	0	0	0	0	0	0	0	0	0	0

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	8+
2004	0	590	265	84	258	753	8	4	0	0	0	0	0	0	0	0	0
2005	0	176	97	26	9	5	201	1	0	0	0	0	0	0	0	0	0
2006	0	1772	716	241	47	46	74	108	1	0	0	0	0	0	0	0	1
2007	1	27	218	6	1	0	0	0	0	0	0	0	0	0	0	0	0
2008	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	0	0	2	27	3	2	1	4	0	0	0	0	0	0	0	0	0
2013	0	4	9	16	256	8	6	3	15	0	0	0	0	0	0	0	15
2014	0	0	20	6	12	68	2	2	1	3	0	0	0	0	0	0	3
2015	0	0	6	10	1	3	12	1	0	0	0	0	0	0	0	0	1
2016	0	0	38	9	6	1	0	11	0	0	0	0	0	0	0	0	1
2017	0	0	3	12	1	0	0	0	0	0	0	0	0	0	0	0	0
2018	0	0	11	13	29	1	0	0	0	1	0	0	0	0	0	0	1
2019	0	2	31	132	42	124	3	2	0	0	1	0	0	0	0	0	1
2020	0	36	591	366	508	108	281	6	6	2	2	1	0	0	0	0	11
2021	0	27	1389	554	264	406	37	229	2	1	0	0	0	0	0	0	4

Table 8.2.11. Haddock in Subarea 4, Division 6.a and Subdivision 20. Mean weight at age data (kg) for total catch. Ages 0–7 and 8+ and years 1972–2021 are used in the assessment.

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	8+
1965	0.010	0.070	0.227	0.370	0.655	0.846	1.170	1.190	1.479	1.714	2.175	0.000	0.000	0.000	0.000	0.000	1.691
1966	0.010	0.088	0.247	0.394	0.536	0.962	1.254	1.512	1.827	1.723	2.955	2.035	0.000	0.000	0.000	0.000	1.877
1967	0.014	0.116	0.278	0.478	0.591	0.641	1.072	1.511	1.898	2.084	2.342	0.000	0.000	0.000	0.000	0.000	1.979
1968	0.010	0.129	0.254	0.516	0.743	0.827	0.829	1.483	2.071	2.622	2.065	0.000	0.000	0.000	0.000	0.000	2.179
1969	0.012	0.064	0.217	0.410	0.817	0.905	1.029	1.074	1.808	2.772	3.259	0.000	0.000	0.000	0.000	0.000	1.904
1970	0.013	0.075	0.222	0.353	0.738	0.925	1.195	1.246	1.427	2.438	3.489	3.864	0.000	0.000	0.000	0.000	1.450
1971	0.012	0.109	0.246	0.359	0.509	0.888	1.269	1.525	1.338	1.284	1.961	4.270	3.513	0.000	0.000	0.000	1.355
1972	0.025	0.117	0.242	0.383	0.503	0.585	0.987	1.380	1.967	1.979	1.618	2.861	0.000	0.000	0.000	0.000	1.693
1973	0.043	0.118	0.239	0.369	0.578	0.611	0.648	1.044	1.378	2.658	1.603	1.988	2.123	0.000	0.000	0.000	1.660
1974	0.025	0.129	0.226	0.339	0.536	0.867	0.828	0.863	1.377	1.704	1.854	4.057	1.927	0.890	0.000	0.000	1.502
1975	0.023	0.105	0.240	0.353	0.442	0.678	1.190	1.077	1.031	1.564	2.188	2.764	0.000	3.318	0.000	0.000	1.076
1976	0.014	0.129	0.225	0.394	0.505	0.578	0.916	1.829	1.656	1.247	2.296	2.425	1.679	0.000	0.000	0.000	1.300
1977	0.020	0.111	0.238	0.339	0.586	0.612	0.787	1.160	1.715	1.971	1.490	2.067	0.000	3.898	0.000	0.000	1.584
1978	0.011	0.104	0.254	0.396	0.424	0.707	0.784	0.921	1.350	1.995	1.990	1.329	2.182	4.475	0.000	0.000	1.446
1979	0.009	0.093	0.287	0.417	0.611	0.669	0.931	1.241	1.320	1.453	2.505	1.575	1.233	1.580	0.000	0.000	1.418
1980	0.012	0.081	0.276	0.464	0.693	0.985	0.908	1.264	1.511	1.501	1.676	3.104	1.050	2.134	2.921	0.000	1.664
1981	0.009	0.060	0.264	0.445	0.726	1.055	1.222	1.195	1.545	1.672	1.531	1.515	2.982	4.273	1.896	0.000	1.612
1982	0.010	0.074	0.286	0.423	0.759	1.109	1.415	1.578	1.466	2.136	2.122	1.877	1.886	3.179	0.000	0.000	1.523
1983	0.011	0.132	0.303	0.431	0.612	0.904	1.211	1.191	1.630	1.460	1.449	1.972	2.853	4.689	0.000	0.000	1.555

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	8+
1984	0.010	0.142	0.303	0.461	0.645	0.736	1.077	1.205	1.821	2.030	1.732	1.950	2.422	2.822	4.995	0.000	1.847
1985	0.010	0.148	0.296	0.466	0.649	0.835	0.934	1.344	1.638	2.097	2.109	2.061	2.555	2.471	2.721	4.139	1.845
1986	0.023	0.123	0.261	0.406	0.600	0.848	1.195	1.098	1.524	1.356	2.178	2.366	2.498	2.993	2.778	2.894	1.654
1987	0.010	0.125	0.264	0.405	0.594	0.974	1.215	1.322	1.260	1.358	1.870	2.132	2.609	2.450	2.768	2.638	1.339
1988	0.042	0.163	0.232	0.411	0.581	0.731	1.203	1.363	1.281	0.974	1.633	2.163	2.547	3.139	3.435	2.863	1.156
1989	0.036	0.200	0.282	0.367	0.590	0.770	0.935	1.259	1.586	1.507	1.034	1.534	2.431	2.559	2.307	0.980	1.322
1990	0.040	0.187	0.313	0.422	0.506	0.795	0.995	1.179	1.495	1.898	2.519	2.259	2.188	0.562	1.852	4.731	1.768
1991	0.030	0.175	0.308	0.454	0.574	0.644	0.959	1.136	1.313	1.701	2.163	2.012	1.622	1.070	1.208	2.888	1.419
1992	0.019	0.102	0.306	0.466	0.717	0.923	0.903	1.382	1.514	1.813	2.014	2.064	2.441	1.781	0.000	0.000	1.746
1993	0.010	0.110	0.282	0.454	0.660	0.877	1.053	1.062	1.545	1.460	1.830	1.894	2.155	2.460	0.000	0.000	1.646
1994	0.018	0.121	0.247	0.435	0.599	0.846	1.240	1.274	1.289	1.573	2.060	2.070	2.834	2.403	2.523	0.000	1.439
1995	0.012	0.107	0.290	0.369	0.581	0.774	1.058	1.418	1.261	1.320	1.889	2.491	1.713	1.699	2.243	0.000	1.368
1996	0.022	0.126	0.241	0.382	0.484	0.746	0.847	0.825	1.616	1.538	1.433	1.830	2.358	2.636	3.433	0.000	1.617
1997	0.029	0.138	0.280	0.360	0.585	0.634	0.923	0.997	1.293	2.196	1.961	2.058	2.757	2.270	2.867	2.782	1.548
1998	0.027	0.153	0.255	0.396	0.444	0.665	0.777	1.041	1.109	1.251	2.373	2.334	1.656	2.433	2.085	2.509	1.210
1999	0.025	0.166	0.250	0.356	0.477	0.510	0.735	0.798	0.826	1.305	1.533	2.478	2.086	2.698	2.904	2.220	0.914
2000	0.052	0.121	0.256	0.355	0.480	0.605	0.656	1.033	0.973	1.529	1.911	2.323	2.365	2.310	3.595	1.843	1.083
2001	0.029	0.111	0.219	0.321	0.466	0.658	0.735	0.945	1.690	1.148	1.725	2.923	1.286	2.534	1.239	3.425	1.573
2002	0.017	0.109	0.255	0.311	0.527	0.703	0.829	0.818	1.279	1.945	1.798	1.839	2.352	2.762	0.000	0.000	1.508
2003	0.024	0.082	0.221	0.327	0.400	0.681	0.758	1.110	1.281	1.612	2.022	2.219	2.506	2.606	1.981	3.092	1.535
2004	0.039	0.139	0.238	0.378	0.395	0.440	0.686	0.926	1.184	1.602	1.753	2.605	2.170	0.000	0.000	0.000	1.507
2005	0.054	0.160	0.271	0.364	0.495	0.479	0.522	0.925	1.054	1.373	1.847	2.750	2.545	2.309	3.431	0.000	1.263
2006	0.042	0.126	0.283	0.352	0.442	0.507	0.538	0.550	1.048	1.395	2.031	2.525	1.834	3.532	5.274	2.580	1.277
2007	0.042	0.159	0.227	0.407	0.478	0.538	0.657	0.700	0.745	0.902	2.272	0.971	1.712	2.348	4.244	0.000	0.749
2008	0.034	0.141	0.252	0.359	0.570	0.642	0.758	0.836	0.878	0.834	2.058	1.248	3.538	2.685	3.792	2.923	0.854
2009	0.050	0.158	0.305	0.329	0.384	0.631	0.754	0.726	1.016	1.077	0.957	1.055	0.944	3.019	2.097	0.000	0.998
2010	0.031	0.104	0.305	0.417	0.456	0.470	0.718	0.897	1.308	1.414	1.381	1.423	2.725	2.245	2.654	2.567	1.413
2011	0.040	0.157	0.265	0.449	0.533	0.531	0.543	0.722	1.002	0.912	1.693	1.892	1.621	0.000	0.000	0.000	1.221
2012	0.034	0.160	0.442	0.407	0.568	0.687	0.680	0.642	1.146	0.848	1.426	2.158	2.121	2.095	2.368	0.000	1.247
2013	0.034	0.171	0.426	0.596	0.485	0.717	0.843	0.790	0.757	1.098	1.643	2.216	2.607	1.810	2.512	0.000	0.767
2014	0.042	0.140	0.432	0.590	0.653	0.534	0.772	0.825	0.928	0.793	1.692	2.800	1.323	2.682	0.000	1.602	0.830
2015	0.031	0.145	0.421	0.564	0.765	0.702	0.631	0.683	0.970	0.723	0.714	0.719	1.425	2.954	0.000	0.000	0.780
2016	0.048	0.161	0.363	0.638	0.765	0.874	1.022	0.737	0.798	1.083	2.622	1.122	1.286	1.978	3.312	2.835	0.998
2017	0.040	0.149	0.343	0.450	0.781	0.961	1.338	1.045	1.020	0.654	2.834	0.930	2.682	2.237	4.673	5.554	0.936
2018	0.043	0.139	0.355	0.503	0.533	1.021	1.030	1.147	1.421	0.890	1.235	1.883	2.383	3.356	2.198	4.662	0.961
2019	0.046	0.151	0.310	0.462	0.628	0.580	1.009	0.983	2.065	2.677	1.324	3.551	3.491	2.628	4.051	5.040	1.910
2020	0.041	0.125	0.371	0.501	0.580	0.838	0.613	1.640	2.340	2.318	3.309	1.625	1.257	0.000	0.000	0.000	2.481
2021	0.045	0.151	0.311	0.445	0.516	0.572	0.735	0.690	1.009	1.182	1.645	1.964	0.000	2.046	0.000	0.000	1.128

Table 8.2.12. Haddock in Subarea 4, Division 6.a and Subdivision 20. Mean weight at age data (kg) for landings. Ages 0–7 and 8+ and years 1972–2021 are used in the assessment.

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	8+
1965	0.000	0.308	0.348	0.413	0.680	0.904	1.211	1.197	1.479	1.714	2.175	0.000	0.000	0.000	0.000	0.000	1.691
1966	0.000	0.300	0.382	0.445	0.554	1.001	1.275	1.515	1.827	1.723	2.955	2.035	0.000	0.000	0.000	0.000	1.877
1967	0.000	0.260	0.399	0.530	0.610	0.646	1.077	1.511	1.898	2.084	2.342	0.000	0.000	0.000	0.000	0.000	1.979
1968	0.000	0.256	0.360	0.595	0.769	0.832	0.835	1.484	2.071	2.622	2.065	0.000	0.000	0.000	0.000	0.000	2.179
1969	0.000	0.178	0.302	0.508	0.878	0.989	1.058	1.081	1.808	2.772	3.259	0.000	0.000	0.000	0.000	0.000	1.904
1970	0.000	0.249	0.309	0.402	0.787	0.997	1.235	1.250	1.427	2.438	3.489	3.864	0.000	0.000	0.000	0.000	1.450
1971	0.000	0.256	0.332	0.393	0.525	0.905	1.280	1.525	1.338	1.284	1.961	4.270	3.513	0.000	0.000	0.000	1.355
1972	0.000	0.243	0.325	0.415	0.518	0.587	0.989	1.380	1.967	1.979	1.618	2.861	0.000	0.000	0.000	0.000	1.693
1973	0.000	0.228	0.310	0.400	0.596	0.621	0.649	1.044	1.378	2.658	1.603	1.988	2.123	0.000	0.000	0.000	1.660
1974	0.000	0.268	0.314	0.381	0.567	0.882	0.866	0.867	1.377	1.704	1.854	4.057	1.927	0.890	0.000	0.000	1.502
1975	0.000	0.254	0.336	0.400	0.476	0.683	1.193	1.077	1.031	1.564	2.188	2.764	0.000	3.318	0.000	0.000	1.077
1976	0.000	0.243	0.331	0.452	0.509	0.601	0.917	1.829	1.656	1.247	2.296	2.425	1.679	0.000	0.000	0.000	1.300
1977	0.000	0.272	0.344	0.381	0.595	0.625	0.800	1.160	1.715	1.971	1.490	2.067	0.000	3.898	0.000	0.000	1.584
1978	0.000	0.257	0.333	0.427	0.456	0.717	0.812	0.922	1.350	1.995	1.990	1.329	2.182	4.475	0.000	0.000	1.446
1979	0.000	0.262	0.348	0.447	0.620	0.675	0.932	1.241	1.320	1.453	2.505	1.575	1.233	1.580	0.000	0.000	1.418
1980	0.000	0.274	0.347	0.501	0.706	0.992	0.907	1.261	1.511	1.499	1.676	3.104	1.050	2.134	2.921	0.000	1.664
1981	0.000	0.334	0.364	0.503	0.734	1.056	1.222	1.195	1.545	1.672	1.531	1.515	2.982	4.273	1.896	0.000	1.612
1982	0.000	0.299	0.349	0.478	0.788	1.153	1.415	1.578	1.466	2.136	2.122	1.877	1.886	3.179	0.000	0.000	1.523
1983	0.000	0.320	0.375	0.464	0.624	0.914	1.242	1.191	1.630	1.460	1.449	1.972	2.853	4.689	0.000	0.000	1.555
1984	0.000	0.280	0.350	0.493	0.666	0.764	1.077	1.205	1.821	2.030	1.732	1.951	2.422	2.822	4.995	0.000	1.847
1985	0.000	0.279	0.348	0.478	0.651	0.844	0.935	1.344	1.638	2.097	2.109	2.061	2.555	2.471	2.721	4.139	1.845
1986	0.000	0.277	0.348	0.428	0.600	0.848	1.195	1.098	1.524	1.356	2.178	2.366	2.498	2.993	2.778	2.894	1.654
1987	0.000	0.265	0.335	0.440	0.603	0.974	1.215	1.322	1.260	1.358	1.870	2.132	2.609	2.450	2.768	2.638	1.339
1988	0.000	0.236	0.322	0.437	0.594	0.732	1.203	1.363	1.370	0.974	1.633	2.163	2.547	3.139	3.435	2.863	1.173
1989	0.000	0.319	0.356	0.413	0.602	0.769	0.934	1.256	1.579	1.507	1.025	1.534	2.431	2.559	2.307	0.980	1.316
1990	0.000	0.260	0.372	0.439	0.525	0.796	1.015	1.196	1.504	1.898	2.519	2.259	2.188	0.562	1.852	4.731	1.776
1991	0.000	0.269	0.363	0.462	0.576	0.645	0.959	1.136	1.313	1.701	2.163	2.012	1.622	1.070	1.208	2.888	1.419
1992	0.000	0.287	0.367	0.486	0.723	0.924	0.904	1.382	1.515	1.813	2.014	2.064	2.441	1.781	0.000	0.000	1.747
1993	0.000	0.293	0.372	0.484	0.666	0.878	1.053	1.067	1.545	1.460	1.830	1.894	2.155	2.460	0.000	0.000	1.646
1994	0.000	0.269	0.378	0.473	0.617	0.851	1.241	1.274	1.289	1.573	2.060	2.070	2.834	2.403	2.523	0.000	1.439
1995	0.000	0.316	0.400	0.424	0.600	0.782	1.058	1.418	1.261	1.320	1.889	2.491	1.713	1.699	2.243	0.000	1.368
1996	0.000	0.326	0.364	0.471	0.519	0.747	0.847	0.825	1.616	1.538	1.433	1.830	2.358	2.636	3.433	0.000	1.617
1997	0.000	0.344	0.410	0.418	0.615	0.641	0.923	0.997	1.293	2.196	1.961	2.058	2.757	2.270	2.867	2.782	1.548
1998	0.000	0.271	0.370	0.441	0.470	0.670	0.778	1.041	1.109	1.251	2.373	2.334	1.656	2.433	2.085	2.509	1.210
1999	0.000	0.297	0.349	0.422	0.490	0.523	0.746	0.798	0.826	1.305	1.533	2.478	2.086	2.698	2.904	2.220	0.914
2000	0.000	0.334	0.368	0.421	0.515	0.617	0.663	1.033	0.973	1.529	1.911	2.323	2.365	2.310	3.595	1.843	1.083
2001	0.000	0.379	0.352	0.448	0.483	0.675	0.735	0.946	1.695	1.148	1.725	2.923	1.286	2.534	1.239	3.425	1.576
2002	0.000	0.427	0.446	0.397	0.569	0.713	0.829	0.901	1.279	1.945	1.798	1.839	2.352	2.762	0.000	0.000	1.508
2003	0.000	0.283	0.377	0.464	0.441	0.684	0.759	1.110	1.281	1.612	2.022	2.219	2.506	2.606	1.981	3.092	1.535

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	8+
2004	0.000	0.366	0.383	0.474	0.454	0.468	0.688	0.932	1.184	1.602	1.753	2.605	2.170	0.000	0.000	0.000	1.507
2005	0.000	0.399	0.399	0.428	0.548	0.516	0.536	0.926	1.056	1.373	1.847	2.750	2.545	2.309	3.431	0.000	1.265
2006	0.000	0.392	0.386	0.418	0.493	0.546	0.574	0.583	1.093	1.431	2.109	2.643	1.926	3.592	5.292	2.709	1.326
2007	0.000	0.379	0.385	0.466	0.497	0.542	0.662	0.705	0.748	0.902	2.272	0.971	1.712	2.348	4.244	0.000	0.753
2008	0.000	0.281	0.391	0.403	0.582	0.644	0.781	0.836	0.877	0.834	2.058	1.309	3.538	2.685	3.792	2.923	0.854
2009	0.000	0.463	0.418	0.401	0.408	0.641	0.774	0.747	1.016	1.078	0.961	1.058	0.950	3.019	2.097	0.000	1.001
2010	0.000	0.275	0.471	0.456	0.472	0.476	0.732	0.897	1.394	1.414	1.381	1.424	2.725	2.245	2.654	2.567	1.441
2011	0.000	0.383	0.414	0.474	0.561	0.534	0.545	0.722	1.002	0.912	1.683	1.862	1.621	0.000	0.000	0.000	1.215
2012	0.000	0.397	0.527	0.442	0.597	0.688	0.681	0.642	1.146	0.848	1.426	2.158	2.121	2.095	2.368	0.000	1.247
2013	0.000	0.437	0.566	0.622	0.491	0.719	0.843	0.794	0.757	1.098	1.557	2.216	2.607	1.810	2.512	0.000	0.766
2014	0.302	0.308	0.511	0.658	0.659	0.554	0.772	0.828	0.936	0.793	1.692	2.800	1.323	2.682	0.000	1.602	0.832
2015	0.000	0.325	0.495	0.584	0.786	0.704	0.642	0.683	0.970	0.723	0.714	0.719	1.425	2.954	0.000	0.000	0.780
2016	0.268	0.385	0.445	0.644	0.766	0.874	1.031	0.737	0.798	1.083	2.622	1.122	1.286	1.978	3.312	2.835	0.998
2017	0.000	0.254	0.457	0.472	0.789	0.967	1.362	1.047	1.024	0.654	2.836	0.930	2.682	2.333	4.673	5.554	0.938
2018	0.000	0.418	0.470	0.526	0.543	1.023	1.030	1.158	1.422	0.889	1.235	1.883	2.383	3.356	2.198	4.662	0.961
2019	0.000	0.776	0.435	0.491	0.636	0.588	1.010	0.983	2.070	2.677	1.324	3.551	3.491	2.628	4.051	5.040	1.911
2020	0.000	0.359	0.450	0.531	0.588	0.879	0.616	1.640	2.340	2.318	3.309	1.625	1.257	0.000	0.000	0.000	2.481
2021	0.000	0.441	0.378	0.468	0.527	0.572	0.739	0.692	1.009	1.182	1.645	1.964	0.000	2.046	0.000	0.000	1.128

Table 8.2.13. Haddock in Subarea 4, Division 6.a and Subdivision 20. Mean weight at age data (kg) for discards. Ages 0–7 and 8+ and years 1972–2021 are used in the assessment.

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	8+
1965	0.062	0.131	0.203	0.335	0.607	0.321	0.321	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1966	0.053	0.141	0.208	0.245	0.309	0.321	0.321	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1967	0.043	0.170	0.210	0.273	0.306	0.321	0.321	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1968	0.054	0.181	0.212	0.257	0.317	0.321	0.321	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1969	0.049	0.129	0.216	0.238	0.300	0.321	0.321	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1970	0.057	0.131	0.210	0.239	0.263	0.321	0.321	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1971	0.052	0.135	0.202	0.244	0.264	0.321	0.321	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1972	0.045	0.140	0.207	0.239	0.261	0.321	0.321	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1973	0.051	0.135	0.201	0.237	0.263	0.321	0.321	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1974	0.046	0.146	0.201	0.234	0.259	0.321	0.321	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1975	0.041	0.126	0.201	0.257	0.275	0.348	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1976	0.053	0.172	0.198	0.239	0.291	0.337	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1977	0.062	0.191	0.198	0.220	0.306	0.347	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1978	0.042	0.175	0.199	0.222	0.225	0.265	0.284	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1979	0.037	0.128	0.221	0.245	0.259	0.314	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1980	0.051	0.147	0.232	0.276	0.325	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1981	0.074	0.160	0.199	0.296	0.621	0.727	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1982	0.055	0.194	0.247	0.265	0.289	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1983	0.066	0.184	0.237	0.343	0.458	0.711	0.792	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	8+
1984	0.047	0.160	0.245	0.315	0.309	0.290	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1985	0.040	0.154	0.221	0.271	0.356	0.423	0.353	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1986	0.057	0.140	0.185	0.246	0.337	0.329	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1987	0.026	0.160	0.201	0.227	0.286	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1988	0.072	0.167	0.172	0.239	0.256	0.352	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1989	0.054	0.188	0.229	0.266	0.336	0.708	0.844	0.000	2.572	0.000	3.048	0.000	0.000	0.000	0.000	0.000	2.810
1990	0.047	0.189	0.229	0.248	0.264	0.290	0.333	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1991	0.059	0.179	0.238	0.341	0.464	0.480	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1992	0.043	0.136	0.246	0.282	0.345	0.000	0.592	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1993	0.028	0.139	0.237	0.287	0.355	0.369	0.000	0.430	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1994	0.042	0.130	0.212	0.273	0.310	0.304	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1995	0.044	0.132	0.250	0.276	0.356	0.384	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1996	0.047	0.133	0.218	0.279	0.297	0.335	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1997	0.060	0.159	0.250	0.286	0.322	0.374	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1998	0.075	0.159	0.232	0.293	0.317	0.391	0.428	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1999	0.047	0.182	0.217	0.273	0.308	0.304	0.227	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2000	0.049	0.129	0.245	0.278	0.316	0.355	0.292	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2001	0.049	0.115	0.206	0.300	0.301	0.300	0.000	0.411	0.416	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.416
2002	0.044	0.125	0.223	0.267	0.334	0.382	0.000	0.358	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2003	0.042	0.124	0.223	0.261	0.327	0.536	0.630	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2004	0.039	0.135	0.218	0.263	0.299	0.330	0.639	0.650	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2005	0.054	0.150	0.232	0.273	0.318	0.301	0.342	0.499	0.493	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.493
2006	0.042	0.121	0.231	0.265	0.279	0.274	0.217	0.164	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2007	0.042	0.146	0.195	0.291	0.314	0.358	0.375	0.356	0.368	0.400	0.000	0.000	0.000	0.000	0.000	0.000	0.368
2008	0.034	0.139	0.218	0.275	0.350	0.523	0.327	0.817	1.146	0.544	0.000	0.164	0.000	0.000	0.000	0.000	0.683
2009	0.050	0.146	0.249	0.256	0.288	0.370	0.329	0.362	0.324	0.396	0.425	0.368	0.324	0.000	0.000	0.000	0.421
2010	0.031	0.101	0.223	0.307	0.316	0.338	0.333	0.393	0.277	0.000	0.000	1.263	0.000	0.000	0.000	0.000	0.350
2011	0.040	0.154	0.219	0.310	0.310	0.354	0.352	0.502	0.351	0.589	1.995	2.215	0.000	0.000	0.000	0.000	2.111
2012	0.034	0.146	0.298	0.274	0.282	0.403	0.330	0.382	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2013	0.034	0.148	0.248	0.368	0.347	0.480	0.768	0.533	0.842	0.000	2.113	0.000	0.000	0.000	0.000	0.000	0.894
2014	0.042	0.135	0.299	0.339	0.393	0.339	0.571	0.603	0.483	0.900	0.000	0.000	0.000	0.000	0.000	0.000	0.526
2015	0.031	0.141	0.266	0.351	0.362	0.410	0.406	0.565	0.579	0.592	0.585	0.000	0.000	0.000	0.000	0.000	0.586
2016	0.048	0.155	0.245	0.369	0.356	0.878	0.464	0.508	0.683	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.683
2017	0.040	0.148	0.235	0.306	0.521	0.440	0.916	0.560	0.606	0.408	2.670	0.000	0.000	1.514	0.000	0.000	0.625
2018	0.043	0.133	0.243	0.337	0.353	0.481	0.000	0.561	0.616	0.905	0.000	0.000	0.000	0.000	0.000	0.000	0.903
2019	0.046	0.141	0.212	0.293	0.298	0.359	0.570	0.470	0.844	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.844
2020	0.041	0.118	0.250	0.328	0.367	0.403	0.379	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2021	0.045	0.145	0.269	0.329	0.363	0.440	0.418	0.490	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table 8.2.14. Haddock in Subarea 4, Division 6.a and Subdivision 20. Mean weight at age data (kg) for BMS landings. Ages 0–7 and 8+ and years 2016–2021 are used in the assessment.

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	8+
2016	0.068	0.239	0.213	0.386	0.389	0.000	0.000	0.481	0.000	0.991	0.000	0.000	0.000	0.000	0.000	0.000	0.991
2017	0.040	0.148	0.235	0.306	0.521	0.440	0.916	0.560	0.606	0.408	2.670	0.000	0.000	1.514	0.000	0.000	0.625
2018	0.000	0.286	0.233	0.299	0.291	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2019	0.089	0.185	0.271	0.298	0.000	0.376	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2020	0.000	0.220	0.267	0.259	0.365	0.792	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2021	0.000	0.078	0.183	0.260	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table 8.2.15. Haddock in Subarea 4, Division 6.a and Subdivision 20. Mean weight at age data (kg) for IBC. Ages 0–7 and 8+ and years 1972–2021 are used in the assessment.

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	8+
1965	0.010	0.040	0.180	0.302	0.400	0.420	0.440	0.500	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1966	0.010	0.040	0.180	0.302	0.400	0.420	0.440	0.500	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1967	0.010	0.040	0.180	0.302	0.400	0.420	0.440	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1968	0.010	0.040	0.180	0.302	0.400	0.420	0.440	0.500	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1969	0.010	0.040	0.180	0.302	0.400	0.420	0.440	0.500	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1970	0.010	0.040	0.180	0.302	0.400	0.420	0.440	0.500	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1971	0.010	0.040	0.180	0.302	0.400	0.420	0.440	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1972	0.023	0.067	0.136	0.255	0.288	0.231	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1973	0.035	0.068	0.141	0.246	0.327	0.396	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1974	0.022	0.058	0.150	0.260	0.359	0.579	0.277	0.447	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1975	0.020	0.039	0.173	0.275	0.267	0.413	0.585	0.000	0.585	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.585
1976	0.012	0.046	0.181	0.304	0.473	0.360	0.725	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1977	0.013	0.042	0.184	0.307	0.490	0.352	0.442	1.234	1.315	1.319	0.000	0.000	0.000	0.000	0.000	0.000	1.317
1978	0.011	0.040	0.174	0.286	0.372	0.473	0.411	0.456	1.315	0.000	1.400	0.000	0.000	0.000	0.000	0.000	1.345
1979	0.009	0.039	0.177	0.285	0.384	0.461	0.735	1.234	1.315	0.000	1.400	0.000	0.000	0.000	0.000	0.000	1.333
1980	0.012	0.039	0.176	0.268	0.623	0.722	1.102	1.591	0.000	1.796	0.000	0.000	0.000	0.000	0.000	0.000	1.796
1981	0.009	0.040	0.176	0.371	0.467	0.858	1.200	1.234	1.315	1.319	1.400	0.000	0.000	0.000	0.000	0.000	1.346
1982	0.010	0.040	0.206	0.379	0.636	0.751	1.225	1.233	1.315	1.319	0.000	0.000	0.000	0.000	0.000	0.000	1.316
1983	0.008	0.047	0.173	0.428	0.584	1.006	1.225	1.234	1.315	1.319	0.000	0.000	0.000	0.000	0.000	0.000	1.318
1984	0.009	0.045	0.211	0.414	0.626	0.751	1.225	1.234	1.315	1.319	1.400	1.400	0.000	0.000	0.000	0.000	1.356
1985	0.009	0.043	0.186	0.371	0.550	0.563	0.565	1.234	1.315	1.319	1.400	0.000	0.000	0.000	0.000	0.000	1.319
1986	0.010	0.040	0.186	0.375	0.626	1.259	1.225	1.234	1.315	1.319	1.400	0.000	0.000	0.000	0.000	0.000	1.328
1987	0.006	0.038	0.258	0.442	0.908	1.171	1.225	1.234	1.315	1.319	0.000	0.000	0.000	0.000	0.000	0.000	1.316
1988	0.018	0.077	0.196	0.274	0.455	0.549	1.225	1.234	1.315	1.319	1.400	0.000	0.000	0.000	0.000	0.000	1.330
1989	0.015	0.165	0.251	0.347	0.670	0.923	1.065	1.492	1.315	0.000	1.400	0.000	0.000	0.000	0.000	0.000	1.329
1990	0.005	0.104	0.229	0.506	0.609	0.842	0.829	0.796	0.956	1.319	0.000	0.000	0.000	0.000	0.000	0.000	0.956
1991	0.027	0.058	0.206	0.357	0.472	0.477	1.225	1.234	1.315	1.319	0.000	0.000	0.000	0.000	0.000	0.000	1.316
1992	0.015	0.059	0.217	0.422	0.552	0.615	0.548	1.234	0.621	0.820	0.000	0.000	0.000	0.000	0.000	0.000	0.659
1993	0.008	0.053	0.206	0.399	0.521	0.578	1.225	0.582	1.315	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.315
1994	0.011	0.055	0.155	0.435	0.595	0.698	0.490	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1995	0.012	0.045	0.193	0.285	0.387	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1996	0.018	0.077	0.136	0.162	0.264	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1997	0.007	0.076	0.149	0.309	0.419	0.601	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1998	0.020	0.075	0.166	0.291	0.351	0.453	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1999	0.018	0.064	0.177	0.304	0.416	0.309	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2000	0.058	0.070	0.113	0.176	0.370	0.203	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2001	0.014	0.086	0.133	0.110	0.353	0.431	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2002	0.016	0.064	0.178	0.283	0.374	0.431	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2003	0.012	0.031	0.056	0.231	0.326	0.339	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	8+
2004	0.000	0.116	0.183	0.255	0.276	0.446	0.539	0.840	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2005	0.000	0.107	0.187	0.239	0.268	0.287	0.598	0.619	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2006	0.000	0.127	0.232	0.273	0.273	0.280	0.283	0.286	0.287	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.287
2007	0.035	0.141	0.192	0.290	0.315	0.370	0.427	0.342	0.368	0.400	0.000	0.000	0.000	0.000	0.000	0.000	0.368
2008	0.000	0.281	0.391	0.403	0.582	0.644	0.781	0.836	0.877	0.834	2.058	1.309	3.538	2.685	3.791	0.000	0.854
2009	0.000	0.463	0.418	0.401	0.408	0.641	0.774	0.747	1.016	1.078	0.961	1.058	0.950	3.020	2.100	0.000	1.001
2010	0.000	0.275	0.471	0.456	0.472	0.476	0.732	0.897	1.394	1.414	1.381	1.424	2.725	2.245	2.654	0.000	1.434
2011	0.000	0.383	0.414	0.474	0.561	0.534	0.545	0.722	1.002	0.912	1.683	1.862	1.621	0.000	0.000	0.000	1.215
2012	0.000	0.397	0.527	0.442	0.597	0.688	0.681	0.642	1.146	0.848	1.426	2.158	2.121	2.095	2.368	0.000	1.247
2013	0.000	0.437	0.566	0.622	0.491	0.719	0.843	0.793	0.757	1.098	1.557	2.216	2.607	1.810	2.512	0.000	0.766
2014	0.302	0.308	0.511	0.658	0.659	0.554	0.772	0.828	0.936	0.793	1.692	2.800	1.323	2.682	0.000	1.856	0.832
2015	0.000	0.325	0.495	0.584	0.786	0.704	0.642	0.683	0.970	0.723	0.714	0.719	1.425	2.954	0.000	0.000	0.780
2016	0.268	0.385	0.445	0.644	0.766	0.874	1.031	0.737	0.798	1.083	2.622	1.122	1.286	1.978	3.312	3.841	0.999
2017	0.000	0.254	0.457	0.472	0.789	0.967	1.362	1.047	1.024	0.654	2.836	0.930	2.682	2.333	4.673	0.000	0.937
2018	0.000	0.418	0.470	0.526	0.543	1.023	1.030	1.158	1.422	0.889	1.235	1.883	2.383	3.356	2.198	0.000	0.958
2019	0.000	0.776	0.435	0.491	0.636	0.588	1.010	0.983	2.070	2.677	1.324	3.551	3.491	2.628	4.051	5.109	1.912
2020	0.000	0.359	0.450	0.531	0.588	0.879	0.616	1.640	2.340	2.318	3.309	1.625	1.257	0.000	0.000	0.000	2.481
2021	0.000	0.441	0.378	0.468	0.527	0.572	0.739	0.692	1.009	1.182	1.645	1.964	0.000	2.046	0.000	0.000	1.128

Table 8.2.16. Haddock in Subarea 4, Division 6.a and Subdivision 20. Mean weight at age data (kg) for the stock. Ages 0–7 and 8+ and years 1972–2021 are used in the assessment.

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	8+
1965	0.004	0.028	0.147	0.292	0.553	0.728	1.006	0.979	0.924	1.071	1.359	0.000	0.000	0.000	0.000	0.000	1.057
1966	0.004	0.035	0.160	0.311	0.453	0.827	1.078	1.244	1.142	1.077	1.847	1.272	0.000	0.000	0.000	0.000	1.173
1967	0.006	0.046	0.180	0.378	0.499	0.551	0.922	1.244	1.186	1.303	1.464	0.000	0.000	0.000	0.000	0.000	1.237
1968	0.004	0.052	0.165	0.408	0.628	0.711	0.713	1.221	1.294	1.639	1.291	0.000	0.000	0.000	0.000	0.000	1.362
1969	0.005	0.026	0.141	0.324	0.690	0.778	0.885	0.884	1.130	1.733	2.037	0.000	0.000	0.000	0.000	0.000	1.190
1970	0.005	0.030	0.144	0.279	0.624	0.796	1.028	1.025	0.892	1.524	2.181	2.415	0.000	0.000	0.000	0.000	0.906
1971	0.005	0.044	0.159	0.284	0.430	0.764	1.091	1.255	0.836	0.803	1.226	2.669	2.196	0.000	0.000	0.000	0.846
1972	0.010	0.047	0.157	0.303	0.425	0.503	0.849	1.136	1.229	1.237	1.011	1.788	0.000	0.000	0.000	0.000	1.058
1973	0.017	0.047	0.155	0.292	0.488	0.525	0.557	0.859	0.861	1.661	1.002	1.243	1.327	0.000	0.000	0.000	1.037
1974	0.010	0.052	0.146	0.268	0.453	0.746	0.712	0.710	0.861	1.065	1.159	2.536	1.204	0.556	0.000	0.000	0.939
1975	0.009	0.042	0.156	0.279	0.373	0.583	1.023	0.886	0.644	0.978	1.368	1.728	0.000	2.074	0.000	0.000	0.673
1976	0.006	0.052	0.146	0.311	0.427	0.497	0.788	1.505	1.035	0.779	1.435	1.516	1.049	0.000	0.000	0.000	0.813
1977	0.008	0.044	0.154	0.268	0.495	0.526	0.677	0.955	1.072	1.232	0.931	1.292	0.000	2.436	0.000	0.000	0.990
1978	0.004	0.042	0.165	0.313	0.358	0.608	0.674	0.758	0.844	1.247	1.244	0.831	1.364	2.797	0.000	0.000	0.904
1979	0.004	0.037	0.186	0.329	0.516	0.575	0.801	1.021	0.825	0.908	1.566	0.984	0.771	0.988	0.000	0.000	0.886
1980	0.005	0.032	0.179	0.367	0.586	0.847	0.781	1.040	0.944	0.938	1.048	1.940	0.656	1.334	1.826	0.000	1.040
1981	0.004	0.024	0.171	0.352	0.613	0.907	1.051	0.983	0.966	1.045	0.957	0.947	1.864	2.671	1.185	0.000	1.008
1982	0.004	0.030	0.185	0.334	0.641	0.954	1.217	1.299	0.916	1.335	1.326	1.173	1.179	1.987	0.000	0.000	0.952
1983	0.004	0.053	0.196	0.340	0.517	0.777	1.041	0.980	1.019	0.913	0.906	1.233	1.783	2.931	0.000	0.000	0.972

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	8+
1984	0.004	0.057	0.196	0.364	0.545	0.633	0.926	0.992	1.138	1.269	1.083	1.219	1.514	1.764	3.122	0.000	1.155
1985	0.004	0.059	0.192	0.368	0.548	0.718	0.803	1.106	1.024	1.311	1.318	1.288	1.597	1.544	1.701	2.587	1.153
1986	0.009	0.049	0.169	0.321	0.507	0.729	1.028	0.904	0.953	0.848	1.361	1.479	1.561	1.871	1.736	1.809	1.033
1987	0.004	0.050	0.171	0.320	0.502	0.838	1.045	1.088	0.788	0.849	1.169	1.333	1.631	1.531	1.730	1.649	0.837
1988	0.017	0.065	0.150	0.325	0.491	0.629	1.035	1.122	0.801	0.609	1.021	1.352	1.592	1.962	2.147	1.789	0.722
1989	0.014	0.080	0.183	0.290	0.499	0.662	0.804	1.036	0.991	0.942	0.646	0.959	1.519	1.599	1.442	0.613	0.827
1990	0.016	0.075	0.203	0.333	0.428	0.684	0.856	0.970	0.934	1.186	1.574	1.412	1.368	0.351	1.158	2.957	1.105
1991	0.012	0.070	0.200	0.359	0.485	0.554	0.825	0.935	0.821	1.063	1.352	1.258	1.014	0.669	0.755	1.805	0.887
1992	0.008	0.041	0.198	0.368	0.606	0.794	0.777	1.137	0.946	1.133	1.259	1.290	1.526	1.113	0.000	0.000	1.091
1993	0.004	0.044	0.183	0.359	0.558	0.754	0.906	0.874	0.966	0.913	1.144	1.184	1.347	1.538	0.000	0.000	1.029
1994	0.007	0.048	0.160	0.344	0.506	0.728	1.066	1.049	0.806	0.983	1.288	1.294	1.771	1.502	1.577	0.000	0.899
1995	0.005	0.043	0.188	0.292	0.491	0.666	0.910	1.167	0.788	0.825	1.181	1.557	1.071	1.062	1.402	0.000	0.855
1996	0.009	0.050	0.156	0.302	0.409	0.642	0.728	0.679	1.010	0.961	0.896	1.144	1.474	1.648	2.146	0.000	1.011
1997	0.012	0.055	0.181	0.284	0.494	0.545	0.794	0.821	0.808	1.373	1.226	1.286	1.723	1.419	1.792	1.739	0.967
1998	0.011	0.061	0.165	0.313	0.375	0.572	0.668	0.857	0.693	0.782	1.483	1.459	1.035	1.521	1.303	1.568	0.756
1999	0.010	0.066	0.162	0.281	0.403	0.439	0.632	0.657	0.516	0.816	0.958	1.549	1.304	1.686	1.815	1.388	0.571
2000	0.021	0.048	0.166	0.280	0.406	0.520	0.564	0.850	0.608	0.956	1.194	1.452	1.478	1.444	2.247	1.152	0.677
2001	0.012	0.044	0.142	0.254	0.394	0.566	0.632	0.778	1.056	0.718	1.078	1.827	0.804	1.584	0.774	2.141	0.983
2002	0.007	0.044	0.165	0.246	0.445	0.605	0.713	0.673	0.799	1.216	1.124	1.149	1.470	1.726	0.000	0.000	0.942
2003	0.010	0.033	0.143	0.258	0.338	0.586	0.652	0.914	0.801	1.008	1.264	1.387	1.566	1.629	1.238	1.933	0.959
2004	0.016	0.056	0.154	0.299	0.334	0.378	0.590	0.762	0.740	1.001	1.096	1.628	1.356	0.000	0.000	0.000	0.942
2005	0.022	0.064	0.176	0.288	0.418	0.412	0.449	0.761	0.659	0.858	1.154	1.719	1.591	1.443	2.144	0.000	0.790
2006	0.017	0.050	0.183	0.278	0.373	0.436	0.463	0.453	0.655	0.872	1.269	1.578	1.146	2.208	3.296	1.613	0.798
2007	0.017	0.064	0.147	0.322	0.404	0.463	0.565	0.576	0.466	0.564	1.420	0.607	1.070	1.468	2.653	0.000	0.468
2008	0.014	0.056	0.163	0.284	0.482	0.552	0.652	0.688	0.549	0.521	1.286	0.780	2.211	1.678	2.370	1.827	0.534
2009	0.020	0.063	0.198	0.260	0.324	0.543	0.648	0.597	0.635	0.673	0.598	0.659	0.590	1.887	1.311	0.000	0.624
2010	0.012	0.042	0.198	0.329	0.385	0.404	0.617	0.738	0.818	0.884	0.863	0.889	1.703	1.403	1.659	1.604	0.883
2011	0.016	0.063	0.172	0.355	0.451	0.459	0.469	0.597	0.654	0.633	1.143	1.294	1.023	0.000	0.000	0.000	0.803
2012	0.014	0.064	0.286	0.322	0.480	0.591	0.585	0.528	0.716	0.530	0.891	1.349	1.326	1.309	1.480	0.000	0.779
2013	0.014	0.068	0.276	0.471	0.410	0.617	0.725	0.650	0.473	0.686	1.027	1.385	1.629	1.131	1.570	0.000	0.479
2014	0.017	0.056	0.280	0.466	0.552	0.459	0.664	0.679	0.580	0.496	1.058	1.750	0.827	1.676	0.000	1.001	0.519
2015	0.012	0.058	0.273	0.446	0.646	0.604	0.543	0.562	0.606	0.452	0.446	0.449	0.891	1.846	0.000	0.000	0.488
2016	0.019	0.064	0.235	0.504	0.646	0.752	0.879	0.607	0.499	0.677	1.639	0.701	0.804	1.236	2.070	1.772	0.624
2017	0.016	0.060	0.222	0.356	0.660	0.826	1.151	0.860	0.638	0.409	1.771	0.581	1.676	1.398	2.921	3.471	0.585
2018	0.017	0.056	0.230	0.397	0.450	0.878	0.886	0.944	0.888	0.556	0.772	1.177	1.489	2.098	1.374	2.914	0.601
2019	0.018	0.060	0.201	0.365	0.531	0.499	0.868	0.809	1.291	1.673	0.828	2.219	2.182	1.643	2.532	3.150	1.194
2020	0.016	0.050	0.240	0.396	0.490	0.721	0.527	1.350	1.463	1.449	2.068	1.016	0.786	0.000	0.000	0.000	1.551
2021	0.018	0.061	0.200	0.350	0.434	0.494	0.627	0.572	0.709	0.709	0.709	0.709	0.709	0.709	0.709	0.709	0.709

Table 8.2.17. Haddock in Subarea 4, Division 6.a and Subdivision 20. Estimates of natural mortality from the most recent key run of SMS (ICES WGSAM, 2021). Ages 0–7 and 8+ and years 1972–2021 are used in the assessment. *values since 2020 are set equal to 2020 values until the next SMS key run in completed by WGSAM.

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	8+
1965	1.290	1.507	0.828	0.540	0.440	0.301	0.259	0.239	0.218	0.207	0.201	0.201	0.201	0.201	0.201	0.201	0.203
1966	1.290	1.507	0.828	0.540	0.440	0.301	0.259	0.239	0.218	0.207	0.201	0.201	0.201	0.201	0.201	0.201	0.203
1967	1.290	1.507	0.828	0.540	0.440	0.301	0.259	0.239	0.218	0.207	0.201	0.201	0.201	0.201	0.201	0.201	0.203
1968	1.290	1.507	0.828	0.540	0.440	0.301	0.259	0.239	0.218	0.207	0.201	0.201	0.201	0.201	0.201	0.201	0.203
1969	1.290	1.507	0.828	0.540	0.440	0.301	0.259	0.239	0.218	0.207	0.201	0.201	0.201	0.201	0.201	0.201	0.203
1970	1.290	1.507	0.828	0.540	0.440	0.301	0.259	0.239	0.218	0.207	0.201	0.201	0.201	0.201	0.201	0.201	0.203
1971	1.290	1.507	0.828	0.540	0.440	0.301	0.259	0.239	0.218	0.207	0.201	0.201	0.201	0.201	0.201	0.201	0.203
1972	1.290	1.507	0.828	0.540	0.440	0.301	0.259	0.239	0.218	0.207	0.201	0.201	0.201	0.201	0.201	0.201	0.203
1973	1.291	1.490	0.802	0.527	0.427	0.295	0.256	0.236	0.217	0.207	0.201	0.201	0.201	0.201	0.201	0.201	0.207
1974	1.293	1.474	0.776	0.514	0.414	0.290	0.253	0.234	0.216	0.207	0.202	0.202	0.202	0.202	0.202	0.202	0.212
1975	1.295	1.457	0.750	0.501	0.401	0.285	0.249	0.231	0.215	0.206	0.202	0.202	0.202	0.202	0.202	0.202	0.214
1976	1.297	1.440	0.724	0.488	0.389	0.280	0.246	0.229	0.213	0.206	0.202	0.202	0.202	0.202	0.202	0.202	0.206
1977	1.299	1.424	0.698	0.475	0.377	0.275	0.243	0.227	0.212	0.206	0.202	0.202	0.202	0.202	0.202	0.202	0.204
1978	1.302	1.406	0.673	0.462	0.365	0.270	0.240	0.224	0.211	0.206	0.202	0.202	0.202	0.202	0.202	0.202	0.208
1979	1.305	1.388	0.647	0.450	0.353	0.266	0.237	0.222	0.210	0.205	0.202	0.202	0.202	0.202	0.202	0.202	0.208
1980	1.307	1.369	0.623	0.437	0.342	0.262	0.234	0.220	0.209	0.205	0.202	0.202	0.202	0.202	0.202	0.202	0.205
1981	1.309	1.348	0.599	0.425	0.332	0.258	0.231	0.218	0.208	0.205	0.202	0.202	0.202	0.202	0.202	0.202	0.206
1982	1.310	1.326	0.576	0.413	0.323	0.254	0.229	0.217	0.207	0.204	0.202	0.202	0.202	0.202	0.202	0.202	0.207
1983	1.310	1.303	0.554	0.401	0.314	0.251	0.226	0.215	0.206	0.204	0.201	0.201	0.201	0.201	0.201	0.201	0.204
1984	1.310	1.278	0.533	0.391	0.306	0.248	0.224	0.214	0.206	0.204	0.201	0.201	0.201	0.201	0.201	0.201	0.203
1985	1.308	1.254	0.514	0.380	0.299	0.246	0.223	0.212	0.205	0.203	0.201	0.201	0.201	0.201	0.201	0.201	0.204
1986	1.305	1.230	0.495	0.371	0.293	0.244	0.221	0.211	0.205	0.203	0.201	0.201	0.201	0.201	0.201	0.201	0.204
1987	1.301	1.208	0.479	0.362	0.288	0.243	0.220	0.211	0.204	0.203	0.201	0.201	0.201	0.201	0.201	0.201	0.204
1988	1.296	1.188	0.464	0.354	0.283	0.242	0.219	0.210	0.204	0.203	0.201	0.201	0.201	0.201	0.201	0.201	0.203
1989	1.291	1.171	0.450	0.346	0.280	0.241	0.219	0.209	0.204	0.202	0.201	0.201	0.201	0.201	0.201	0.201	0.202
1990	1.286	1.155	0.438	0.339	0.276	0.241	0.219	0.209	0.203	0.202	0.201	0.201	0.201	0.201	0.201	0.201	0.203
1991	1.282	1.143	0.428	0.334	0.274	0.241	0.219	0.209	0.203	0.202	0.201	0.201	0.201	0.201	0.201	0.201	0.203
1992	1.277	1.133	0.419	0.329	0.272	0.241	0.219	0.209	0.203	0.202	0.201	0.201	0.201	0.201	0.201	0.201	0.202
1993	1.274	1.126	0.411	0.324	0.270	0.242	0.220	0.209	0.203	0.202	0.200	0.200	0.200	0.200	0.200	0.200	0.202
1994	1.272	1.121	0.405	0.321	0.269	0.243	0.221	0.209	0.203	0.202	0.200	0.200	0.200	0.200	0.200	0.200	0.203
1995	1.270	1.118	0.400	0.318	0.269	0.244	0.222	0.210	0.203	0.202	0.200	0.200	0.200	0.200	0.200	0.200	0.202
1996	1.269	1.117	0.396	0.316	0.269	0.245	0.223	0.211	0.204	0.202	0.200	0.200	0.200	0.200	0.200	0.200	0.202
1997	1.269	1.118	0.394	0.314	0.269	0.247	0.225	0.211	0.204	0.202	0.200	0.200	0.200	0.200	0.200	0.200	0.203
1998	1.268	1.121	0.393	0.313	0.270	0.249	0.227	0.212	0.204	0.202	0.200	0.200	0.200	0.200	0.200	0.200	0.203
1999	1.267	1.125	0.393	0.313	0.270	0.251	0.229	0.213	0.204	0.202	0.200	0.200	0.200	0.200	0.200	0.200	0.204
2000	1.266	1.131	0.395	0.313	0.271	0.253	0.230	0.214	0.204	0.203	0.200	0.200	0.200	0.200	0.200	0.200	0.204
2001	1.263	1.138	0.397	0.312	0.272	0.255	0.232	0.215	0.205	0.204	0.200	0.200	0.200	0.200	0.200	0.200	0.204
2002	1.259	1.146	0.401	0.313	0.273	0.256	0.234	0.217	0.205	0.204	0.201	0.201	0.201	0.201	0.201	0.201	0.205

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	8+
2003	1.252	1.154	0.406	0.313	0.274	0.258	0.236	0.218	0.205	0.205	0.201	0.201	0.201	0.201	0.201	0.201	0.204
2004	1.244	1.161	0.411	0.313	0.274	0.259	0.237	0.219	0.206	0.206	0.201	0.201	0.201	0.201	0.201	0.201	0.204
2005	1.233	1.168	0.417	0.312	0.275	0.260	0.238	0.220	0.206	0.207	0.201	0.201	0.201	0.201	0.201	0.201	0.206
2006	1.219	1.172	0.423	0.312	0.275	0.260	0.239	0.222	0.206	0.208	0.201	0.201	0.201	0.201	0.201	0.201	0.206
2007	1.204	1.175	0.429	0.311	0.274	0.260	0.240	0.223	0.207	0.210	0.202	0.202	0.202	0.202	0.202	0.202	0.207
2008	1.186	1.176	0.436	0.310	0.274	0.259	0.239	0.224	0.207	0.211	0.202	0.202	0.202	0.202	0.202	0.202	0.209
2009	1.167	1.175	0.442	0.309	0.273	0.258	0.239	0.225	0.207	0.212	0.202	0.202	0.202	0.202	0.202	0.202	0.206
2010	1.146	1.173	0.449	0.308	0.271	0.257	0.238	0.226	0.208	0.213	0.203	0.203	0.203	0.203	0.203	0.203	0.206
2011	1.124	1.170	0.455	0.307	0.270	0.256	0.237	0.226	0.208	0.215	0.203	0.203	0.203	0.203	0.203	0.203	0.208
2012	1.100	1.166	0.460	0.306	0.268	0.254	0.235	0.226	0.208	0.216	0.203	0.203	0.203	0.203	0.203	0.203	0.210
2013	1.075	1.162	0.466	0.305	0.266	0.252	0.233	0.226	0.208	0.217	0.204	0.204	0.204	0.204	0.204	0.204	0.208
2014	1.049	1.157	0.471	0.304	0.264	0.249	0.231	0.226	0.208	0.218	0.204	0.204	0.204	0.204	0.204	0.204	0.216
2015	1.021	1.151	0.476	0.304	0.262	0.247	0.229	0.226	0.208	0.219	0.204	0.204	0.204	0.204	0.204	0.204	0.209
2016	0.992	1.146	0.480	0.304	0.259	0.244	0.226	0.225	0.208	0.219	0.205	0.205	0.205	0.205	0.205	0.205	0.210
2017	0.963	1.140	0.485	0.304	0.257	0.241	0.223	0.225	0.208	0.220	0.205	0.205	0.205	0.205	0.205	0.205	0.211
2018	0.932	1.134	0.489	0.304	0.255	0.239	0.220	0.224	0.208	0.220	0.205	0.205	0.205	0.205	0.205	0.205	0.219
2019	0.901	1.128	0.492	0.304	0.252	0.236	0.218	0.223	0.207	0.221	0.205	0.205	0.205	0.205	0.205	0.205	0.208
2020	0.870	1.122	0.496	0.303	0.250	0.233	0.215	0.222	0.207	0.221	0.205	0.205	0.205	0.205	0.205	0.205	0.209
2021*	0.870	1.122	0.496	0.303	0.250	0.233	0.215	0.222	0.207	0.221	0.205	0.205	0.205	0.205	0.205	0.205	0.212

Table 8.2.18. Haddock in Subarea 4, Division 6.a and Subdivision 20. Estimates of the proportion mature-at-age. Ages 0–7 and 8+ and years 1972–2021 are used in the assessment.

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	8+
1965	0.000	0.050	0.478	0.933	0.992	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1966	0.000	0.050	0.478	0.933	0.992	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1967	0.000	0.050	0.478	0.933	0.992	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1968	0.000	0.050	0.478	0.933	0.992	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1969	0.000	0.050	0.478	0.933	0.992	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1970	0.000	0.050	0.478	0.933	0.992	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1971	0.000	0.050	0.478	0.933	0.992	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1972	0.000	0.050	0.478	0.933	0.992	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1973	0.000	0.050	0.478	0.933	0.992	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1974	0.000	0.050	0.478	0.933	0.992	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1975	0.000	0.050	0.478	0.933	0.992	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1976	0.000	0.050	0.478	0.933	0.992	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1977	0.000	0.050	0.478	0.933	0.992	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1978	0.000	0.050	0.478	0.933	0.992	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1979	0.000	0.050	0.478	0.933	0.992	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1980	0.000	0.050	0.478	0.933	0.992	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1981	0.000	0.050	0.478	0.933	0.992	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1982	0.000	0.050	0.478	0.933	0.992	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	8+
1983	0.000	0.050	0.478	0.933	0.992	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1984	0.000	0.050	0.478	0.933	0.992	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1985	0.000	0.050	0.478	0.933	0.992	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1986	0.000	0.050	0.478	0.933	0.992	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1987	0.000	0.050	0.478	0.933	0.992	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1988	0.000	0.050	0.478	0.933	0.992	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1989	0.000	0.050	0.478	0.933	0.992	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1990	0.000	0.050	0.478	0.933	0.992	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1991	0.000	0.050	0.478	0.933	0.992	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1992	0.000	0.052	0.475	0.931	0.992	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1993	0.000	0.054	0.471	0.929	0.992	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1994	0.000	0.055	0.470	0.928	0.992	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1995	0.000	0.054	0.474	0.930	0.992	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1996	0.000	0.054	0.484	0.935	0.993	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1997	0.000	0.053	0.500	0.942	0.995	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1998	0.000	0.052	0.519	0.949	0.996	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1999	0.000	0.052	0.539	0.956	0.997	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2000	0.000	0.053	0.559	0.962	0.998	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2001	0.000	0.054	0.579	0.966	0.998	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2002	0.000	0.055	0.598	0.970	0.998	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2003	0.000	0.057	0.615	0.973	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2004	0.000	0.058	0.629	0.975	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2005	0.000	0.061	0.639	0.975	0.998	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2006	0.000	0.063	0.642	0.973	0.998	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2007	0.000	0.067	0.638	0.969	0.998	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2008	0.000	0.071	0.628	0.963	0.997	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2009	0.000	0.076	0.612	0.956	0.996	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2010	0.000	0.081	0.596	0.949	0.995	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2011	0.000	0.085	0.580	0.943	0.994	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2012	0.000	0.089	0.569	0.938	0.994	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2013	0.000	0.091	0.562	0.936	0.994	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2014	0.000	0.092	0.560	0.937	0.995	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2015	0.000	0.092	0.562	0.939	0.996	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2016	0.000	0.092	0.567	0.943	0.996	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2017	0.000	0.091	0.574	0.947	0.997	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2018	0.000	0.090	0.581	0.950	0.998	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2019	0.000	0.089	0.587	0.954	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2020	0.000	0.088	0.589	0.956	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2021	0.000	0.087	0.588	0.957	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Table 8.2.19. Haddock in Subarea 4, Division 6.a and Subdivision 20. Data available for calibration of the assessment. Only those data used in the final assessment are shown here.

delta-GAM NS-WC Q1								
1983	2022							
1	1	0.00	0.25					
1	8							
1	310.631	386.023	69.312	63.087	10.807	2.2452	0.2004	0.3941
1	1646.370	210.403	115.773	17.050	14.687	2.5221	0.4781	0.1681
1	342.570	736.613	112.792	31.601	4.558	3.9307	0.6483	0.293
1	689.440	176.354	273.593	19.224	6.872	1.1714	1.0534	0.1855
1	1052.219	224.840	54.879	45.306	3.288	1.297	0.1872	0.5463
1	167.454	402.421	78.687	12.104	7.890	0.8207	0.1937	0.4912
1	175.985	70.509	172.954	13.473	1.997	2.9445	0.2888	0.1623
1	253.559	77.998	34.785	31.790	2.671	0.525	0.8235	0.0964
1	713.061	139.421	31.118	7.645	6.634	1.2939	0.1117	0.2605
1	996.146	288.213	36.258	2.942	2.007	1.2025	0.163	0.1887
1	1625.078	487.476	137.376	14.054	0.882	0.3305	0.7188	0.3965
1	297.984	456.786	110.846	19.482	2.550	0.5745	0.0468	0.4528
1	1967.191	183.893	155.859	22.832	5.628	0.8089	0.1975	0.2644
1	676.669	609.210	79.887	37.349	5.542	1.3068	0.2139	0.0843
1	1127.107	322.206	247.558	21.757	9.796	1.8785	0.5436	0.0954
1	408.364	325.887	94.233	62.563	7.001	2.6474	0.9082	0.2987
1	201.198	149.061	100.015	24.707	15.986	1.7771	0.9442	0.4521
1	5064.348	116.132	47.066	17.986	5.230	3.2929	0.5799	0.3334
1	922.188	1423.013	78.504	11.894	4.766	1.8243	0.9582	0.4695
1	88.108	428.463	588.146	14.046	5.075	1.5996	1.0249	0.461
1	85.073	68.612	230.194	206.669	3.938	1.2333	0.7836	0.671
1	62.746	76.250	39.017	87.849	71.668	1.092	0.5686	0.3978
1	66.341	44.395	33.165	10.806	25.169	25.7863	1.2524	0.537
1	353.108	44.454	25.415	8.759	3.999	7.6316	10.0427	1.1044
1	85.803	275.523	24.902	8.115	3.299	1.5828	3.7637	5.4955
1	66.158	64.409	139.736	8.856	2.441	1.0342	0.7216	3.1837
1	51.901	46.100	39.986	44.106	2.627	0.8788	0.5909	1.4885
1	351.140	41.331	30.483	13.757	19.384	1.5002	0.5246	0.8839
1	34.252	224.695	35.814	11.034	7.936	12.0479	0.366	0.5352
1	21.758	32.820	162.856	12.276	7.367	3.8339	4.6682	0.419
1	53.188	17.501	19.570	49.697	5.392	2.8295	1.3655	2.7102
1	50.015	25.178	10.450	8.787	21.002	1.4911	0.9783	1.7128
1	406.368	32.740	17.513	3.451	5.001	10.8115	0.5942	1.1788
1	101.315	177.511	17.392	4.434	1.600	0.9906	5.0948	0.3448
1	145.937	75.097	98.768	6.344	2.037	0.4607	0.5069	2.1413
1	66.629	76.859	38.982	28.185	1.838	0.6414	0.1129	0.9432
1	249.055	33.724	35.591	7.487	10.882	0.5647	0.2055	0.2555
1	375.578	112.695	19.775	11.746	3.581	5.4325	0.1384	0.1767
1	874.692	426.189	58.191	6.482	6.934	1.5137	3.327	0.1261
1	281.4063	1066.5743	614.1949	16.3631	6.5696	3.4056	0.5769	1.9476

Table 8.2.19. (cont.) Haddock in Subarea 4, Division 6.a and Subdivision 20. Data available for calibration of the assessment. Only those data used in the final assessment are shown here.

Delta-GAM NS-WC Q3+Q4									
1991	2021								
1	1	0.50	1						
0	8								
1	2120.2904	510.9633	50.5526	4.5176	1.7522	4.9677	0.2075	0.0772	0.2759
1	4099.3007	1376.7595	197.3717	11.0507	1.5546	0.5689	1.4839	0.0581	0.1361
1	649.7388	1306.4762	247.2837	37.094	2.372	0.9528	0.0838	0.2561	0.0636
1	2132.4868	488.3349	285.1813	37.336	12.3191	0.8857	0.074	0.012	0.1794
1	1849.5743	2009.938	151.9891	82.8374	11.163	4.5449	0.6399	0	0.4602
1	800.4737	625.6801	409.2852	40.8925	23.863	3.6663	0.8788	0.0894	0.0487
1	417.1539	783.4659	175.9369	140.2079	9.8047	6.2284	1.1148	0.4879	0.0658
1	353.9586	281.3886	174.5721	43.072	29.0067	2.84	1.9402	0.2527	0.1947
1	5913.313	217.0262	83.9042	42.9204	11.3981	8.9205	0.8019	0.6138	0.3077
1	1365.6261	4412.7528	56.0301	17.3987	8.2863	2.8268	2.2776	0.1885	0.1521
1	80.5127	752.236	1256.6737	33.6129	8.488	4.005	1.5388	0.8674	0.1093
1	164.8033	119.7366	289.6783	492.8343	11.3291	3.9872	2.1411	0.5429	0.4125
1	93.7262	170.0681	66.6366	146.4076	131.5696	2.9551	1.4133	0.3985	0.2447
1	116.9462	104.583	81.206	27.4086	54.9233	69.0721	1.585	0.5354	0.3724
1	344.3737	86.03	45.7023	22.4295	11.0097	18.2694	13.3369	0.2794	0.2053
1	163.9786	222.4661	33.5594	11.5875	7.8926	4.3545	6.2314	6.7515	0.1957
1	138.2654	101.9277	234.3451	17.3326	8.9849	2.6256	1.3999	2.0401	2.0461
1	79.3606	59.0419	46.8892	91.1589	6.297	3.8236	2.1804	0.7404	1.8262
1	310.4693	38.988	35.2896	21.272	33.9236	1.9727	1.4098	0.7086	0.5391
1	39.6267	357.4425	43.5855	27.2178	14.8287	23.3767	1.2562	0.443	0.4367
1	34.1438	39.2448	269.997	27.168	14.3742	6.3857	11.6345	0.4724	0.3711
1	81.8385	26.1303	24.6701	126.7925	7.9334	4.7998	3.2774	4.3424	0.241
1	93.8427	31.5255	17.6065	11.4954	56.9446	2.8576	2.4052	0.8857	2.1469
1	1388.4633	51.0801	23.2352	7.1019	6.4102	29.5827	1.4257	0.8034	1.2445
1	185.4331	491.8846	43.4841	12.4634	2.9269	3.6635	13.7288	0.6961	0.6284
1	296.7165	108.1365	207.3861	16.1641	4.3905	1.0369	1.6297	4.4449	0.3362
1	104.2394	159.119	92.4202	107.1817	6.5294	1.622	0.3861	0.7212	1.7299
1	324.8276	53.5959	57.5749	30.1772	41.0787	1.5255	0.8149	0.0581	0.402
1	1160.9366	270.1042	26.2353	29.3072	12.8548	17.9016	0.6503	0.0546	0.1296
1	1453.1934	1325.5992	130.12	19.7021	18.5265	5.2992	10.1321	0.1779	0.0803
1	305.2693	956.6695	629.5557	61.4074	10.5822	8.135	2.3215	3.5156	0.1387

Table 8.3.1. Haddock in Subarea 4, Division 6.a and Subdivision 20. SAM final assessment: Model inputs

	Dataset	Year	Ages	Details
Catch data	Catch numbers	1972-2021	0-8+	Catch-at-age in numbers. Combination of landings, discards, BMS landings and industrial by-catch
	Catch weights	1972-2021	0-8+	Mean weights-at-age in the total catch.
	Landing weights	1972-2021	0-8+	Mean weight-at-age in the landings.
	Discard weights	1972-2021	0-8+	Mean weight-at-age in the discards.
	Discard numbers	1972-2021	0-8+	Numbers-at-age for discards. Used for plus group calculations.
	Landings fraction (numbers)	1972-2021	0-8+	Numbers-at-age for landings. Used to separate out the landings portion of the total catch for use in the forecast. This is converted to a landings fraction within the model code.
Biological data	Stock weights	1972-2021	0-8+	Mean weights-at-age. Produced from applying survey-derived correction factors to mean weights-at-age in the catch.
	Natural mortality	1974-2020	0-8+	Natural mortality estimates from the SMS key run produced by WGSAM. Smoothed.
	Maturity	1991-2021	0-8+	Proportion mature. Survey-derived maturity ogives. Smoothed. Time varying.
	Proportion of natural mortality before spawning	1972-2021	0-8+	Set to zero for all ages and years.
	Proportion of fishing mortality before spawning	1972-2021	0-8+	Set to zero for all ages and years.
Tuning data	Survey: delta-GAM NS-WC Q1	1983-2022	1-8+	Delta-GAM modelled survey indices covering the North Sea and West Coast of Scotland in quarter 1.
	Survey: delta-GAM NS-WC Q3+Q4	1991-2021	0-8+	Delta-GAM modelled survey indices covering the North Sea in quarter 3 and West Coast of Scotland in quarter 4.
	Weightings: coefficient of variations for delta-GAM NS-WC Q1	1983-2022	1-8+	Coefficient of variations for the delta-GAM modelled survey indices covering the North Sea and West Coast of Scotland in quarter 1.

Table 8.3.2. Haddock in Subarea 4, Division 6.a and Subdivision 20. SAM final assessment: Model settings. Settings not listed use the default setting in SAM.

Configuration setting	Details								
Assessment age range	0-8+								
Is maximum considered a plus group	1 1 1								
Coupling of the fishing mortality states	0 1 2 3 4 5 6 7 7								
Correlation of fishing mortality across ages	AR(1)								
Coupling of the survey catchability parameters	-1	-1	-1	-1	-1	-1	-1	-1	-1
	-1	0	1	2	3	4	5	6	6
	7	8	9	10	11	12	13	14	14
Coupling of process variance parameters for F	0 0 0 0 0 0 0 0 0								
Coupling of process variance parameters for N	0 1 1 1 1 1 1 1 2								
Coupling of the variance parameters for observations	0	1	2	2	2	2	2	2	2
	-1	3	4	4	4	4	4	4	4
	5	6	7	7	7	7	7	7	7
Covariance structure for each fleet	Independent (ID) for all								
Stock recruitment code	Random walk (0)								
F range	2-4								

Table 8.3.3. Haddock in Subarea 4, Division 6.a and Subdivision 20. SAM final assessment: Parameter estimates.

	Estimate	Lower bound	Upper bound	Sd(par)	Log(par)
logFpar_0	-8.081	0.000	0.000	0.061	0.000
logFpar_1	-7.473	0.001	0.001	0.051	0.001
logFpar_2	-7.353	0.001	0.001	0.052	0.001
logFpar_3	-7.766	0.000	0.000	0.056	0.000
logFpar_4	-7.959	0.000	0.000	0.067	0.000
logFpar_5	-8.244	0.000	0.000	0.089	0.000
logFpar_6	-8.541	0.000	0.000	0.121	0.000
logFpar_7	-8.077	0.000	0.000	0.085	0.000
logFpar_8	-7.263	0.001	0.001	0.069	0.001
logFpar_9	-7.185	0.001	0.001	0.072	0.001
logFpar_10	-7.353	0.001	0.001	0.074	0.001
logFpar_11	-7.518	0.000	0.001	0.081	0.001
logFpar_12	-7.694	0.000	0.001	0.097	0.000
logFpar_13	-8.016	0.000	0.000	0.123	0.000
logFpar_14	-8.703	0.000	0.000	0.156	0.000
logSdLogFsta_0	-1.698	0.139	0.240	0.136	0.183
logSdLogN_0	0.078	0.869	1.345	0.109	1.081
logSdLogN_1	-2.024	0.103	0.170	0.127	0.132
logSdLogN_2	-0.699	0.390	0.633	0.121	0.497
logSdLogObs_0	-0.016	0.788	1.230	0.111	0.984
logSdLogObs_1	-0.859	0.318	0.565	0.144	0.424
logSdLogObs_2	-1.184	0.268	0.350	0.066	0.306
logSdLogObs_3	-1.193	0.227	0.405	0.145	0.303
logSdLogObs_4	-1.403	0.214	0.283	0.070	0.246
logSdLogObs_5	-0.931	0.284	0.547	0.163	0.394
logSdLogObs_6	-1.171	0.224	0.428	0.162	0.310
logSdLogObs_7	-1.084	0.299	0.383	0.062	0.338
itrans_rho_0	1.811	3.628	10.304	0.261	6.114

Table 8.3.4. Haddock in Subarea 4, Division 6.a and Subdivision 20. Estimates of fishing mortality at age from the final SAM assessment. Estimates refer to the full year (January–December) except for age 0, for which the mortality rate given refers to the second half-year only (July–December).

	0	1	2	3	4	5	6	7	8+	Mean F(2–4)
1972	0.022	0.175	0.587	0.919	0.887	0.839	0.859	0.825	0.825	0.798
1973	0.022	0.172	0.572	0.887	0.859	0.819	0.845	0.817	0.817	0.773
1974	0.023	0.179	0.596	0.907	0.874	0.829	0.851	0.822	0.822	0.793
1975	0.025	0.198	0.667	1.014	0.978	0.927	0.945	0.906	0.906	0.886
1976	0.025	0.195	0.662	1.007	0.975	0.922	0.930	0.889	0.889	0.881
1977	0.024	0.191	0.657	0.998	0.977	0.915	0.914	0.872	0.872	0.877
1978	0.024	0.188	0.660	1.017	1.005	0.936	0.931	0.890	0.890	0.894
1979	0.022	0.172	0.614	0.960	0.952	0.872	0.860	0.825	0.825	0.842
1980	0.020	0.154	0.553	0.873	0.872	0.784	0.765	0.740	0.740	0.766
1981	0.017	0.128	0.461	0.729	0.731	0.650	0.629	0.614	0.614	0.640
1982	0.016	0.127	0.462	0.735	0.749	0.664	0.643	0.627	0.627	0.649
1983	0.018	0.138	0.517	0.827	0.860	0.770	0.737	0.708	0.708	0.735
1984	0.018	0.143	0.550	0.882	0.934	0.849	0.822	0.786	0.786	0.789
1985	0.018	0.146	0.577	0.920	0.980	0.895	0.880	0.848	0.848	0.826
1986	0.018	0.151	0.620	0.981	1.039	0.948	0.938	0.917	0.917	0.880
1987	0.018	0.158	0.665	1.045	1.097	0.999	1.004	0.991	0.991	0.936
1988	0.017	0.150	0.645	1.006	1.041	0.935	0.929	0.922	0.922	0.897
1989	0.017	0.150	0.651	1.001	1.029	0.922	0.913	0.903	0.903	0.894
1990	0.017	0.148	0.653	0.980	0.983	0.874	0.857	0.835	0.835	0.872
1991	0.018	0.159	0.714	1.068	1.054	0.935	0.912	0.871	0.871	0.945
1992	0.016	0.146	0.656	0.975	0.964	0.859	0.833	0.789	0.789	0.865
1993	0.017	0.153	0.697	1.029	1.010	0.891	0.855	0.790	0.790	0.912
1994	0.016	0.143	0.655	0.971	0.956	0.835	0.770	0.693	0.693	0.860
1995	0.013	0.121	0.552	0.816	0.809	0.698	0.608	0.520	0.520	0.725
1996	0.014	0.130	0.596	0.889	0.905	0.797	0.678	0.558	0.558	0.797
1997	0.013	0.120	0.547	0.806	0.817	0.717	0.584	0.457	0.457	0.723
1998	0.013	0.131	0.596	0.872	0.884	0.766	0.599	0.446	0.446	0.784
1999	0.015	0.146	0.667	0.989	1.004	0.875	0.667	0.478	0.478	0.886
2000	0.013	0.131	0.591	0.881	0.902	0.785	0.595	0.420	0.420	0.792
2001	0.010	0.100	0.430	0.633	0.650	0.570	0.426	0.299	0.299	0.571
2002	0.008	0.083	0.344	0.496	0.512	0.455	0.335	0.233	0.233	0.451
2003	0.006	0.061	0.244	0.343	0.355	0.320	0.232	0.158	0.158	0.314
2004	0.006	0.065	0.256	0.355	0.366	0.333	0.237	0.159	0.159	0.326
2005	0.007	0.076	0.303	0.425	0.440	0.409	0.293	0.196	0.196	0.389
2006	0.009	0.094	0.379	0.542	0.568	0.530	0.382	0.264	0.264	0.497
2007	0.008	0.090	0.362	0.525	0.558	0.524	0.380	0.274	0.274	0.482
2008	0.007	0.072	0.286	0.415	0.441	0.413	0.296	0.221	0.221	0.381
2009	0.006	0.061	0.241	0.357	0.386	0.362	0.256	0.196	0.196	0.328

	0	1	2	3	4	5	6	7	8+	Mean F(2–4)
2010	0.005	0.055	0.220	0.333	0.364	0.346	0.244	0.191	0.191	0.306
2011	0.005	0.050	0.206	0.321	0.356	0.343	0.244	0.197	0.197	0.294
2012	0.004	0.047	0.197	0.312	0.351	0.340	0.240	0.204	0.204	0.286
2013	0.004	0.047	0.202	0.323	0.363	0.348	0.239	0.208	0.208	0.296
2014	0.005	0.054	0.248	0.408	0.454	0.432	0.287	0.255	0.255	0.370
2015	0.005	0.059	0.283	0.486	0.546	0.521	0.341	0.311	0.311	0.439
2016	0.004	0.048	0.236	0.415	0.471	0.444	0.286	0.269	0.269	0.374
2017	0.004	0.042	0.209	0.373	0.427	0.405	0.260	0.247	0.247	0.336
2018	0.004	0.042	0.214	0.393	0.459	0.448	0.294	0.286	0.286	0.355
2019	0.003	0.037	0.193	0.363	0.433	0.433	0.287	0.284	0.284	0.330
2020	0.003	0.030	0.159	0.304	0.371	0.378	0.252	0.252	0.252	0.278
2021	0.002	0.023	0.119	0.230	0.284	0.295	0.197	0.199	0.199	0.211

Table 8.3.5. Haddock in Subarea 4, Division 6.a and Subdivision 20. Estimates of stock numbers at age (thousands) from the final SAM assessment. Estimates refer to 1 January, except for age 0 for estimates refer to 1 July. *SAM estimated survivors and projected recruitment.

	0	1	2	3	4	5	6	7	8+
1972	12649827	12492893	2152973	73463	44733	417868	7969	489	1189
1973	32687783	3327113	2420147	523314	16467	11721	133339	2610	796
1974	64979645	9085312	593688	667726	126309	4561	3808	43740	1001
1975	6249833	18314250	1716094	142299	173929	34735	1536	1272	12493
1976	7216914	1624482	3585954	403028	30572	45530	10416	459	3856
1977	10302559	1900065	301615	942045	86431	8144	13479	3219	1334
1978	18077321	2741129	359497	74038	232878	21390	2517	4238	1973
1979	29049767	4792195	564191	90200	16753	62354	6117	773	1873
1980	7730850	7793410	1052246	158594	21040	4608	20432	1969	926
1981	12568912	1942792	1776722	333661	42190	5893	1672	7523	826
1982	7520588	3284639	425342	662880	103769	14652	2294	780	3065
1983	22651401	1899461	756831	152814	214330	34757	6335	958	1918
1984	5967728	6131119	464036	257052	46825	66316	11807	2423	953
1985	7974824	1531013	1496821	169801	73894	13749	22164	3969	1362
1986	12651223	2095335	365154	526706	47937	20043	4373	7306	1351
1987	2068253	3551946	508805	115405	140586	12529	5763	1395	4036
1988	2182966	544889	949181	154297	28980	36634	3824	1552	2669
1989	3331710	586237	140741	334554	37444	7523	12217	1312	1236
1990	7883152	902453	151518	48153	91338	9601	2374	4084	684
1991	12172282	2208430	240154	46300	13107	26636	3151	845	2165
1992	16645721	3177067	612616	76574	11194	3580	8641	1004	1419
1993	5458651	4245530	784644	216885	23230	3650	1113	3362	1471
1994	18014805	1423361	1017762	225106	58103	7069	1342	355	2348

	0	1	2	3	4	5	6	7	8+
1995	7732879	5178179	390704	334497	60269	17869	2738	568	1562
1996	8352530	1909508	1380399	152823	106818	20205	6952	1275	532
1997	3918301	2360478	499169	506688	47448	32311	7256	2986	573
1998	3125460	1087311	603557	182847	169256	16785	11913	3318	1524
1999	36390173	839335	291285	201490	58934	53248	6195	5265	2227
2000	8706721	10559881	233640	96464	51627	17363	16180	2536	1735
2001	1297496	2437156	2757296	88613	29468	15499	6967	6649	1793
2002	1559523	384068	675847	1141821	30210	11564	6685	3967	3357
2003	1136921	433499	112042	317945	486557	11737	5194	3564	2756
2004	1113678	332079	128509	56585	164996	251197	5998	3056	2109
2005	4611225	317763	97405	60231	28437	81734	129950	3719	2046
2006	1424468	1487223	93533	47368	27655	14583	40203	74596	2790
2007	1038390	421131	509287	42821	20903	11934	6879	21756	27995
2008	822127	311406	129292	257725	18109	8781	5701	3824	17911
2009	4116082	251170	94147	67543	142241	8457	4396	3483	6578
2010	499120	1412479	83076	54270	38123	83375	4687	2728	3961
2011	329439	161230	467606	47612	30399	21708	51645	2747	2642
2012	600032	104660	52434	274697	24494	17075	12287	32173	2401
2013	657116	200586	31772	30563	163960	12315	9464	7163	17435
2014	4126647	217703	62208	16215	19709	95604	6421	5699	10116
2015	1214108	1396820	66586	31050	7538	10745	53327	3901	6375
2016	1426828	423464	402747	29519	12930	3183	4560	31349	2544
2017	662496	521032	133214	198622	12797	5585	1406	2811	11751
2018	1980231	241559	155157	61573	101423	5193	2566	779	4586
2019	6810487	772721	75023	77670	26808	52419	2256	1301	1308
2020	7955652	2846045	222787	40431	41760	12606	29698	1163	1030
2021	2499031	3476044	989209	103403	23095	23772	6357	20125	752
2022*	2499031	1045390	1267583	618465	55647	14784	13934	3937	11066

Table 8.3.6. Haddock in Subarea 4, Division 6.a and Subdivision 20. Stock summary table for the final SAM model. Both estimates and the 5th (low) and 95th (high) percentiles are given.

Year	Recruitment (age 0)	Recruitment low	Recruitment high	SSB estimate	SSB low	SSB high	Fbar (2-4)	Fbar low	Fbar high	TSB estimate	TSB low	TSB high
1972	12649827	7955919	20113092	447664	354535	565255	0.798	0.645	0.987	1308011	1048595	1631606
1973	32687783	20757431	51475117	417535	339652	513277	0.773	0.641	0.931	1328469	1058039	1668020
1974	64979645	41151040	102606259	325315	265847	398085	0.793	0.661	0.950	1481221	1156158	1897679
1975	6249833	3972261	9833292	297219	246663	358137	0.886	0.743	1.057	1225339	942999	1592213
1976	7216914	4592527	11340999	415182	329234	523568	0.881	0.740	1.050	816780	647018	1031083
1977	10302559	6590319	16105854	320170	248714	412156	0.877	0.736	1.045	525041	432120	637944
1978	18077321	11554393	28282709	157491	128915	192402	0.894	0.751	1.065	371981	310222	446034
1979	29049767	18597102	45377445	138197	116000	164641	0.842	0.704	1.007	483671	394139	593541
1980	7730850	5000176	11952788	190866	157376	231481	0.766	0.637	0.921	575045	464672	711634
1981	12568912	8301399	19030232	295790	240726	363448	0.640	0.530	0.774	555136	453878	678983
1982	7520588	5090440	11110874	334187	271866	410793	0.649	0.541	0.778	514024	434842	607624
1983	22651401	15391389	33335912	269887	231847	314169	0.735	0.617	0.875	537549	468141	617248
1984	5967728	4052308	8788517	229279	200048	262782	0.789	0.667	0.933	638865	534288	763910
1985	7974824	5409715	11756222	272109	233784	316718	0.826	0.699	0.975	544228	466426	635008
1986	12651223	8562998	18691287	242521	203724	288707	0.880	0.747	1.036	499399	429508	580662
1987	2068253	1404125	3046503	175563	151959	202834	0.936	0.799	1.096	403845	343155	475270
1988	2182966	1484788	3209442	160702	138476	186494	0.897	0.764	1.054	309278	266956	358309
1989	3331710	2276460	4876122	140052	117647	166724	0.894	0.761	1.050	255045	220463	295053
1990	7883152	5473632	11353356	84855	73348	98167	0.872	0.741	1.027	293429	244106	352718
1991	12172282	8570623	17287476	72369	63722	82189	0.945	0.805	1.111	393389	328964	470431
1992	16645721	11630490	23823591	108819	94038	125922	0.865	0.740	1.012	430500	363851	509356
1993	5458651	3904186	7632031	169965	146699	196921	0.912	0.777	1.071	449248	385320	523782
1994	18014805	12864673	25226697	189463	164156	218673	0.860	0.731	1.013	473025	410177	545503
1995	7732879	5387816	11098636	182341	158483	209790	0.725	0.609	0.864	476906	410358	554247
1996	8352530	5947782	11729542	214411	186398	246633	0.797	0.674	0.942	495412	431245	569126
1997	3918301	2804398	5474646	236707	203930	274753	0.723	0.608	0.860	462284	405286	527299
1998	3125460	2238865	4363147	193454	169556	220720	0.784	0.660	0.931	342516	303446	386616
1999	36390173	25688182	51550735	137730	120449	157492	0.886	0.752	1.045	578982	461481	726401
2000	8706721	6212142	12203038	117042	103682	132124	0.792	0.666	0.941	807856	658910	990471
2001	1297496	918984	1831910	284289	236369	341924	0.571	0.470	0.694	568067	479190	673428
2002	1559523	1114332	2182575	368458	310493	437244	0.451	0.363	0.559	448286	384143	523141
2003	1136921	808945	1597872	270109	229831	317446	0.314	0.247	0.399	303464	261731	351850
2004	1113678	796762	1556649	188026	160161	220738	0.326	0.260	0.408	231132	200976	265812
2005	4611225	3188951	6667834	136860	115716	161868	0.389	0.316	0.479	264275	221401	315451
2006	1424468	1016837	1995510	99835	83504	119359	0.497	0.408	0.604	201590	172164	236045
2007	1038390	739388	1458304	106115	91202	123465	0.482	0.396	0.586	176272	153451	202488
2008	822127	580319	1164693	113882	97145	133503	0.381	0.311	0.466	152389	132649	175066

Year	Recruitment (age 0)	Recruitment low	Recruitment high	SSB estimate	SSB low	SSB high	Fbar (2-4)	Fbar low	Fbar high	TSB estimate	TSB low	TSB high
2009	4116082	2877242	5888324	88656	76294	103020	0.328	0.267	0.403	193944	161975	232222
2010	499120	352251	707224	88234	76611	101620	0.306	0.249	0.375	156800	136369	180292
2011	329439	235037	461757	113933	99173	130890	0.294	0.239	0.362	162925	141770	187236
2012	600032	426627	843918	139435	119157	163163	0.286	0.231	0.354	165971	143671	191733
2013	657116	470354	918034	113522	96595	133414	0.296	0.240	0.365	140418	121911	161734
2014	4126647	2897172	5877875	86111	73355	101084	0.370	0.303	0.451	175641	148174	208201
2015	1214108	868951	1696366	75981	65347	88345	0.439	0.355	0.541	175327	150338	204470
2016	1426828	1019209	1997470	105109	90223	122449	0.374	0.300	0.466	198720	172449	228994
2017	662496	473585	926763	110232	94565	128495	0.336	0.267	0.423	165486	145113	188719
2018	1980231	1411641	2777843	100671	87532	115781	0.355	0.285	0.443	162774	143018	185259
2019	6810487	4787109	9689090	84858	73895	97448	0.330	0.266	0.409	264675	218430	320711
2020	7955652	5493946	11520390	107457	94265	122494	0.278	0.222	0.347	397572	331441	476897
2021	2499031	1516741	4117484	207210	175018	245324	0.211	0.162	0.274	528851	442038	632714
2022				412059	330351	513977				629019	483643	818095

Table 8.6.1. Haddock in Subarea 4, Division 6.a and Subdivision 20. Short-term forecast inputs.

SAM forecast	
Starting year:	2021
Number of simulations:	1000
Initial stock size:	Simulated from the estimated distribution at the start of the final data year (including covariances)
Recruitment	Sampled with replacement from 2000 to the final year of catch data
Fbar age range:	2-4
Intermediate year:	TAC constraint needed. F multiplier = 0.53. FintYr = 0.111
F and M before spawning:	Taken as 0

2022

Age	Mat	NM	SWt	CWt	LWt	DWt	Sel	LF
0	0.000	0.881	0.018	0.044	0.000	0.044	0.001	0.000
1	0.088	1.124	0.057	0.140	0.400	0.135	0.015	0.020
2	0.588	0.495	0.211	0.329	0.421	0.249	0.080	0.463
3	0.956	0.304	0.373	0.475	0.497	0.370	0.152	0.823
4	1.000	0.251	0.485	0.576	0.584	0.463	0.185	0.931
5	1.000	0.234	0.502	0.581	0.584	0.539	0.189	0.930
6	1.000	0.216	0.592	0.694	0.695	0.661	0.126	0.960
7	1.000	0.222	0.756	0.912	0.918	0.730	0.126	0.967
8	1.000	0.210	0.907	1.445	1.453	1.185	0.126	0.970

2023

Age	Mat	NM	SWt	CWt	LWt	DWt	Sel	LF
0	0.000	0.881	0.018	0.044	0.000	0.044	0.001	0.000
1	0.088	1.124	0.057	0.140	0.400	0.135	0.015	0.020
2	0.588	0.495	0.211	0.329	0.421	0.249	0.080	0.463
3	0.956	0.304	0.369	0.469	0.497	0.338	0.152	0.823
4	1.000	0.251	0.486	0.577	0.584	0.483	0.185	0.931
5	1.000	0.234	0.581	0.672	0.680	0.568	0.189	0.930
6	1.000	0.216	0.535	0.627	0.626	0.640	0.126	0.960
7	1.000	0.222	0.636	0.767	0.767	0.764	0.126	0.967
8	1.000	0.210	0.778	1.239	1.245	1.043	0.126	0.970

2024

Age	Mat	NM	SWt	CWt	LWt	DWt	Sel	LF
0	0.000	0.881	0.018	0.044	0.000	0.044	0.001	0.000
1	0.088	1.124	0.057	0.140	0.400	0.135	0.015	0.020
2	0.588	0.495	0.211	0.329	0.421	0.249	0.080	0.463
3	0.956	0.304	0.369	0.469	0.497	0.338	0.152	0.823
4	1.000	0.251	0.482	0.573	0.584	0.426	0.185	0.931
5	1.000	0.234	0.582	0.674	0.680	0.595	0.189	0.930
6	1.000	0.216	0.668	0.783	0.788	0.674	0.126	0.960
7	1.000	0.222	0.555	0.670	0.668	0.741	0.126	0.967
8	1.000	0.210	0.611	0.973	0.974	0.935	0.126	0.970

Table 8.6.2. Haddock in Subarea 4, Division 6.a and Subdivision 20. Short-term forecast output. A number of management options are highlighted.

Basis	Total catch (2023)	Projected landings* (2023)	Projected discards** (2023)	F_{total} (ages 2–4) (2023)	$F_{projected\ landings}$ (ages 2–4) (2023)	$F_{projected\ discards}$ (ages 2–4) (2023)	SSB (2024)	% SSB change^	% TAC change ^^	% advice change^^^
ICES advice basis										
MSY approach: F_{MSY}	137058	118373	18685	0.24	0.192	0.048	438042	89	160	6.5
Other scenarios										
F = $F_{MSY\ lower}$	109157	94391	14766	0.186	0.149	0.037	461609	93	107	-15.2
F = $F_{MSY\ upper}$[#]	137058	118373	18685	0.24	0.192	0.048	438042	89	160	6.5
F = 0	0	0	0	0	0	0	556373	112	-100	-100
F_{pa}	137058	118373	18685	0.24	0.192	0.048	438042	89	160	6.5
F_{lim}	223464	192501	30963	0.43	0.35	0.085	363491	73	324	74
SSB (2024) = B_{lim}	496564	419677	76887	1.54	1.24	0.31	136540	28	842	286
SSB (2024) = B_{pa} = MSY $B_{trigger}$	429169	363631	65538	1.13	0.91	0.22	189733	38	715	233
F = F_{2022}	67653	58557	9096	0.111	0.089	0.022	498369	101	28	-47
Rollover TAC	52690	45652	7038	0.085	0.068	0.0170	511261	103	0	-59

*** Marketable landings.**

**** Including below minimum size (BMS) landings and industrial bycatch (IBC), assuming recent discard rate.**

^ SSB 2024 relative to SSB 2023.

^^ Human consumption fishery (HCF) catch in 2023 relative to TAC in 2022: Subdivision 20 (2761 t) + Subarea 4 (44 924 t) + Division 6.a (5006 t) = 52 691 t.

^^^ Total catch 2023 relative to the advice value 2022 (128 708 t).

[#] For this stock, $F_{MSY\ upper}$ = F_{MSY}.

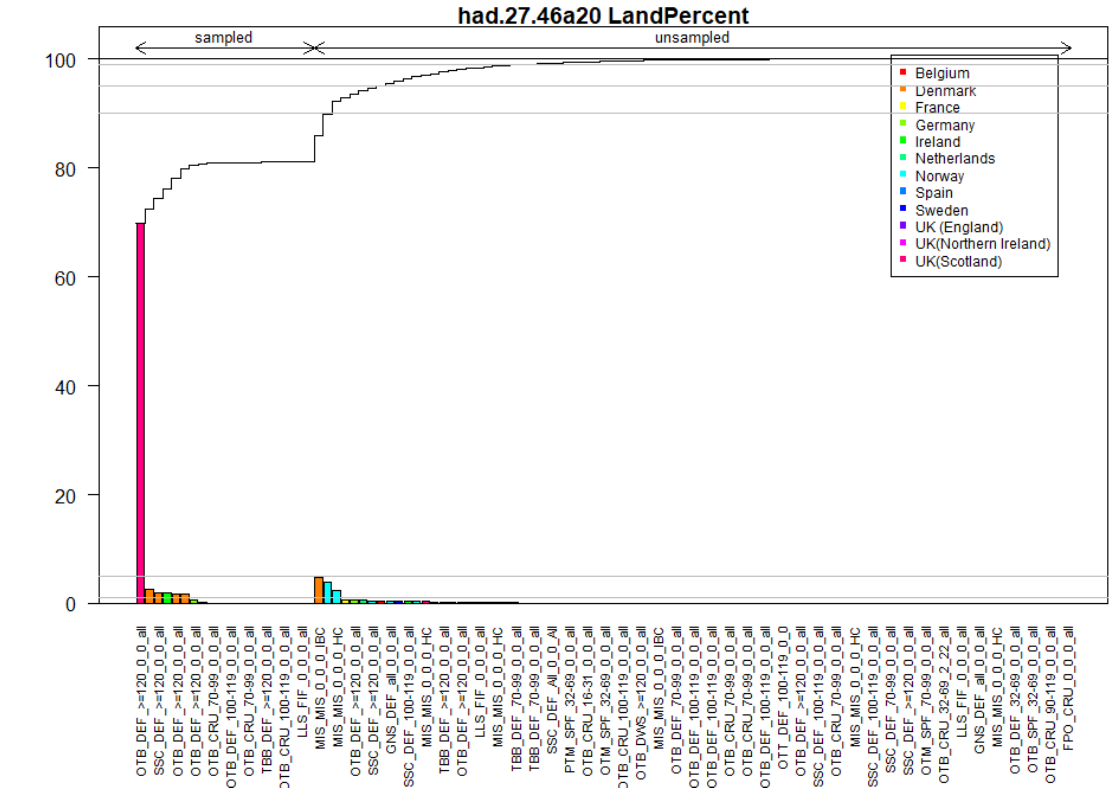


Figure 8.2.1. Haddock in Subarea 4, Division 6.a and Subdivision 20. Reported landings for each sampled and unsampled fleet in the full stock area, along with cumulative landings for fleets in descending order of yield.

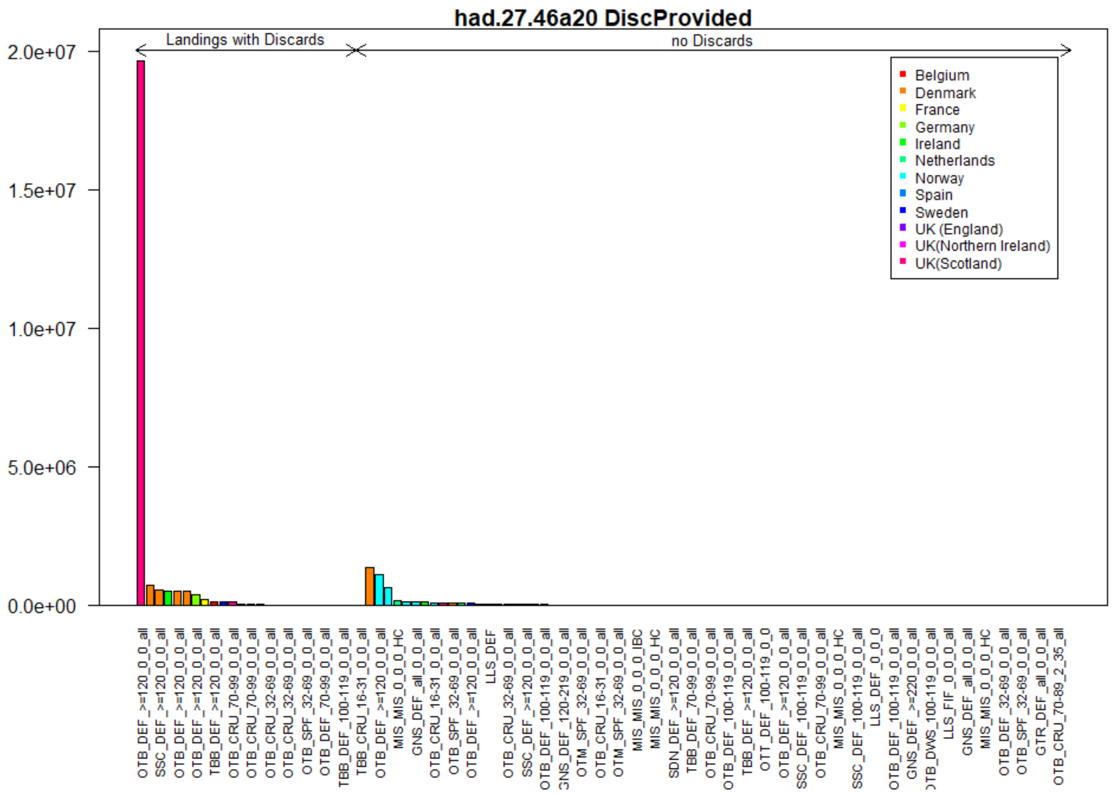


Figure 8.2.2. Haddock in Subarea 4, Division 6.a and Subdivision 20. Summary of landings for fleets with and without discard estimates.

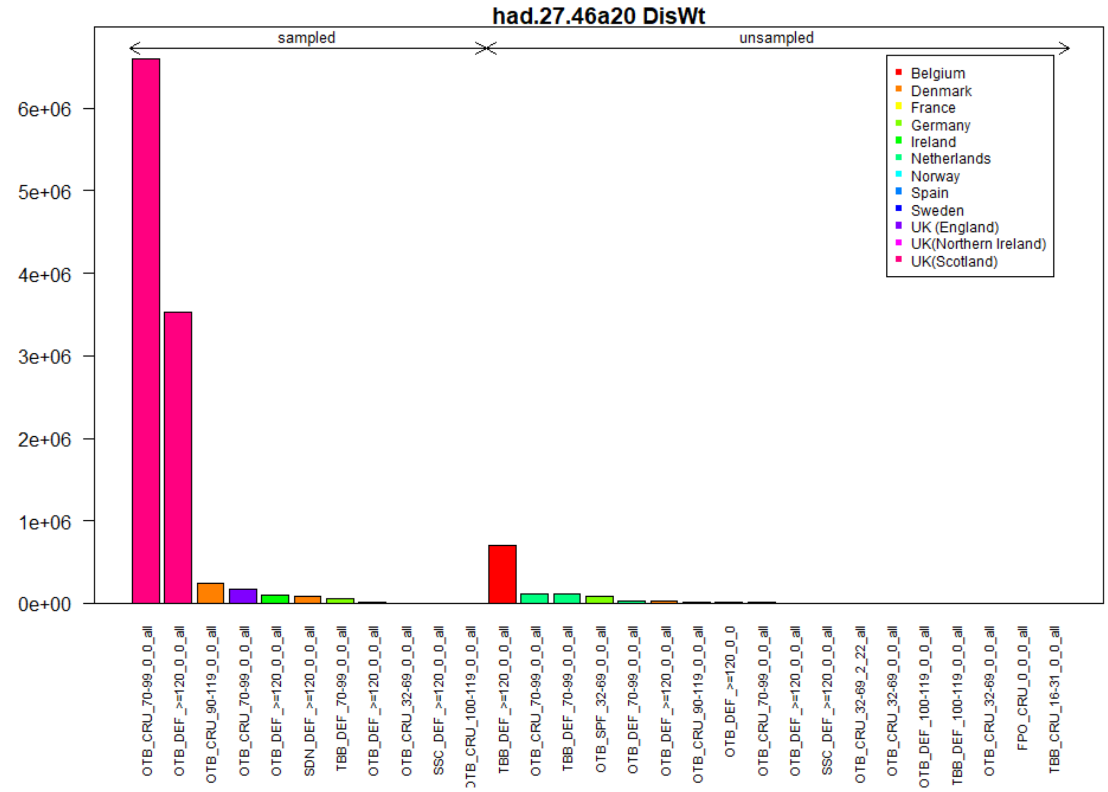


Figure 8.2.3. Haddock in Subarea 4, Division 6.a and Subdivision 20. Reported discards for each sampled and unsampled fleet in the full stock area, in descending order of yield.

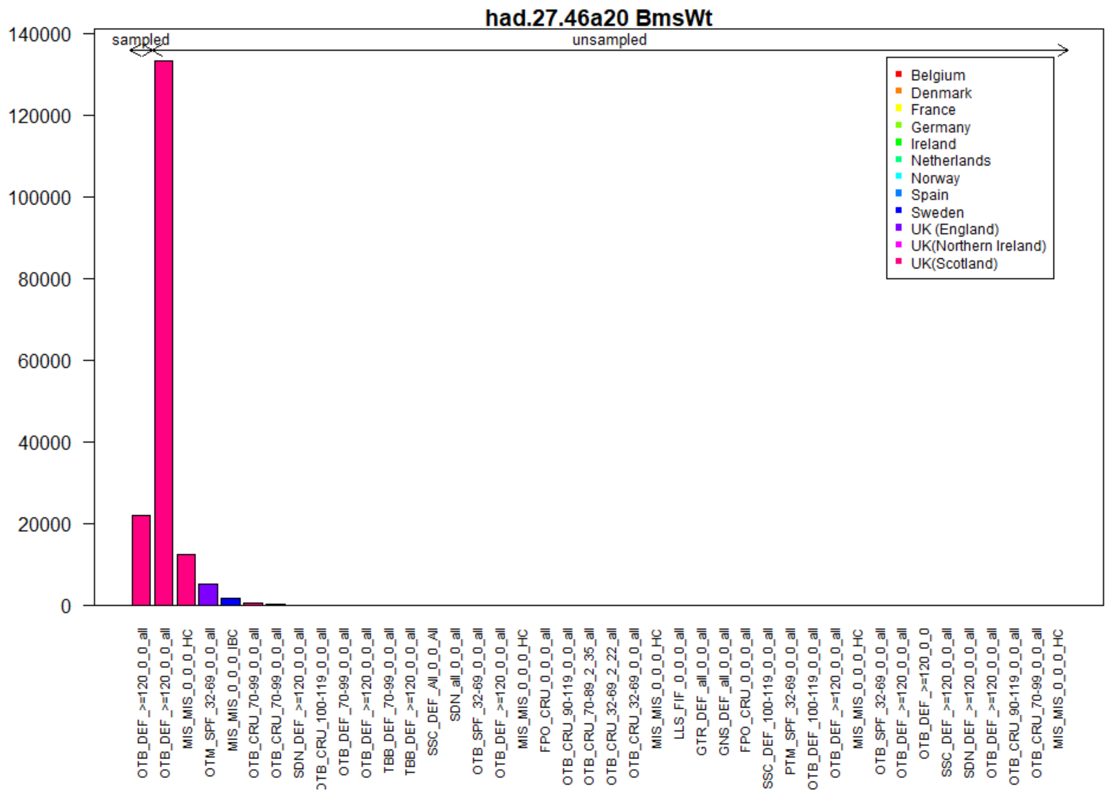


Figure 8.2.4. Haddock in Subarea 4, Division 6.a and Subdivision 20. Reported BMS landings for each sampled and unsampled fleet in the full stock area, in descending order of yield.

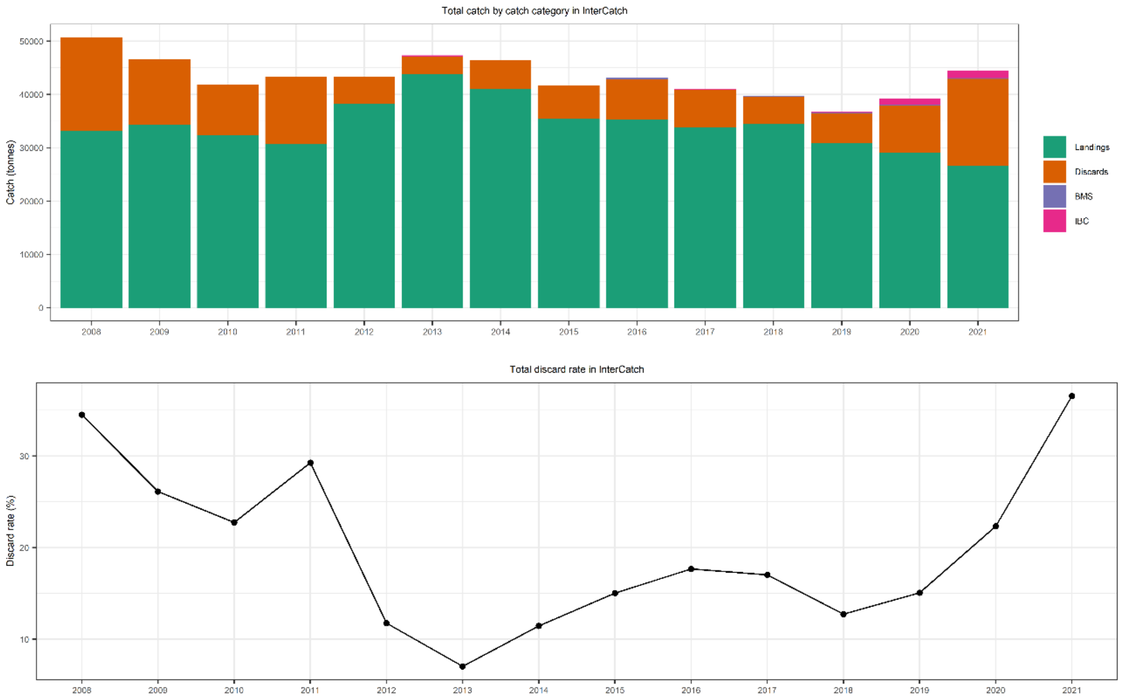


Figure 8.2.5. Haddock in Subarea 4, Division 6.a and Subdivision 20. Yield by catch component and discard rate.

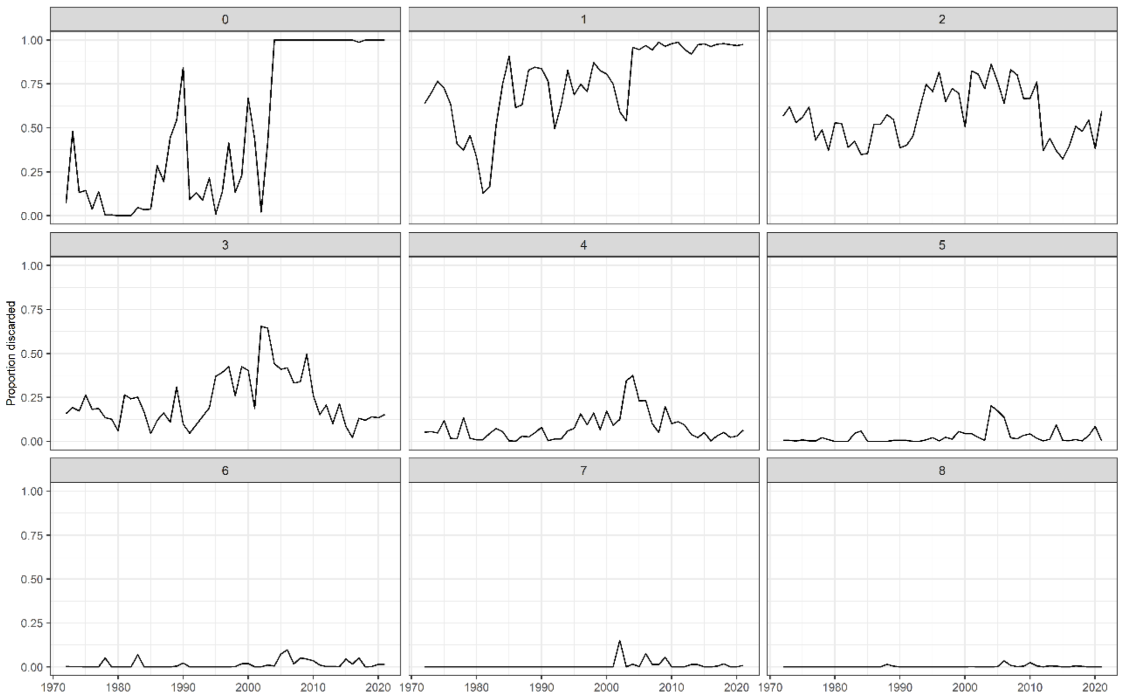


Figure 8.2.6. Haddock in Subarea 4, Division 6.a and Subdivision 20. Proportion of total catch discarded, by age and year.

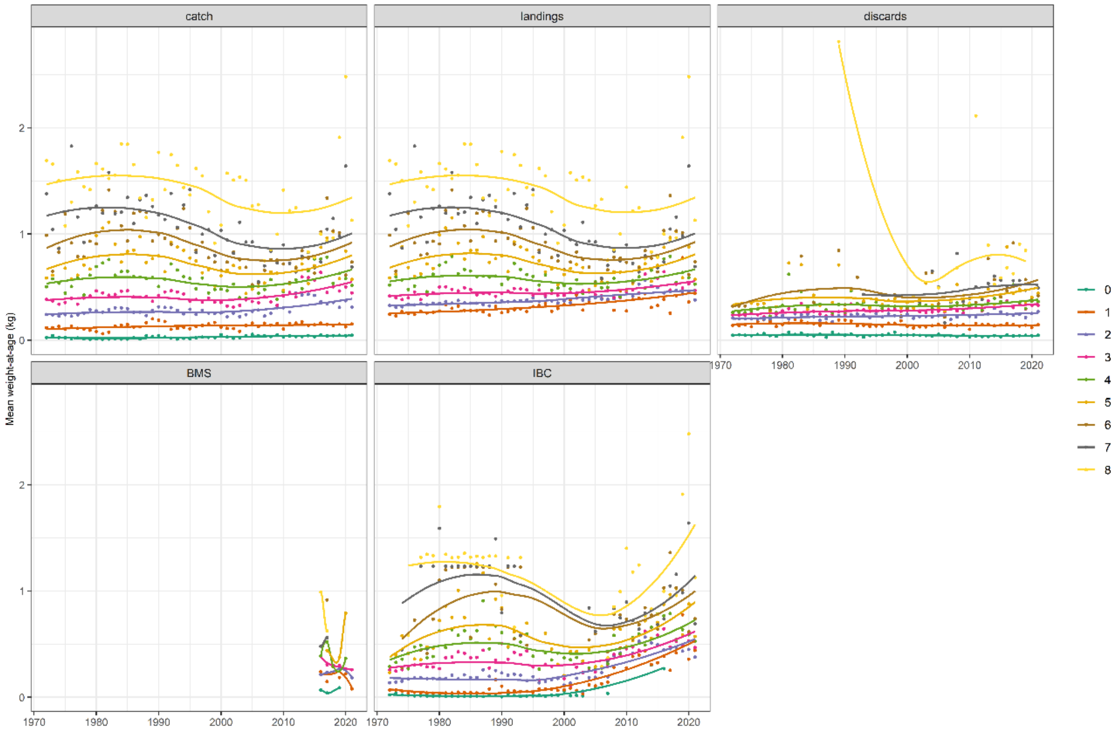


Figure 8.2.7. Haddock in Subarea 4, Division 6.a and Subdivision 20. Mean weights-at-age (0-8+; kg) by catch component. Points indicate the data points. The solid lines give loess smoothers through each time-series of mean weights-at-age, to show underlying trends.

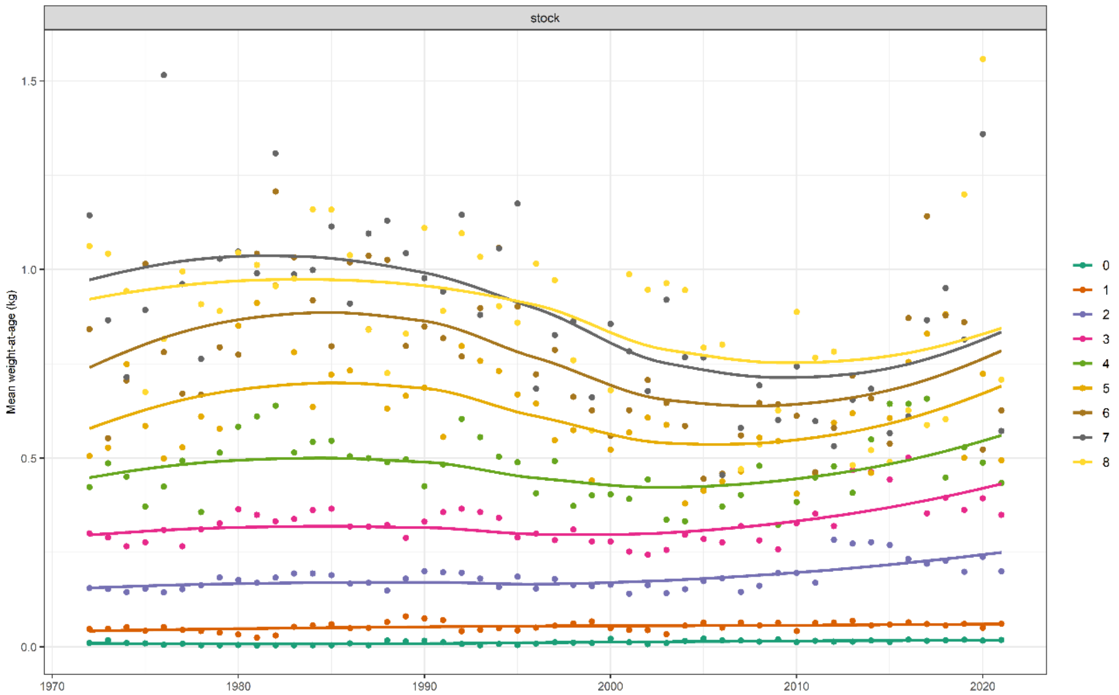


Figure 8.2.8. Haddock in Subarea 4, Division 6.a and Subdivision 20. Mean weights-at-age (kg) for the stock. Points indicate the data points. The solid lines give loess smoothers through each time-series of mean weights-at-age, to show underlying trends.

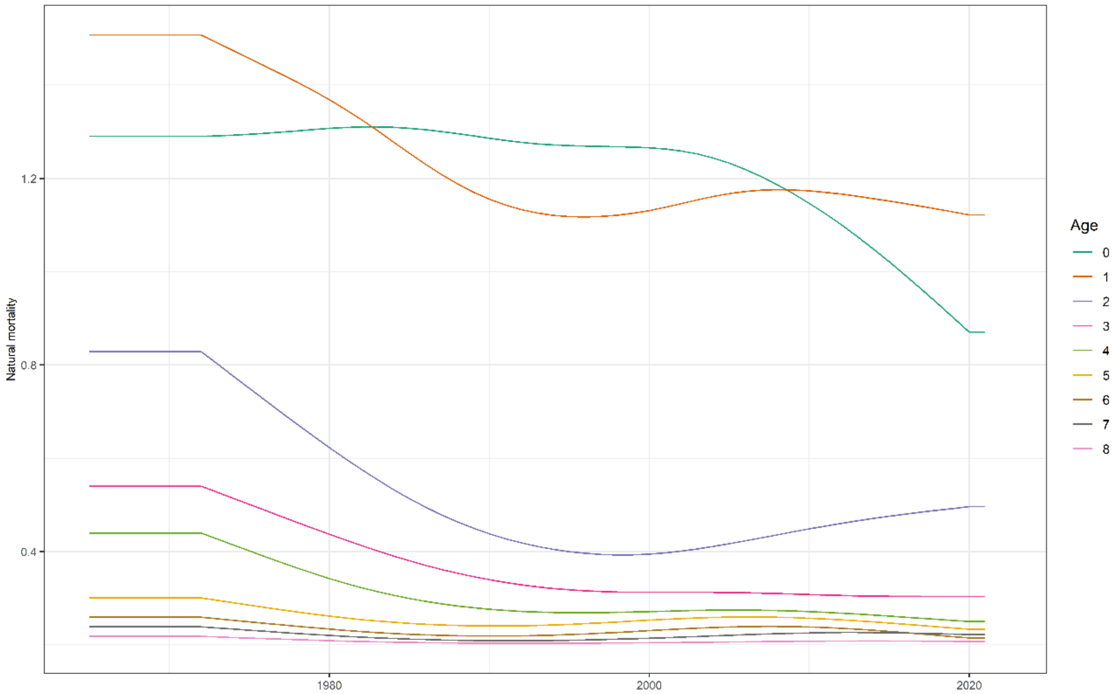


Figure 8.2.9. Haddock in Subarea 4, Division 6.a and Subdivision 20. Time series of estimated natural mortality at age (0-8+), from ICES WGSAM (ICES, 2021).

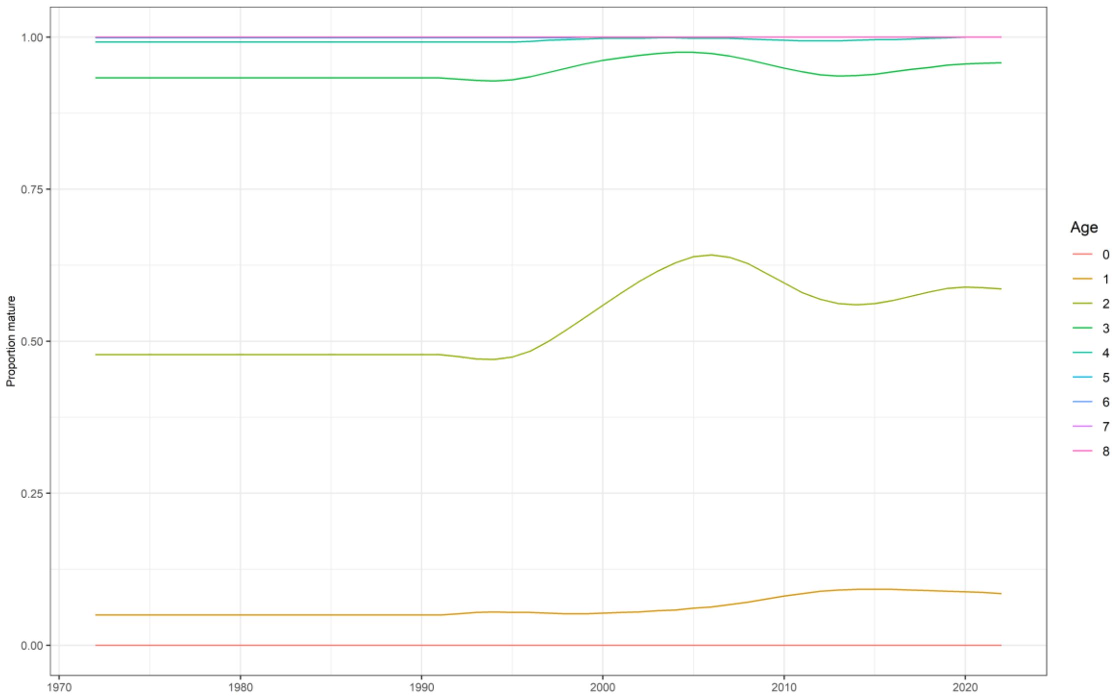


Figure 8.2.10. Haddock in Subarea 4, Division 6.a and Subdivision 20. Time series of estimated maturity-at-age (0-8+).

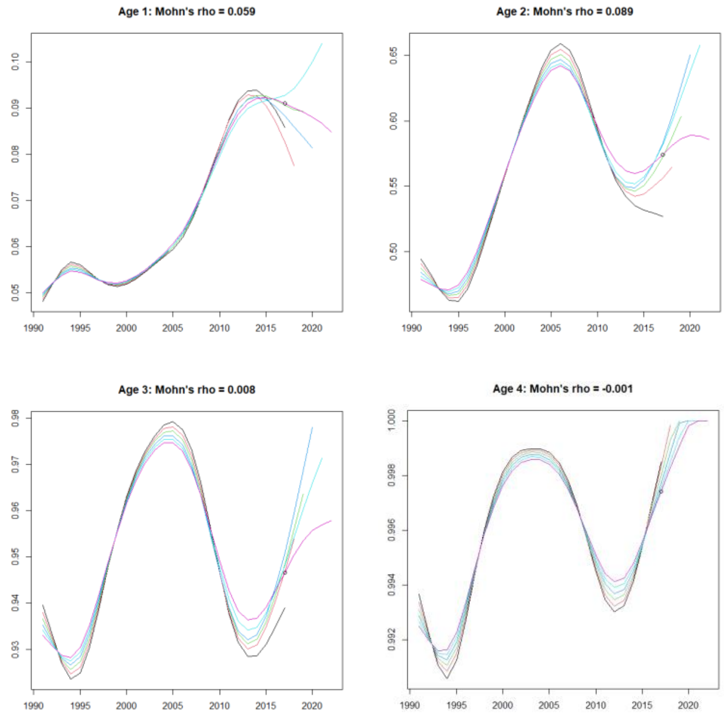


Figure 8.2.11. Haddock in Subarea 4, Division 6.a and Subdivision 20. Retrospective analysis of maturity time series for ages 1-4.

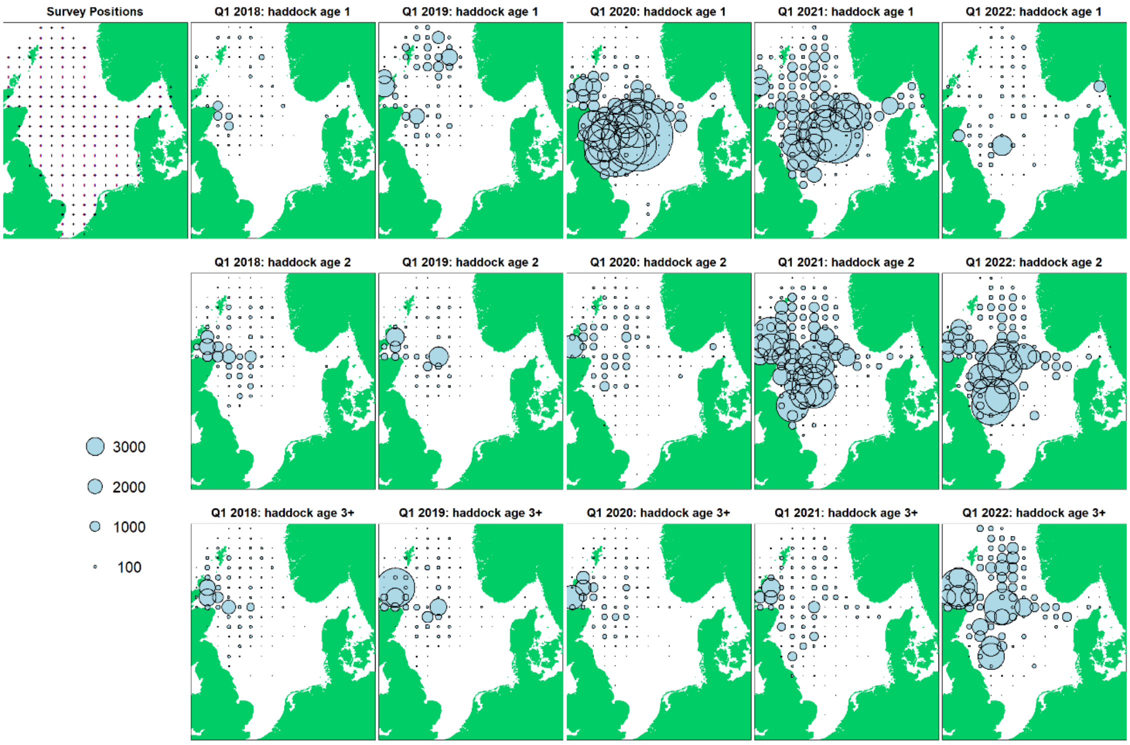


Figure 8.2.12. Haddock in Subarea 4, Division 6.a and Subdivision 20. Survey distributions by age for the international IBTS Q1 survey (North Sea).

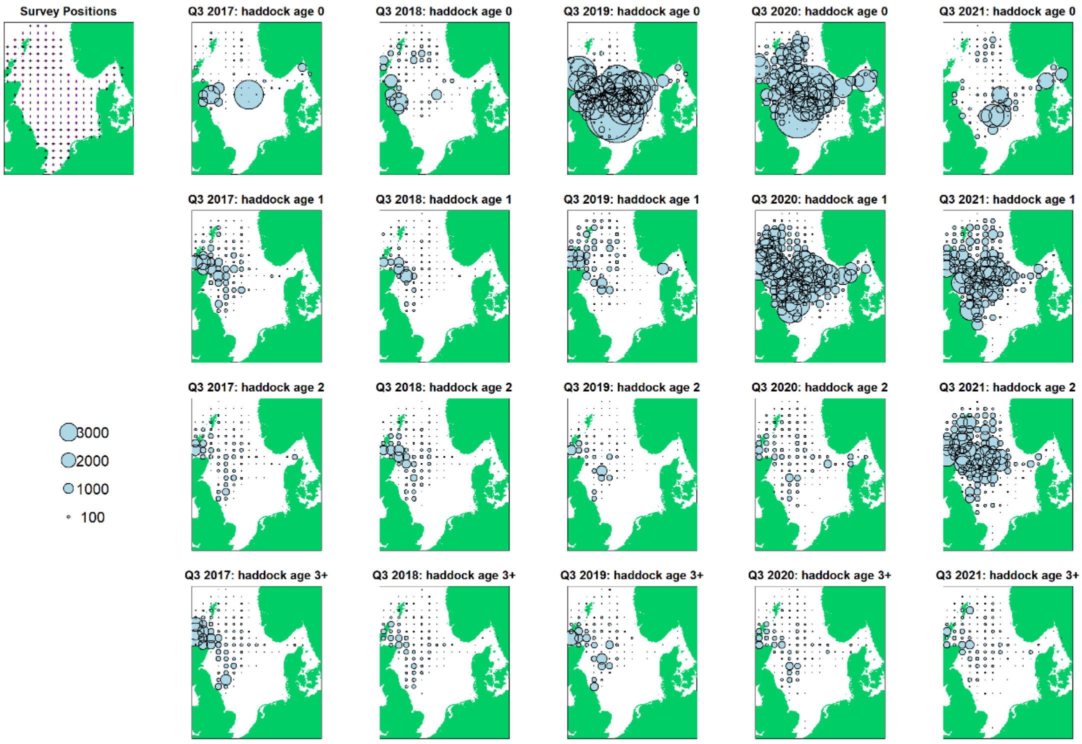


Figure 8.2.13. Haddock in Subarea 4, Division 6.a and Subdivision 20. Survey distributions by age for the international IBTS Q3 survey (North Sea).

Figure 8.2.14. Haddock in Subarea 4, Division 6.a and Subdivision 20. Delta-GAM survey indices for NS-WC Q1 and NS-WC Q3+Q4.

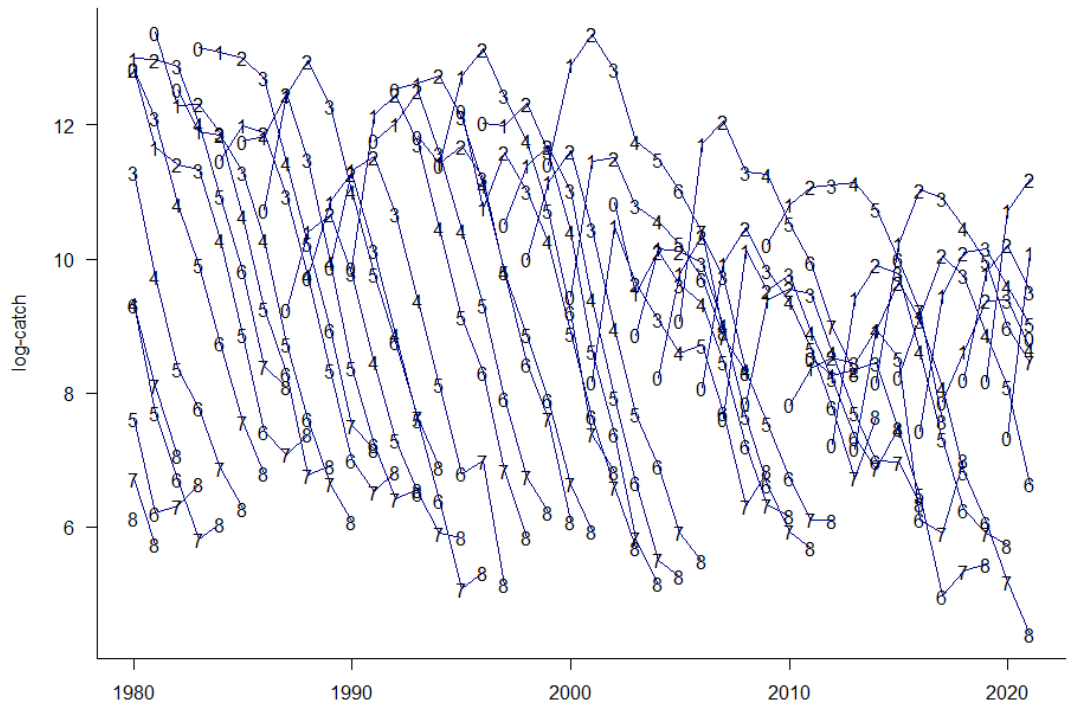


Figure 8.3.1. Haddock in Subarea 4, Division 6.a and Subdivision 20. Log catch curves by cohort for total catches.

Figure 8.3.2. Haddock in Subarea 4, Division 6.a and Subdivision 20. Negative gradients of log catches per cohort, averaged over ages 2–4. The x-axis represents the spawning year of each cohort.

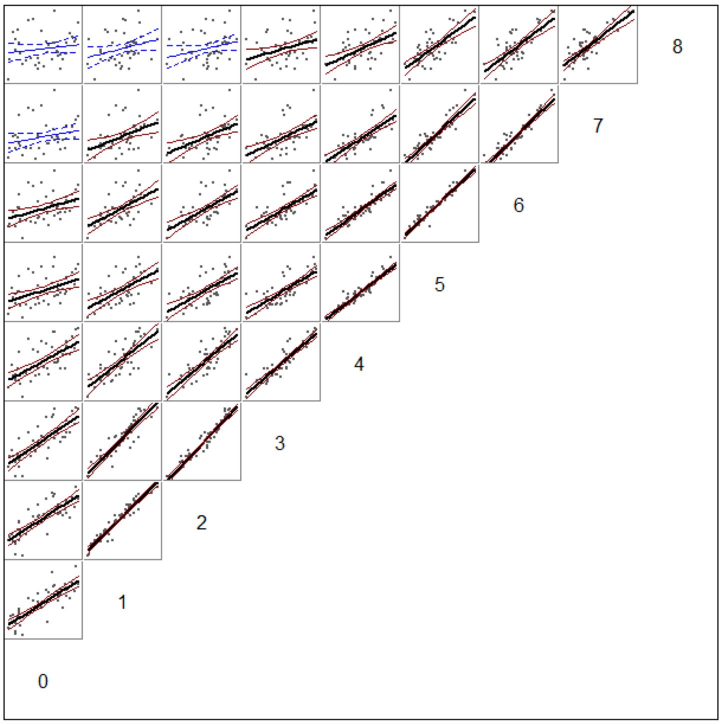


Figure 8.3.3. Haddock in Subarea 4, Division 6.a and Subdivision 20. Correlations in the catch-at-age matrix (including the plus-group for ages 8), comparing estimates at different ages for the same year-classes (cohorts). In each plot, the straight line is a normal linear model fit: a thick line (and black points) represents a significant ($p < 0.05$) regression, while a thin line (and blue points) is not significant. Approximate 95% confidence intervals for each fit are also shown.

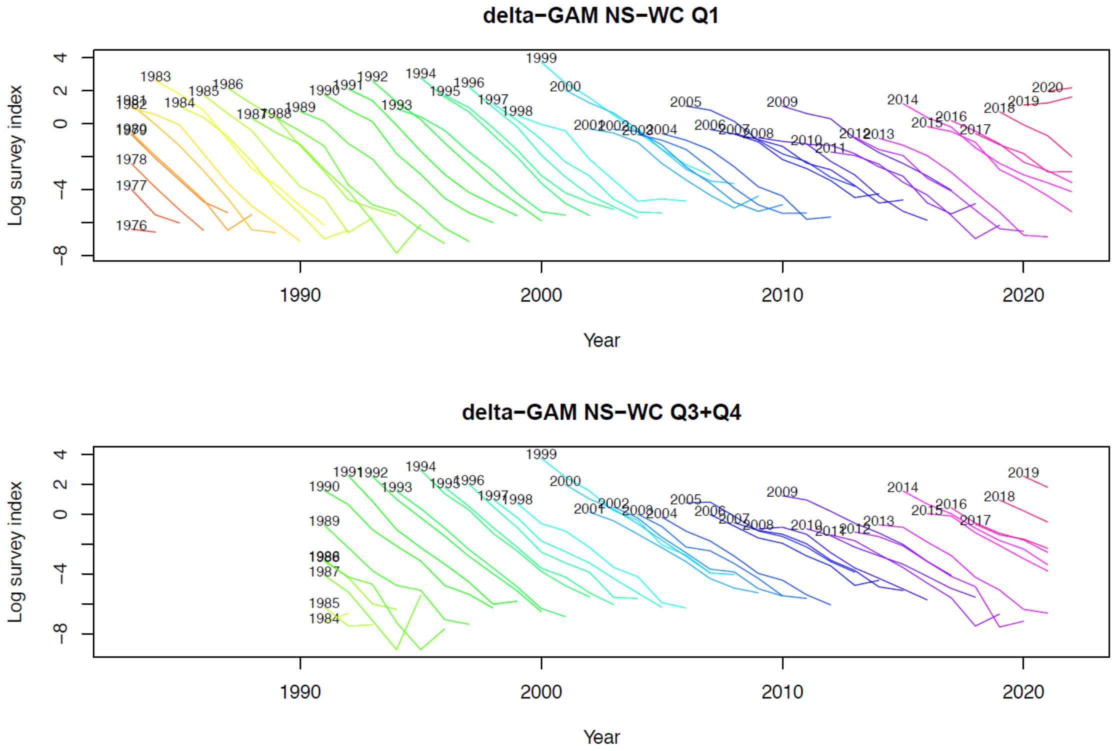


Figure 8.3.4. Haddock in Subarea 4, Division 6.a and Subdivision 20. Log abundance indices by cohort (survey "catch curves") for each of the survey indices.

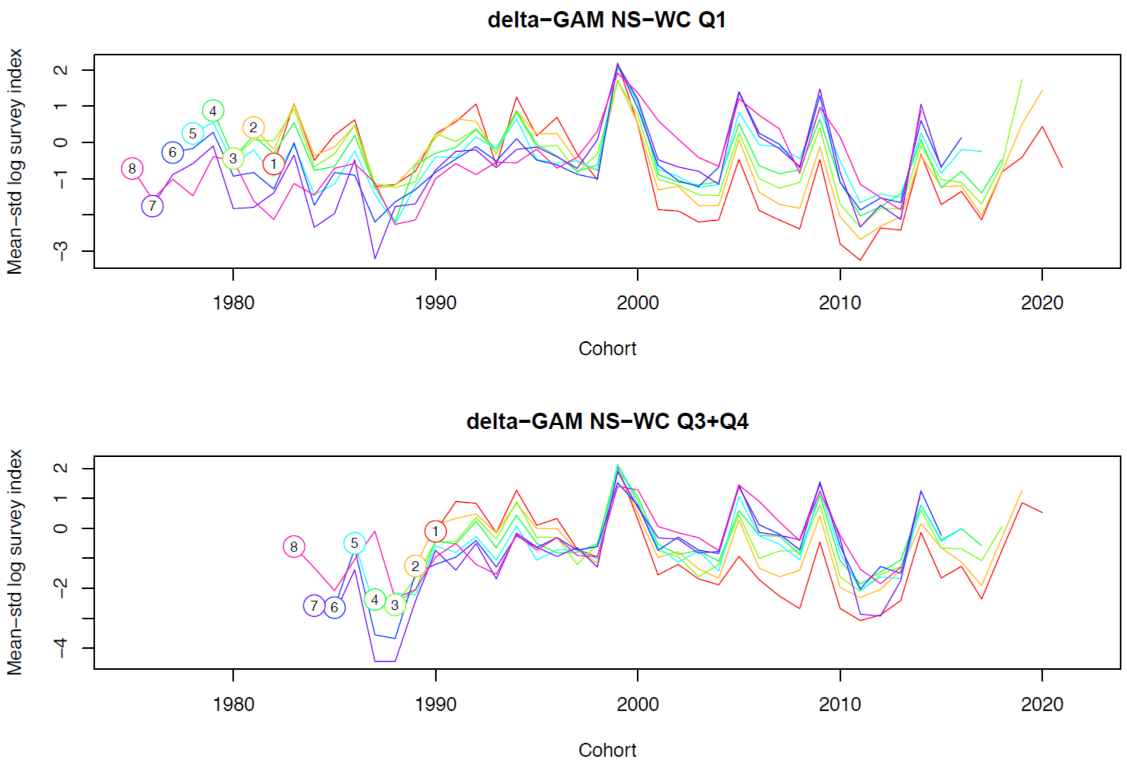


Figure 8.3.5. Haddock in Subarea 4, Division 6.a and Subdivision 20. Mean-standardised log abundance indices by age and cohort for each of the survey indices. The age represented by each line is indicated by a circled number at the start of the line.

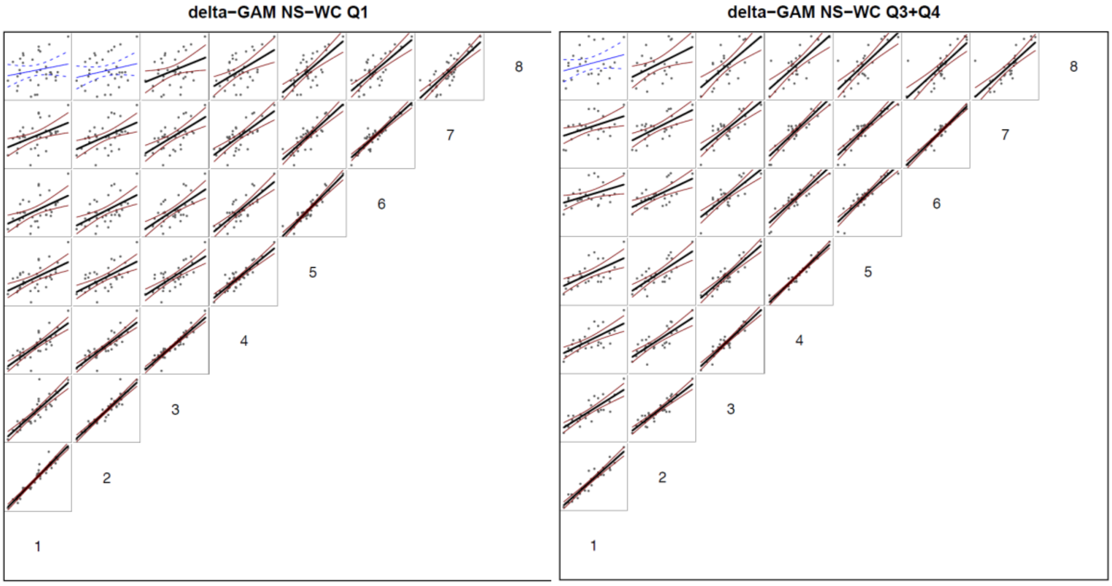


Figure 8.3.6. Haddock in Subarea 4, Division 6.a and Subdivision 20. Within-survey correlations for the delta-GAM NS-WC Q1 (upper) and Q3+Q4 (lower) survey series, comparing index values at different ages for the same year-classes (cohorts). In each plot, the straight line is a normal linear model fit: a thick line (with black points) represents a significant ($p < 0.05$) regression, while a thin line (with blue points) is not significant. Approximate 95% confidence intervals for each fit are also shown.

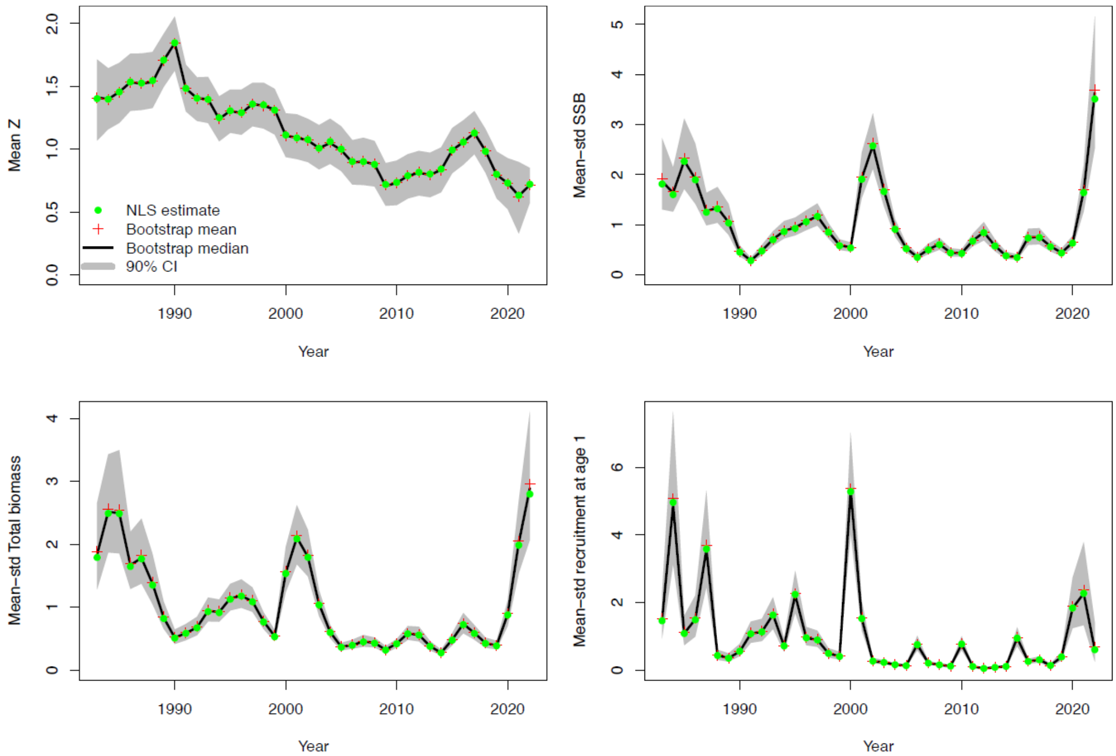
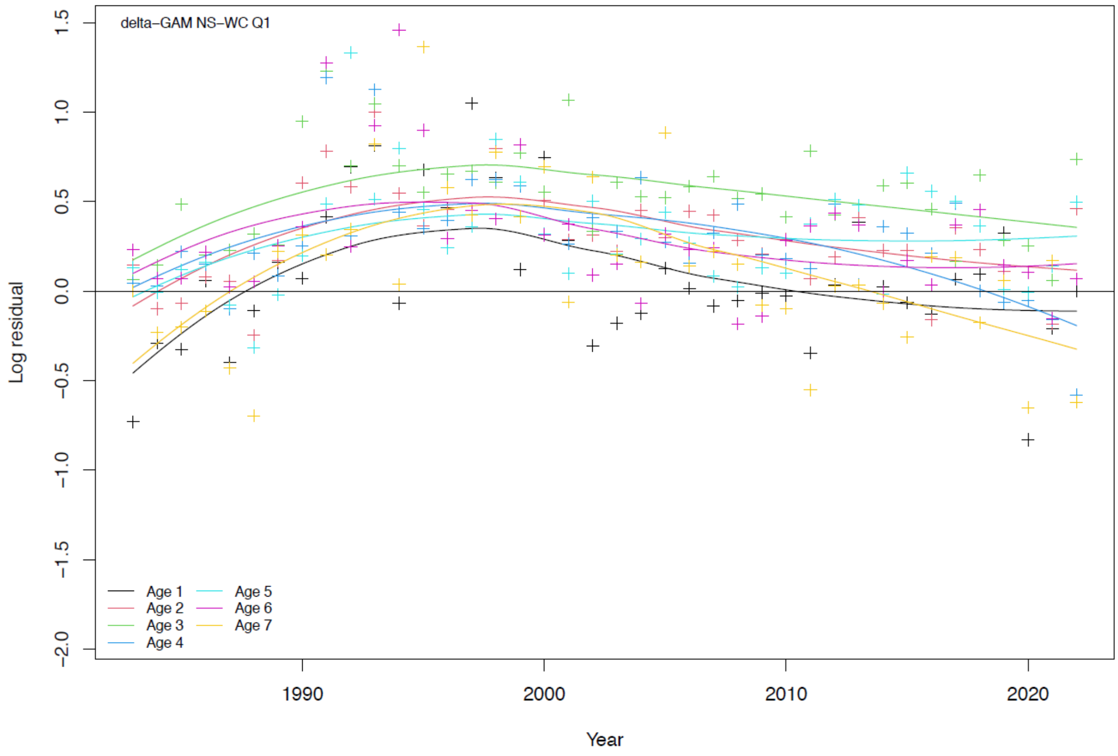


Figure 8.3.7. Haddock in Subarea 4, Division 6.a and Subdivision 20. Summary plots from an exploratory SURBAR assessment, using both available survey derived indices (delta-GAM NS-WC Q1 and delta-GAM NS-WC Q3+Q4). Mean mortality Z (ages 2 to 4), relative spawning stock biomass (SSB), relative total biomass (TSB), and relative recruitment. Shaded grey areas correspond to the 90% CI. Green points give the model estimates, while red crosses and black lines give (respectively) the mean and median values from the uncertainty estimation bootstrap.



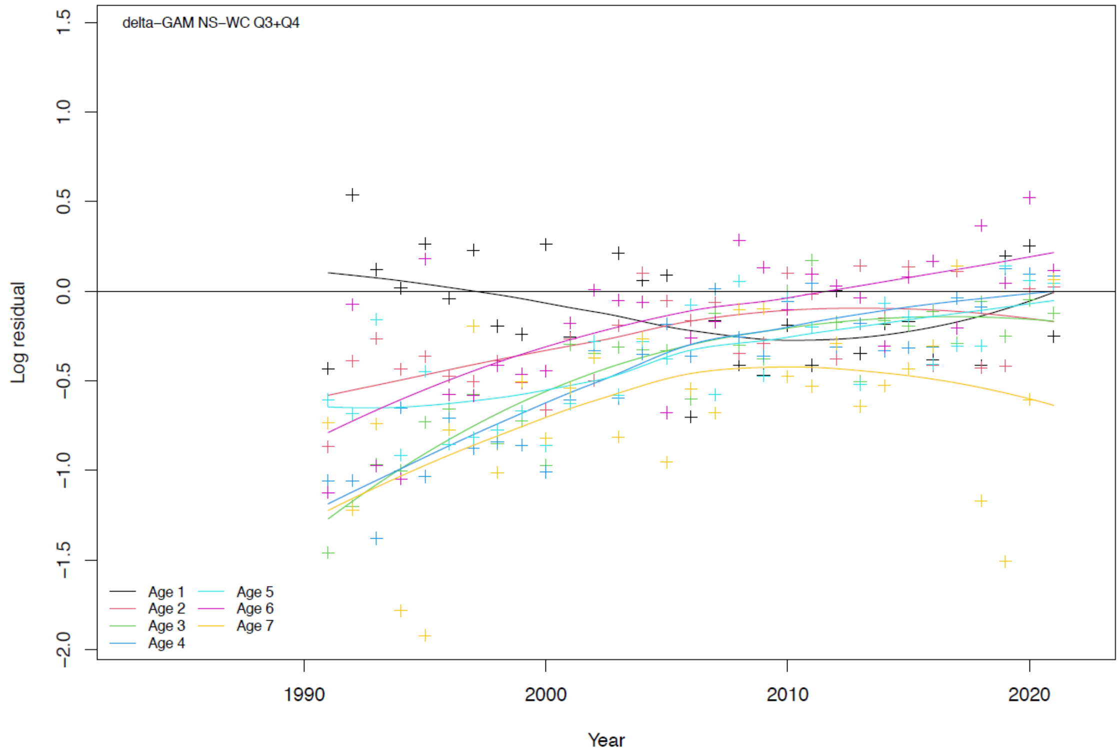


Figure 8.3.8. Haddock in Subarea 4, Division 6.a and Subdivision 20. Log residuals by age from an exploratory SURBAR assessment, using both available survey derived indices (delta-GAM NS-WC Q1 and delta-GAM NS-WC Q3+Q4).

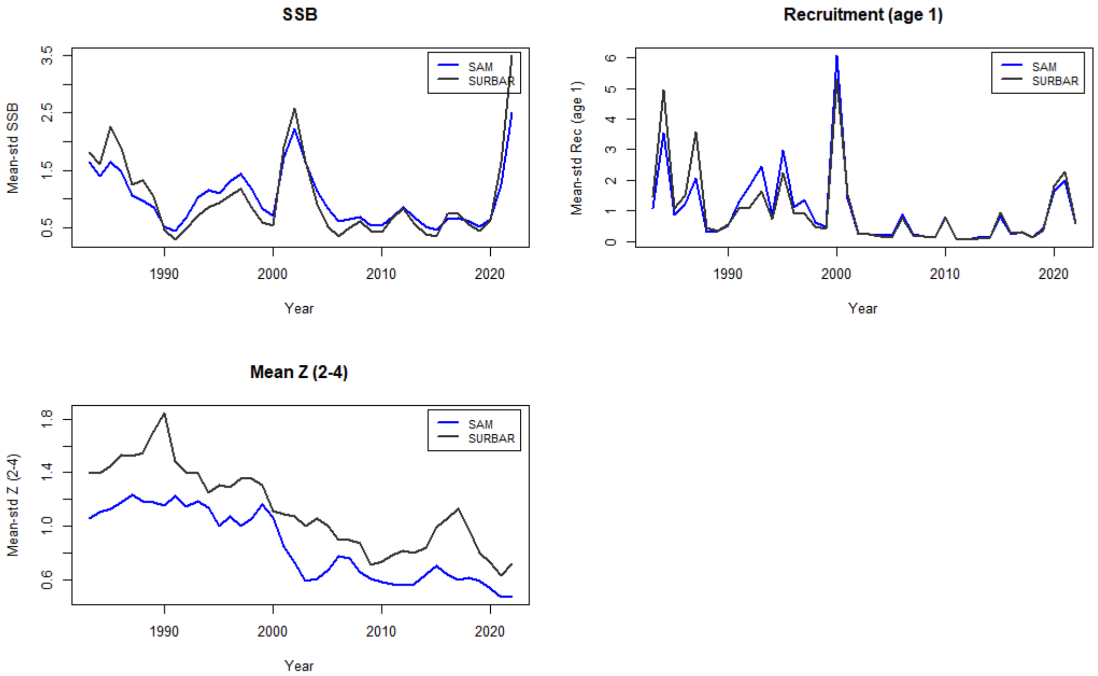


Figure 8.3.9. Haddock in Subarea 4, Division 6.a and Subdivision 20. Comparisons of stock summary estimates from SAM (blue) and SURBAR (black) models. To facilitate comparison, SSB and recruitment values have been mean-standardised using the year range for which estimates are available from all three models, and a composite Z estimate has been made for SAM by adding natural and fishing mortality estimates.

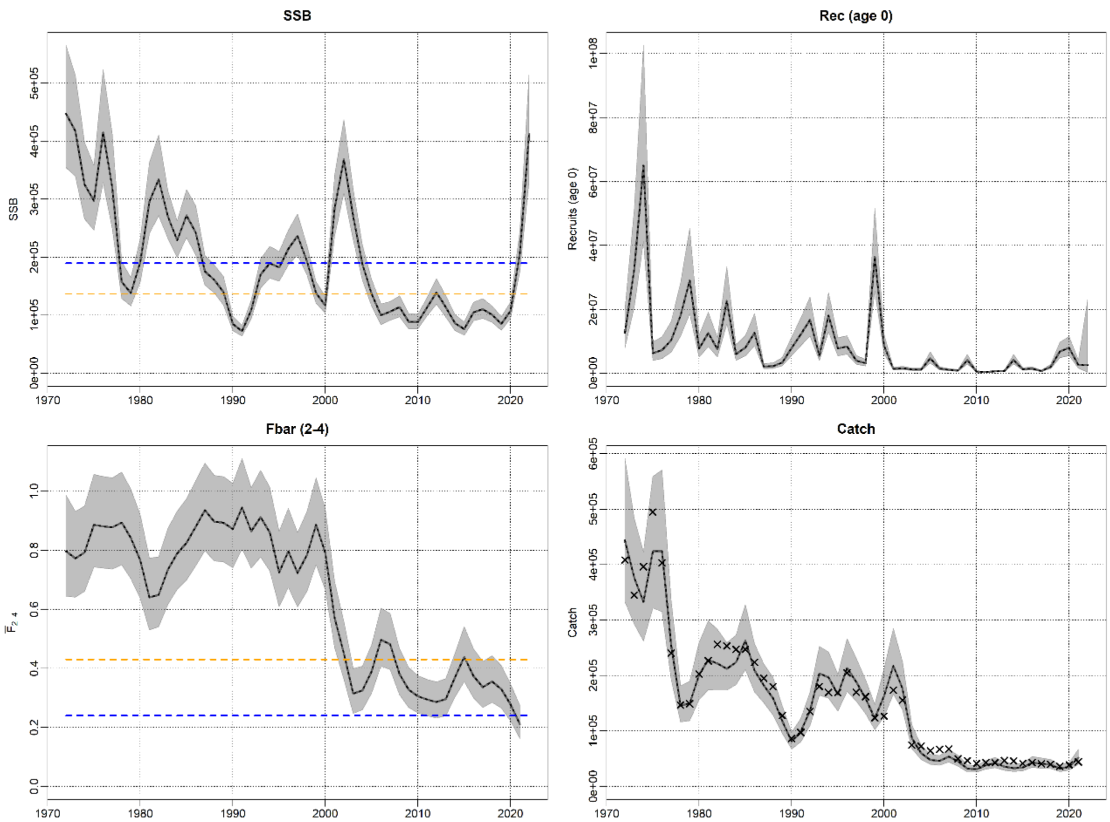


Figure 8.3.10. Haddock in Subarea 4, Division 6.a and Subdivision 20. Stock summary from final SAM assessment. Black lines give the assessment estimates for spawning stock biomass (SSB; tonnes), fishing mortality (Fbar, ages 2-4), recruitment (age 0; thousands) and total catch (tonnes). Grey shading indicates the pointwise 95% confidence intervals, and black crosses give observed values for total catch. Horizontal dashed lines indicate various reference points in relation to SSB (B_{lim} in orange, MSY $B_{trigger}$ in blue) or fishing mortality (F_{lim} in orange, F_{MSY} in blue).

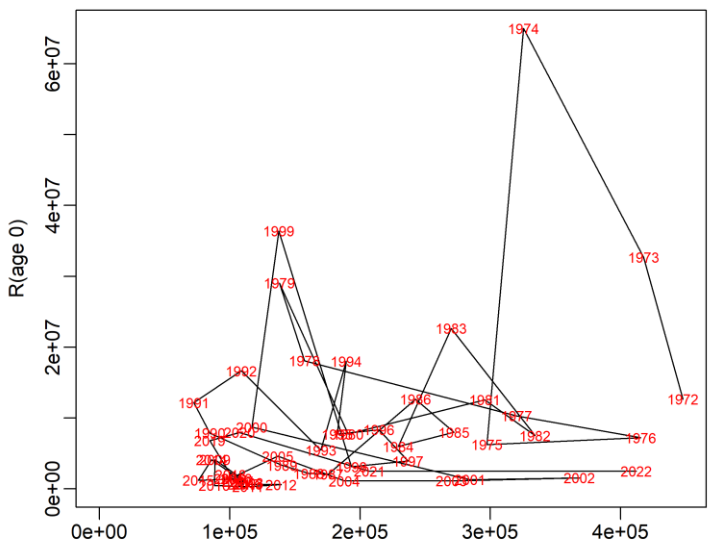


Figure 8.3.11. Haddock in Subarea 4, Division 6.a and Subdivision 20. Stock-recruitment estimates from the final SAM assessment. Points are labelled by year-class.

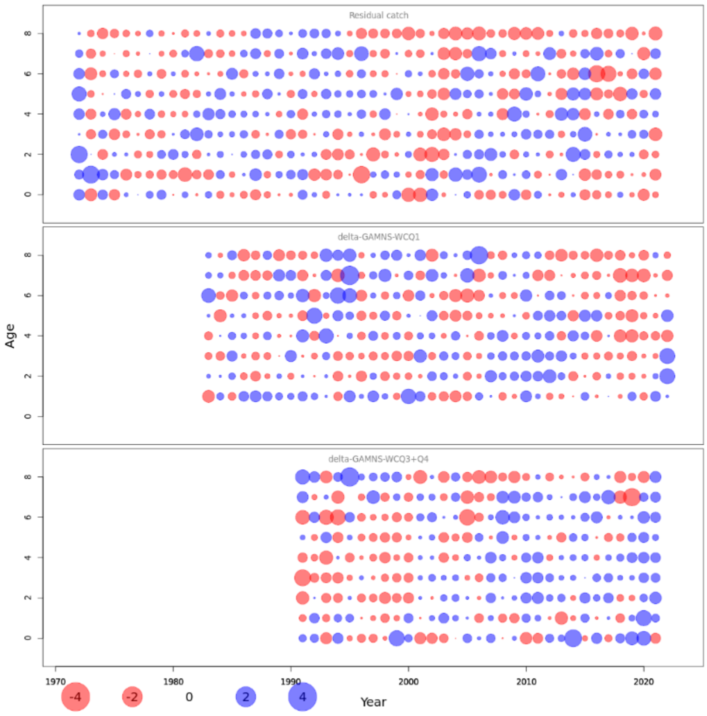


Figure 8.3.12. Haddock in Subarea 4, Division 6.a and Subdivision 20. One-observation-ahead residuals for commercial catch, delta-GAM NS-WC Q1 and delta-GAM NS-CS Q3+Q4 from the final SAM assessment.

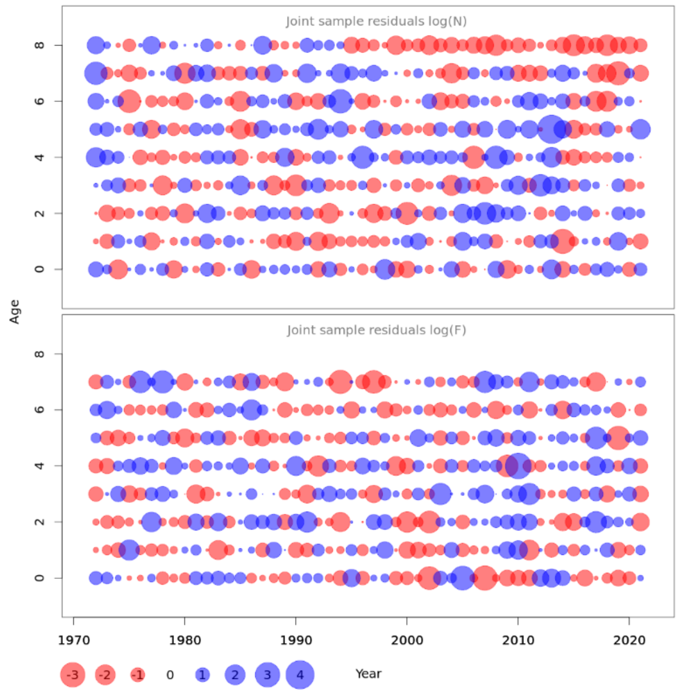


Figure 8.3.13. Haddock in Subarea 4, Division 6.a and Subdivision 20. Residuals for the N-process (survival) and F-process (fishing mortality) from the final SAM assessment.

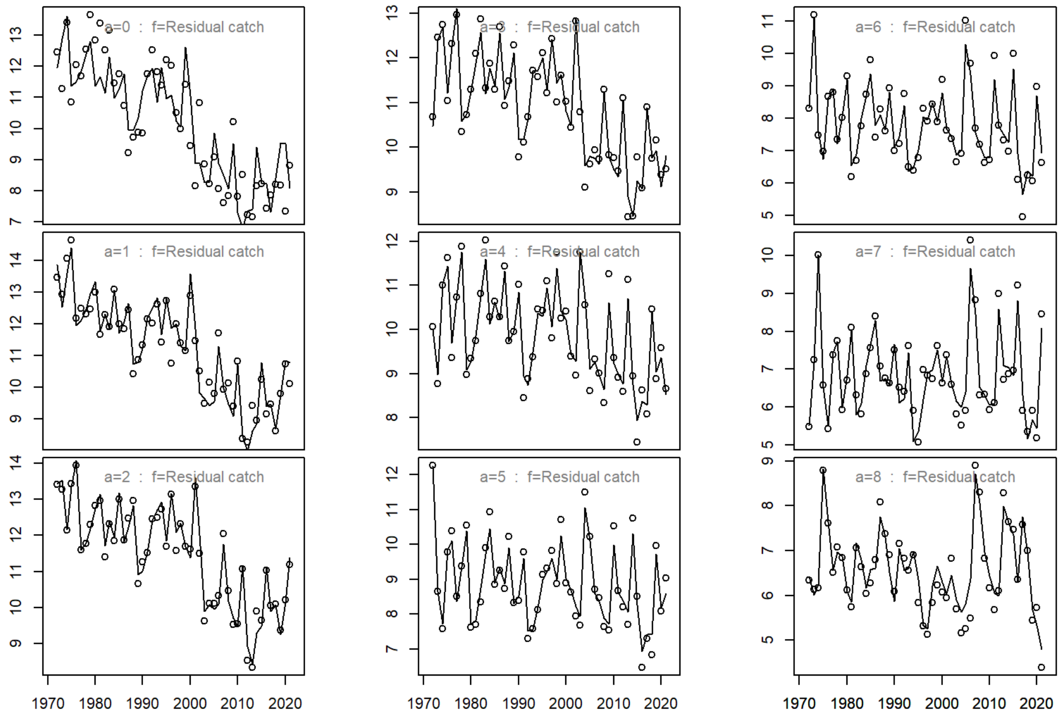


Figure 8.3.14. Haddock in Subarea 4, Division 6.a and Subdivision 20. Time-series of observed (points) and fitted (lines) values for total catch, by age.

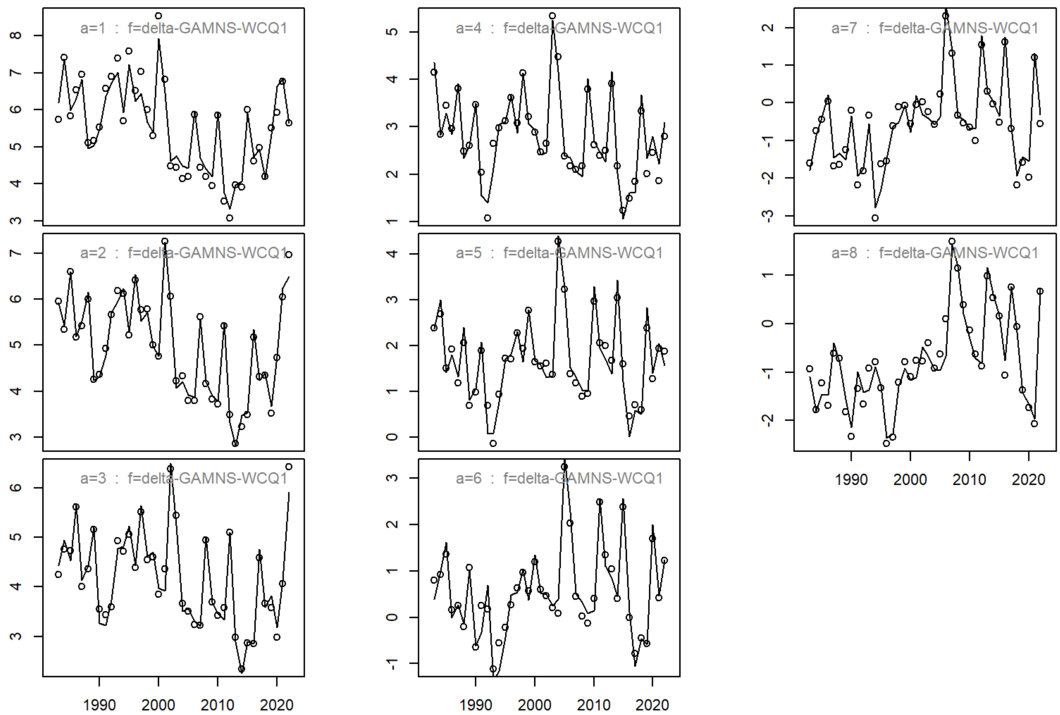


Figure 8.3.15. Haddock in Subarea 4, Division 6.a and Subdivision 20. Time-series of observed (points) and fitted (lines) values for the delta-GAM NS-WC Q1 survey index, by age.

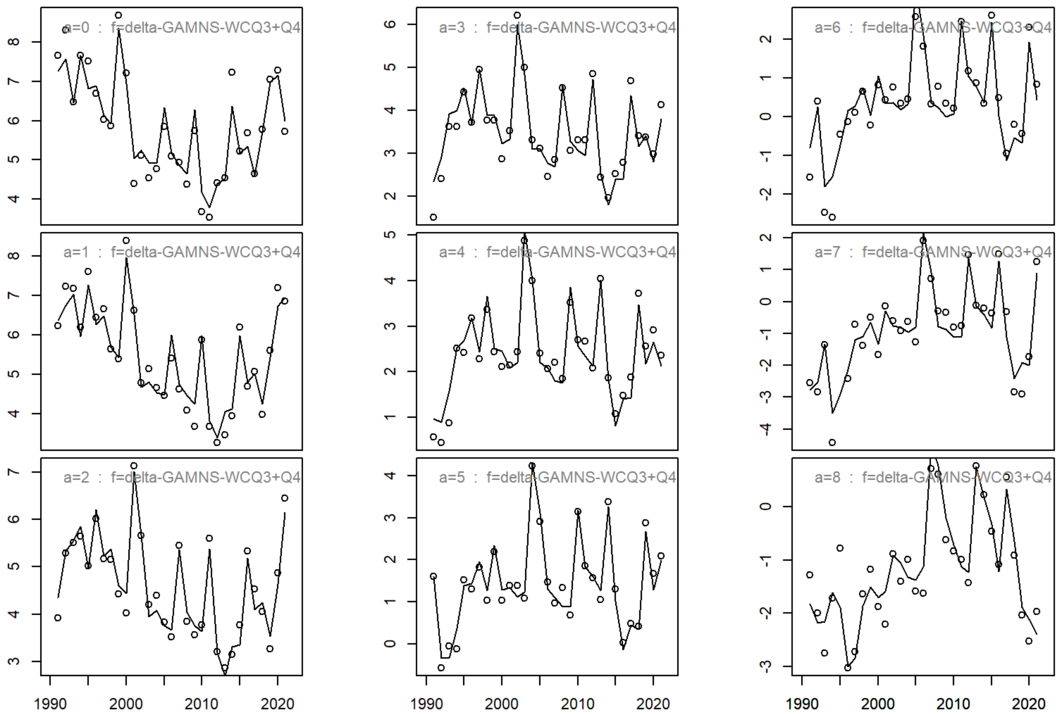


Figure 8.3.16. Haddock in Subarea 4, Division 6.a and Subdivision 20 Time-series of observed (points) and fitted (lines) values for the delta-GAM NS-WC Q3+Q4 survey index, by age.

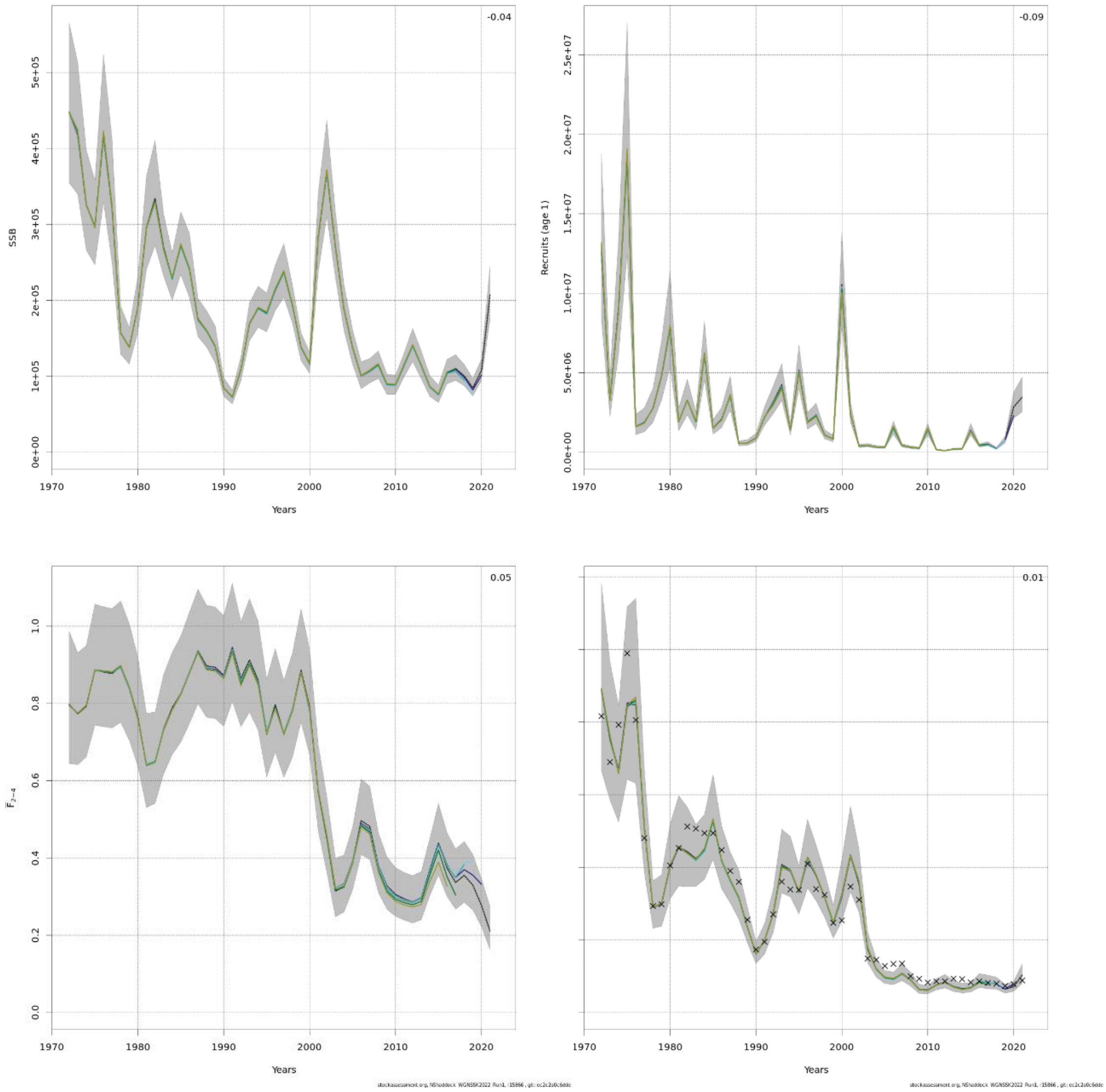


Figure 8.3.17. Haddock in Subarea 4, Division 6.a and Subdivision 20 Leave one out analysis results for spawning stock biomass (SSB; tonnes), fishing mortality (Fbar, ages 2-4), recruitment (age 0; thousands) and total catch (tonnes) from the final SAM assessment.

Figure 8.3.18. Haddock in Subarea 4, Division 6.a and Subdivision 20. Retrospective plots for the SAM assessment. The final-year run is shown in black with the pointwise 95% confidence interval indicated by the grey shading, while retrospective peels are shown with coloured lines. Mohn's rho estimates are given in the top right of each plot.

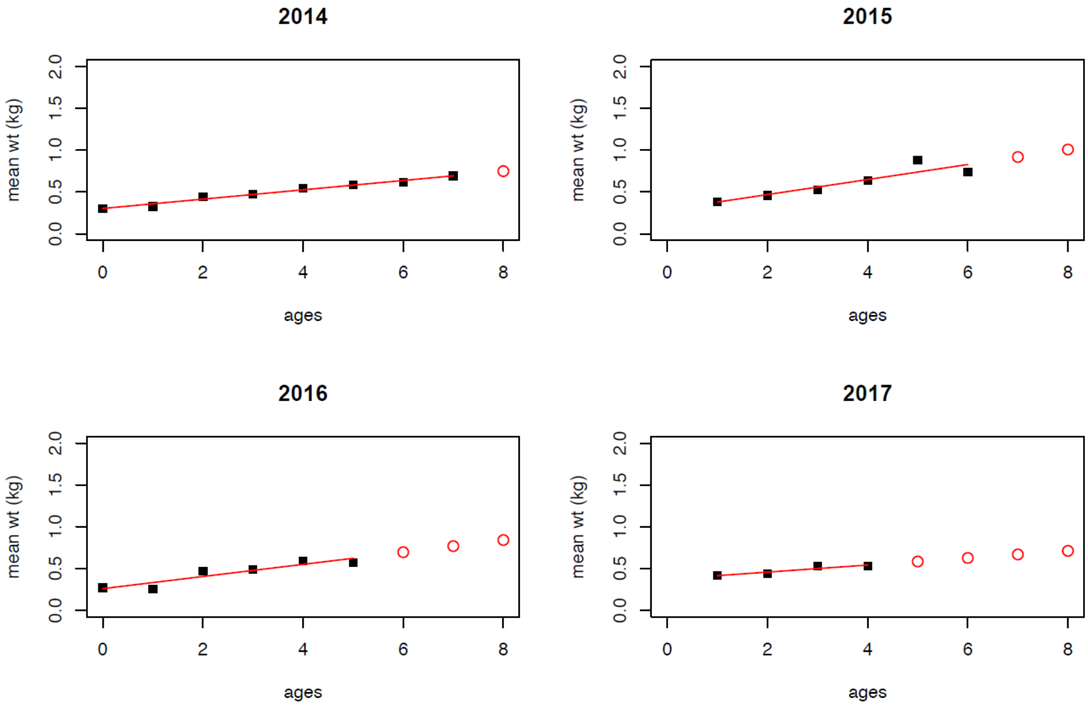


Figure 8.6.1. Haddock in Subarea 4, Division 6.a and Subdivision 20. Results of growth modelling for landings mean weights-at-age using cohort-based linear models (Jaworski, 2011). Cohorts 2014–2017 are shown here. Black points are available observations, red solid lines show linear fits to these points, and red points indicate projected weights for older ages.

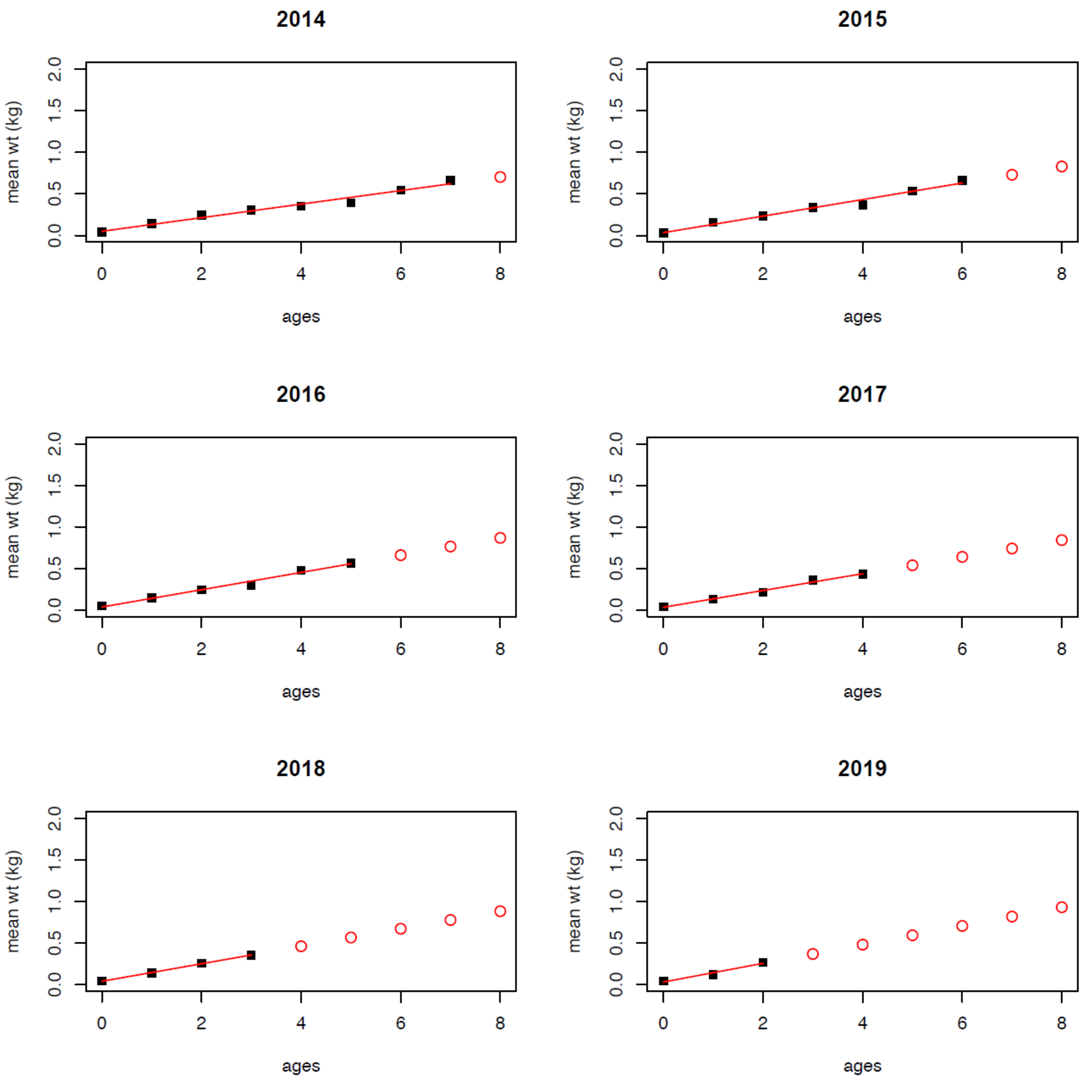


Figure 8.6.2. Haddock in Subarea 4, Division 6.a and Subdivision 20. Results of growth modelling for discards+IBC+BMS mean weights-at-age using cohort-based linear models (Jaworski, 2011). Cohorts 2014–2019 are shown here. Black points are available observations, red solid lines show linear fits to these points, and red points indicate projected weights for older ages.

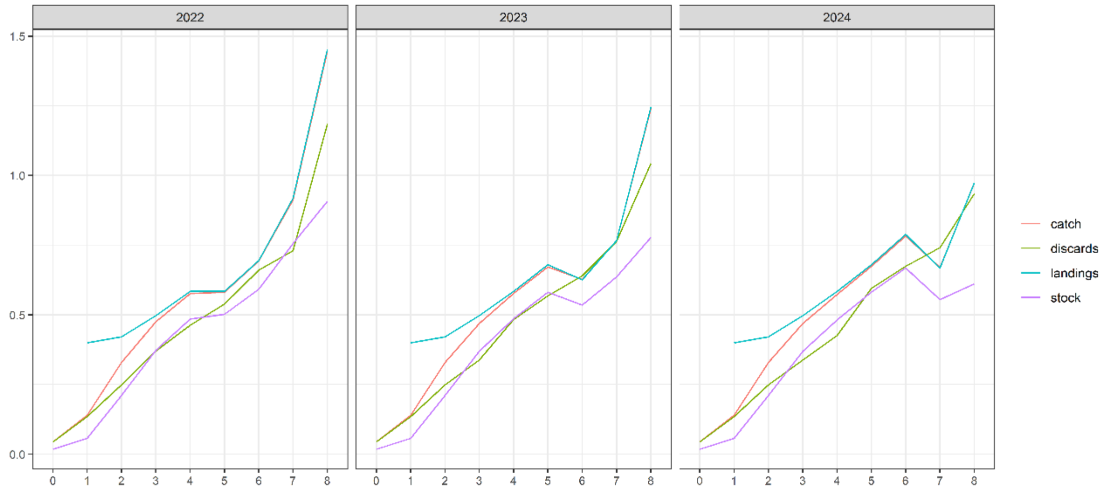


Figure 8.6.3. Haddock in Subarea 4, Division 6.a and Subdivision 20. Mean weights-at-age used in the forecast for total catch, landings, discards (including IBC and BMS) and the stock (discards + BMS).

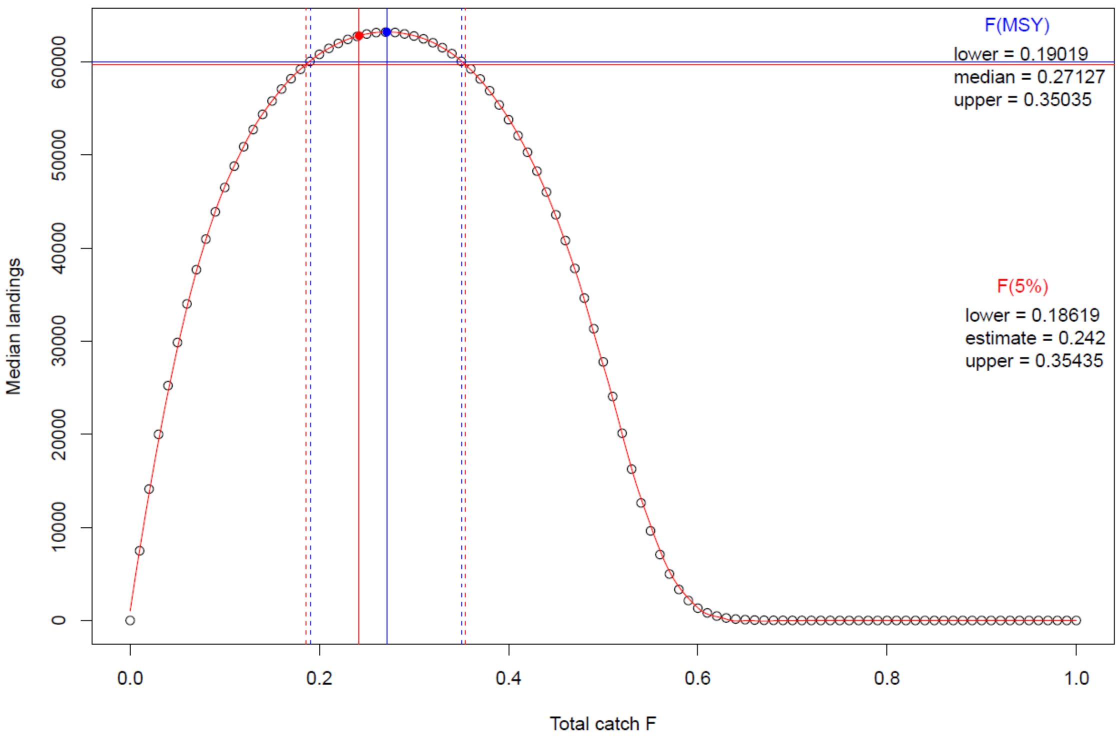


Figure 8.8.1. Haddock in Subarea 4, Division 6.a and Subdivision 20. Results of EqSim estimation from WKNSCS 2022 of $F_{(MSY)}$ with the assessment/advice error but no rule and of $F_{p.05}$ with both assessment/advice error and rule.

9 Lemon sole in Subarea 4, divisions 3.a and 7.d (North Sea, Skagerrak, Kattegat and Eastern English Channel)

9.1 General

The assessment of North Sea lemon sole (*Microstomus kitt*) was subject to a benchmark during the winter of 2017–18 (ICES WKNSEA, 2018). In summary, the benchmark concluded the following:

- There were insufficient age samples submitted to InterCatch to allow for a full age-structured catch-based assessment. InterCatch collation was therefore conducted on the basis of length.
- Age-structured survey indices were developed using GAM estimation (Berg *et al.* 2014), for Q1 (IBTS; ages 1–5, years 2007-present) and Q3 (IBTS and BTS; ages 1–9, years 2005–present). Only ages 2–5 for the Q1 survey were used in the assessment, due to very low sample sizes for age-1 lemon sole in the Q1 IBTS survey.
- Maturity-at-age was fixed through time (based on IBTS Q1 samples), while weights-at-age were based on smoothly-varying observations from both IBTS Q1 and Q3.
- The stock assessment model used for the basis of the advice was SURBAR (Needle, 2015), including *ad hoc* adjustments for the observed low catchability of the available surveys for age 1 and 2 lemon sole.
- The advice was based on the DLS 3.2 rule, applied to relative SSB estimates provided by SURBAR.
- Stock status in relation to F_{MSY} proxies was evaluated using a suite of length-based indicators (LBIs).

Stipulations 1-3 and 6 have been followed in this year's WGNSSK update assessment. However, while SURBAR is still used as an exploratory assessment method, the basis for the advice has now been changed to the new WKLIFE X DLS process (ICES, 2020) applied to an empirical biomass index from the IBTS Q1 survey. The DLS 3.2 rule is no longer used for this stock. This change will be reviewed after the WG meeting, prior to the finalisation of the advice in late June 2022.

This is the eighth year in which the stock status for lemon sole has been evaluated by WGNSSK. Lemon sole has been defined as a category 3 species according to the ICES guidelines for data limited stocks (ICES, 2012). The assessment presented in the 2019 WGNSSK report (ICES, WGNSSK 2019) provided the basis for advice for 2020 and 2021. Subsequently, advice on lemon sole has been requested on an annual basis. The outcome of the current assessment will be used to provide new catch advice for 2023.

9.1.1 Biology and ecosystem aspects

Lemon sole is a commercially important flatfish that is found in the shelf waters of the North Atlantic from the White Sea and Iceland southwards to the Bay of Biscay. Lemon sole spawn for a lengthy period in the North Sea, starting as early as April in the north and ending as late as November in the south (Rae, 1965). In the western English Channel, lemon sole spawn in April and May (Jennings *et al.,* 1993). In the English Channel, investigations of habitat association for plaice, sole and lemon sole have indicated that distribution is restricted to a few sites and that lemon soles appear to prefer sandy and gravely strata, living deeper, at higher salinities and lower temperatures than plaice or sole (Hinz *et al*., 2006). Lemon sole feed on small invertebrates, mainly polychaete worms, bivalves and crustaceans.

9.1.2 Stock ID and possible assessment areas

There is no information available on lemon sole stock identity for the greater North Sea (including the Skagerrak and eastern English Channel areas), and the assessment is assumed to cover one unit stock.

9.1.3 Management regulations

No specific management objectives are known to ICES. An EU TAC is set for EU waters of ICES Division 2.a and Subarea 4, which is a joint TAC together with witch flounder (ICES, 2013). ICES provided advice to the EU in 2018 whether several stocks (including lemon sole) should continue to be managed through TAC and quota regulations (see Annex 11 of ICES WGNSSK, 2018). This concluded that the TAC for lemon sole could be removed, or if maintained that a single-species lemon sole TAC would be more appropriate. However, the joint TAC with witch flounder continues to be the basis for management.

9.2 Fisheries data

9.2.1 Officially-reported landings

Both in the North Sea and in the Skagerrak and Kattegat, lemon sole is mainly a by-catch species in the fisheries for mixed demersal stocks and for plaice. Officially-reported landings in ICES Division 7.d, Subarea 4 and Division 3.a are shown in Figures 9.2.1 to 9.2.4, and in Tables 9.2.1 to 9.2.4. The time-series of officially-reported landings is not fully complete, and a number of countries have gaps in data provision.

9.2.2 ICES estimates of landings and discards

Investigations into the then-extant data for the WKNSEA data meeting (November 2017) suggested that there would be insufficient age samples to permit an age-structured catch-based assessment, so the subsequent data calls and collations have focussed on length-based data.

Commercial catch data were raised to fleet and country level using InterCatch. The benchmark meeting (ICES WKNSEA, 2018) discussed whether areas should be considered separately for raising discards and length compositions, but the prevailing view was that there was no evidence of distinct stocks between areas and that therefore all areas should be treated together for raising. Initial exploration demonstrated that the final discard raising was significantly influenced by a small number of métiers with discard ratios greater than 1.5 (in other words, those métiers for which discards/landings > 1.5). Subsequently, these métiers were discounted in calculating raising factors as they were thought to be non-representative for a high-value stock such as lemon sole. Otherwise, discards for all unsampled fleets were inferred by a discard rate generated using all sampled fleets (weighted by the landings CATON), as it was not thought likely that discard rates for an (essentially) bycatch stock would vary a great deal between different métiers (apart from the extreme and unrepresentative examples discussed above).

Length-distribution allocations were conducted in the same way (weighted by mean numbers at length), with the only distinction being made between landings and discards. Length samples are reasonably well-spread across the main countries catching lemon sole, and length-based allocations are likely to be sufficiently representative.

Both BMS (Below Minimum Size) landings and logbook-recorded discards were included with discards for length-allocation purposes as the length distributions are likely to be similar. For the years 2019-2021, there were no submissions for logbook-recorded discards (0 tonnes). Only Scotland provided submissions of BMS landings for 2019 (a total of 0.224 tonnes for area 4), whilst only England submitted data for 2020 (a total of 0.216 tonnes for area 4) and 2021 (0.021 tonnes for area 4, and 0.008 tonnes for area 7d).

There were no noted revisions to InterCatch submissions for years prior to 2021.

InterCatch summary plots are given in Figures 9.2.5 to 9.2.8. The resultant estimates for landings and discards for 2002–2021, along with official landings for 1968–2021, are given in Table 9.2.5 and Figure 9.2.9. We note that the official landings for 2012 did not include estimates for the UK, which is why they are considerably lower than the InterCatch estimates. It can also be seen that the 2013 discard estimate is very high – the problem appears to originate in the discard estimates provided by the Netherlands, but it has not yet been possible to address this error. The abundances at length in the Dutch submissions are an order of magnitude higher than for any other year or country, for fish less than 210 mm. This gives rise to the high discard estimate in 2013. The issue was avoided in the F_{msy} proxy analysis (see Section 9.6) by removing the 2013 data, but this issue has not yet been addressed for the yield analysis.

In the North Sea, eastern English Channel and Skagerrak, lemon sole are managed using a combined TAC with witch flounder (see Section 24). The ICES estimates of landings for lemon sole and witch are compared with the joint TAC in Figure 9.2.10, which shows that the joint TAC is underutilised for most years since 2006. However, as in recent years, ICES recommends that a joint TAC for lemon sole and witch is unlikely to be effective in controlling mortality on either species.

9.3 Survey data series

9.3.1 Stock distributions

Figure 9.3.1 displays the distribution of the abundance of lemon sole in the greater North Sea obtained from IBTS Q1 (2022) and IBTS Q3 data (2021). Generally, the highest concentrations of lemon sole occur in the central to northern areas of the North Sea. The IBTS Q1 survey was impacted by problems with weather and vessel reliability in 2022, as can be seen by the reduced survey hauls for that year (Figure 9.3.1), but the remaining survey hauls are thought to have been sufficiently representative of overall lemon sole abundance and density.

9.3.2 Maturity and weights-at-age

Following the Stock Annex, maturities were assumed to be fixed through time and set to the following values by age:

Age	Prop. Mature
1	0.00
2	0.72
3 and older	1.00

Weights-at-age were also estimated following the Stock Annex procedure. The mean weights at each age and year were calculated from data in the SMALK dataset of the IBTS Q1 and Q3 series (ICES DATRAS 2019). For each age, the time-series of available weights were plotted together, positioned so that Q1 weights were at *y*+0.25 and Q3 weights at *y*+0.75 (additional mean points were added at the start of each time-series to enable extrapolation). A loess smoother (span = 1) was then fitted through all points for each age, so that the final estimate was (effectively) a smoothed average of consecutive weight estimates. The fitted values are summarised in Figure 9.3.2 and Table 9.3.1. These are slightly different for several ages from the values estimated by the 2019 WG, due to small changes in several of the weight entries in the SMALK dataset. The reasons for these are unknown, but are likely to be due to updated weight-length keys used within DATRAS. We also note that estimates for 2022 are included here: these are not currently used in the stock assessment which concludes in 2021, but they are included for completeness.

Natural mortality (*M*) estimates for lemon sole are not available. For current advisory purposes, however, estimates of *M* are not required, as the assessment is survey-based and hence estimates total mortality *Z*.

9.3.3 Relative abundance indices

The GAM estimation approach (Berg *et* al 2014) was used by WGNSSK to generate updated Q1 (IBTS) and Q3 (IBTS and BTS) survey series for lemon sole. The new series are summarised in Table 9.3.2 and Figures 9.3.3 (bivariate scatterplots), 9.3.4 (catch curves), and 9.3.5 (time series by age and cohort). These summaries indicate that the ability of the survey indices (particularly Q1) to track year-class strength is very limited. For example, in Figure 9.3.3, most of the pairwise comparisons do not show significant correlations (and some comparisons are negative).

Not shown here is a significantly negative correlation between age 1 and age 2 for the Q1 (IBTS) index – this suggests that the Q1 (IBTS) age 1 index will give an incorrect impression of subsequent year-class strength, which is likely to be due to very small samples sizes at that age. The Stock Annex for this assessment calls for the full age range (1-5) to be used from the Q1 (IBTS) series. Following the presentation of the exploratory survey analyses at the 2018 meeting, WGNSSK concluded that the age-1 data from the Q1 (IBTS) survey should not be used to indicate stock trends. Therefore, the Q1 (IBTS) survey index was limited to ages 2-5 for assessment purposes at the 2019 meeting, and this has been continued during 2020-2022.

9.4 SURBAR stock assessment

The SURBAR assessment was conducted according to the run-time settings specified in the Stock Annex, namely:

- The age- and year-effect smoother λ was set to 3.
- Mean mortality Z was calculated over ages 3-5.
- The reference age a_r for age-effect estimates was set to 3.
- GAM-estimated survey indices from both Q1 (IBTS) and Q3 (IBTS & BTS) were used.
- Catchability for ages was set as $q_1 = 0.1, q_2 = 0.5$ and q = 1.0 for all older ages. This correction is intended to reduce the impact on the analysis of the observed pronounced "hooks" at the top of the survey catch curves for this stock (see Figure 9.3.4). A proposal for a systematic method of determining catchability corrections to straighten catch curves prior to SURBAR assessment was presented at the WGNSSK 2020 meeting. While promising, this method remains in development and will be revisited in a future WGNSSK meeting.
- No downweighting of ages in the SURBAR SSQ estimation was used.

The SURBAR stock summary is given in Table 9.4.1, and the corresponding output plots are given in Figures 9.4.1 to 9.4.4. The stock summary (Figure 9.4.1) shows that mean Z_{3-5} has remained relatively constant since 2009, although values are very low and the confidence intervals overlap Z = 0 for most years. The catch curves for the surveys (Figure 9.3.4) are domed and very shallow, and remain shallow even when the catchability revision is applied, so SURBAR indicates very low mean Z_{3-5}. Both SSB and TSB are estimated with more certainty than mean Z_{3-5}, and both show steady declines since 2016. Finally, recruitment at age 1 has fluctuated without trend for much of the time series, with indications of steady increase since 2017 (although the uncertainty about those estimates are relatively large).

Log survey residuals (Figures 9.4.2) show that the Q3 index fits the SURBAR model better than the Q1 index, with lower residuals (in general) and less trends through time. Consequently, the assessment is driven more directly by the Q3 index – this is to be expected given the problems with the Q1 index highlighted in Section 9.3.3 above. There are three outliers in the Q3 index (age 1 in 2013 and 2015, age 2 in 2013), but sensitivity runs reducing the SSQ estimation weighting on these points suggested that their influence on likely advice was not significant (ICES WKNSEA, 2018). The parameter estimates are summarised in Figure 9.4.3.

The retrospective analysis in Figure 9.4.4 shows little retrospective bias or noise for any of the key SURBAR outputs. This is a simple retrospective peel, and does not account for any retrospective bias or noise in the delta-GAM index estimation or the calculation of stock weights-at-age. The survey indices from four subsequent WGNSSK meetings are plotted in Figure 9.4.5, which shows good consistency from year to year with the exception of a small step change three years ago. Retrospective patterns in the stock weights-at-age have not been explored, but the overall consistency in survey indices suggests that a true retrospective analysis for lemon sole would be similar to the simple retrospective analysis presented in Figure 9.4.4.

Finally, the run presented here assumes a lambda smoother of 3.0. A low lambda setting ($\lambda = 1.0$) results in large interannual variations in all outputs, driven by survey noise and the difficulty in following cohorts. Increasing the lambda smoother leads to less variation, as expected, and the outputs for $\lambda = 3.0$ and $\lambda = 5.0$ are very similar, increasing confidence that the setting $\lambda = 3.0$ is probably reasonable (increasing lambda further doesn't lead to much change). Further methodological work on systematically defining the appropriate lambda smoother for a given assessment is underway, and will be presented at a future WGNSSK meeting.

9.5 Generating advice for the data-limited lemon sole stock

North Sea lemon sole are currently managed according to the following advice, given in June 2021:

ICES advises that when the precautionary approach is applied, catches in 2022 should be no more than 3081 tonnes.

Management of lemon sole and witch under a combined species TAC prevents effective control of the single-species exploitation rates and could lead to the overexploitation of either species. ICES advises that management should be implemented at the species level in the entire stock distribution area (Subarea 4 and divisions 3.a. and 7.d).

Following the release of the 2019 advice, ICES has been requested to issue annual advice for North Sea lemon sole.

The application of the previous DLS "2-over-3" rule, based on the most recent advised catch (for 2022) and the SURBAR biomass index, is given in Figure 9.5.1. The change ratio of the abundance index was -14.30%, which implies that catches for 2023 should be 2640 tonnes. As lemon sole are under the EU Landing Obligation, there is no corresponding advice for landings.

However, the ICES WKLIFE X meeting (ICES 2020) concluded, following extensive simulation testing, that the "2-over-3" rule is unlikely to be precautionary for a stock such as lemon sole. Advice should therefore be given according to the new WKLIFE DLS approach (ICES 2020). This is provided for lemon sole in Section 9.5.2, but first in Section 9.5.1 we consider length-based F_{MSY} proxy estimation (as this is required for the WKLIFE approach).

9.5.1 Length-based F_{MSY} proxy estimation

Length-based indicators (LBIs) for F_{msy} proxies were estimated for North Sea lemon sole, following the standard approach outlined by WKLIFE (ICES WKLIFE VI, 2017) and WKPROXY (ICES WKPROXY, 2017), and stipulated in the lemon sole Stock Annex by the 2018 benchmark meeting (ICES WKNSEA, 2018). Data were taken from the length samples submitted to InterCatch for 2002–2021.

The original InterCatch length distributions are given in Figure 9.5.2, from which erroneous length submissions for fish less than 200 mm in 2013 can clearly be seen. These seem to arise from Dutch discard samples, which could not be corrected prior to the WGNSSK meeting (see also Section 9.2.2). To address this without correcting the input data, the 2013 data were removed from the analysis (this has no impact on the final conclusions). Figure 9.5.3 shows the result of this, along with the removal of all fish less than 100 mm (to prevent the misspecification of length at first capture). Finally, the widths of the length bins were doubled to produce smoother distributions for LBI analysis (Figure 9.5.4).

Figure 9.5.5 shows a logit maturity ogive fitted to maturity data from the Q1 (IBTS) and Q3 (IBTS & BTS) survey records, using a binomial GLM with a logit link. This analysis indicates that a suitable estimate of L_{mat} would be 127 mm.

Figure 9.5.6 shows an estimated L_∞ value of 282 mm and associated K value of 0.407/yr, derived from all available survey data (these are unchanged from the estimates provided by WGNSSK 2021). WGNSSK was concerned that the survey-derived value of 282 mm was likely to be too low, given the possibility (although uncertain) that survey catchability for older fish may be poor. Two alternative estimates of L_∞ were hence considered – the longest fish observed in the commercial fishery landings data (695 mm), and a trimmed alternative based on the 99%ile of the commercial catch length distribution (385 mm, collated over all available years). The estimates are summarised in Figure 9.5.7. Given L_{max}, WGNSSK proposed that L_∞ should be derived from the following equation (García-Carreras *et al* 2016):

$$\log_{10} L_\infty = 0.068260 + 0.969112 \log_{10} L_{max}$$

The resultant estimates are then:

Basis	L_{max}	L_∞
Trimmed L_{max}	385 mm	**375 mm**
Observed L_{max}	695 mm	664 mm
Survey data	-	282 mm

WGNSSK conclude that L_∞ should be set to 375 mm (as for last year, and highlighted above), as the estimate of 664 mm does not seem to be representative of the bulk of the stock, and the survey-based estimate (282 mm) may be biased downwards by reduced catchability for older lemon sole in the surveys.

This estimate of L_∞, along with the new estimate of L_{mat} were then used in an LBI estimation run which is summarised in Figures 9.5.8 and 9.5.9, and Table 9.5.1. The key points are:

- Length at first catch (L_c) is above L_{mat} for the full time-series, which indicates fewer immature individuals in the catches.
- The ratio of the mean length of the upper 5th percentile of catches to L_∞ is around 1.0 throughout the time series, which would suggest a reasonable number of large (and hence old) fish in the population. The fitted age-length curve in Figure 9.5.6 would indicate that it is reasonable to assume a large lemon sole is older than a small one. There is a spread, but the underlying trend seems well-defined.
- The L_{mean}/L_{opt} ratio is greater than 1.0 for most of the time series, which suggests that exploitation is targeting the most productive length classes.
- $L_{mean}/L_{F=M}$ is greater than 1.0 for all years in the time-series, which indicates that this stock is being fished at a rate less than (or close to) F_{MSY}.

The LBI results suggest that immature fish are well protected, and that the catch length distribution is not truncated at larger sizes: under optimal and sustainable exploitation the mean length in the catch is expected to be higher than the value observed, and this is the case here. The fact that the ratio of $L_{mean}/L_{F=M}$ is greater than 1.0 throughout the time-series would suggest that F_{MSY} is **not** being exceeded for this stock.

9.5.2 Application of the WKLIFE X DLS approach

The WKLIFE DLS decision tree (ICES 2020) has been replicated for convenience in Figure 9.5.10. Following this through for lemon sole leads to the following conclusions:

1. There is no accepted SPiCT assessment for lemon sole.
2. Indices of abundance, commercial catch length data, and an estimate of the von Bertalanffy K parameter are all available.
3. For lemon sole, $K = 0.407 yr^{-1}$.
4. Hence the ***chr* rule** (method 2.2) should be used to provide advice, given that $0.32 yr^{-1} \leq K \leq 0.45 yr^{-1}$.

ICES (2020) notes that the *chr* rule should be based on an index of biomass. In the case of lemon sole, this could be generated by the existing SURBAR analysis, but an empirical biomass index based on one of the surveys could also be used. WGNSSK considered that it was important to use the most recent data available. The existing SURBAR assessment runs to 2021 only, as it has no data on which to base an estimate of the strength of the 2021 cohort at age 1 in 2022. However, an empirical SSB estimate based on the IBTS Q1 survey (ages 2-5) can be calculated including 2022, and WGNSSK concluded that this would be a preferable basis for the *chr* rule.

The empirical SSB estimate (see Table 9.5.2) is given by:

$$I_y = \sum_{a=2}^{5} i_{a,y} W_{a,y} m_{a,y}$$

where *i* is the IBTS Q1 survey index, *W* is the stock weight, and *m* is the proportion mature. Ages 2-5 only are used, because those are the ages for which there were sufficient observations in the survey catch data (> 50 samples per year was used as a threshold).

Figure 9.5.11 compares the SURBAR SSB index with empirical SSB indices based on the IBTS Q1 and IBTS+BTS Q3 surveys, and shows that the overall trends are similar.

The *chr* rule states that:

$$C_{y+1} = I_y F_{MSY\,proxy} bm$$

The components of this formula were estimated as follows.

- I_y is the biomass index for year y. In this case, using the IBTS Q1 SSB index including 2022, $\boldsymbol{I_y = 418.705}$.
- $F_{MSY\,proxy}$ is the average of the ratio of catch C to the biomass index I, calculated across all years for which $L_{mean}/L_{F=M} > 1$. The comparison between L_{mean} and $L_{F=M}$ is shown in Figure 9.5.12, from which it can be seen that all years should be used in the calculation of $F_{MSY\,proxy}$. The ratio C/I is shown in Figure 9.5.13, and the average is $\mathbf{14.140}$.
- $b = min\{1, I_y/I_{trigger}\}$. The value used for $I_{trigger}$ would often be $1.4I_{loss}$, where I_{loss} is the lowest observed biomass index value. However, for a stock such as lemon sole for which historical exploitation has been relatively light (as shown by the LBI analysis), it is appropriate to set $I_{trigger} = I_{loss}$. Doing so results in $\boldsymbol{b = 1.0}$.
- m is a multiplier intended to avoid biomass declining below B_{lim}. Lemon sole has a relatively fast observed growth rate, and in this situation the WKLIFE decision tree recommends that $\boldsymbol{m = 0.5}$.

Using these estimates in the formula gives:

$$C_{y+1} = 418.705 \times 14.140 \times 1.0 \times 0.5 = \mathbf{2960.31}\ \boldsymbol{t}.$$

This would represent a reduction in the advice of **3.92%.**

9.6 Conclusions and further work

Although the SURBAR estimates for SSB are uncertain, the median values indicate a declining trend since 2016 which is reflected in the reduced advice for 2022. The estimate also suggests that recruitment may be increasing in recent years, although retrospective noise problems indicate that this should be treated as being very uncertain. The empirical IBTS Q1 index, on which the advice is now based, also shows a general declining tendency in recent years, although this may have reversed with the 2022 estimate.

The estimation of status relative to F_{msy} proxies indicates that fishing is occurring at or below F_{msy}, which was also the conclusion in the WGNSSK meetings in 2017–2021.

These conclusions are based on stock dynamics indicated by a survey index and a survey-based assessment, and the inability (in many cases) of the available surveys to track year-class strength is a weak point of the advice. An important issue for the development of new advice in 2023 would be to reconsider the survey series used – further work may indicate an alternative method of collating the survey data that could be more appropriate for lemon sole.

9.7 Issues list

9.7.1 Data and assessment

The current survey indices used for North Sea lemon sole are not able to track cohort strength on a consistent basis, and they exhibit generally poor catchability characteristics which limit the reliability of the advice based thereon. It would be very beneficial to be able to include commercial catch data in the assessment in order to improve reliability and reduce variability. Unfortunately, age data are lacking from commercial catch data, so a (spatial) length-based assessment using both catch and survey data should be explored (for example, Stock Synthesis 3). It may also be appropriate to reconsider the use of SPiCT as the basis for advice – this was tested and shown not to work at the last benchmark (ICES 2018), but new survey series may improve the applicability of the method.

Natural mortality is assumed to be time-invariant in the current assessment. The potential of using key MSVPA runs to provide time-varying natural mortality estimates for North Sea lemon sole should be explored. Similarly, maturity is assumed to be time-invariant, and this needs to be considered again.

9.7.2 Forecast

Lemon sole advice is currently based on the WKLIFE DLS approach. If a more quantitative assessment can be generated, then there may be a requirement (and opportunity) to develop a forecast methodology, and this will need to be addressed when appropriate.

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Table 9.2.1. Lemon sole in Subarea 4, and Divisions 3.a and 7.d. Official lemon sole landings by area (tonnes).

Official landings									
Year	3.a	4	7.d	Total	Year	3.a	4	7.d	Total
1950	307	3754	208	4269	1986	639	5047	251	5937
1951	248	4710	314	5272	1987	669	5516	310	6495
1952	243	4922	298	5463	1988	642	5898	258	6798
1953	132	5440	386	5958	1989	693	5967	364	7024
1954	128	3972	534	4634	1990	872	6190	423	7485
1955	102	3836	141	4079	1991	734	6618	428	7780
1956	96	3395	103	3594	1992	952	6126	364	7442
1957	78	3419	102	3599	1993	1156	5839	422	7417
1958	94	3104	82	3280	1994	803	5262	695	6760
1959	130	3647	82	3859	1995	714	4712	877	6303
1960	153	4035	66	4254	1996	635	4737	1151	6523
1961	161	4900	108	5169	1997	768	4727	563	6058
1962	93	4630	101	4824	1998	868	6466	346	7680
1963	99	3791	66	3956	1999	844	6316	140	7300
1964	134	4121	77	4332	2000	803	5980	388	7171
1965	164	4949	105	5218	2001	584	5389	483	6456
1966	159	5415	201	5775	2002	522	3827	474	4823
1967	191	6188	331	6710	2003	543	3688	491	4722
1968	185	6270	337	6792	2004	607	3543	424	4574
1969	215	4470	315	5000	2005	674	3444	350	4468
1970	169	3434	256	3859	2006	417	3627	246	4290
1971	173	3967	357	4497	2007	432	3892	164	4488
1972	168	3672	475	4315	2008	276	3466	234	3976
1973	214	4568	451	5233	2009	262	2693	442	3397
1974	183	4227	351	4761	2010	350	2625	223	3198
1975	317	5029	33	5379	2011	251	3365	403	4019
1976	361	4830	42	5233	2012	482	2119	358	2959
1977	627	5661	37	6325	2013	289	2981	491	3761
1978	705	6108	141	6954	2014	315	3017	356	3688
1979	833	6428	260	7521	2015	269	2871	253	3393
1980	722	6424	152	7298	2016	299	3266	240	3805
1981	793	5933	290	7016	2017	343	2822	158	3323
1982	735	7168	584	8487	2018	280	2635	99	3014
1983	759	8257	491	9507	2019	329	2805	104	3238
1984	595	6930	586	8111	2020	340	2219	95	2655
1985	793	6435	347	7575	2021	256	1774	90	2121

Table 9.2.2. Lemon sole in Subarea 4, and Divisions 3.a and 7.d. Official lemon sole landings in area 7.d by country.

Year	BEL	DNK	FRA	NED	UK	Other	Total	Year	BEL	DNK	FRA	NED	UK	Other	Total
1950	10	0	174	0	24	0	208	1986	77	0	133	0	41	0	251
1951	5	0	262	0	47	0	314	1987	81	0	185	0	44	0	310
1952	10	0	188	0	100	0	298	1988	74	0	155	0	29	0	258
1953	7	0	196	0	183	0	386	1989	68	0	252	0	44	0	364
1954	9	0	361	0	164	0	534	1990	68	0	272	0	83	0	423
1955	9	0	0	0	132	0	141	1991	83	0	272	0	73	0	428
1956	4	0	0	0	99	0	103	1992	66	0	176	0	122	0	364
1957	7	0	0	0	95	0	102	1993	36	0	311	0	75	0	422
1958	1	0	0	0	81	0	82	1994	97	0	505	0	93	0	695
1959	2	0	0	0	80	0	82	1995	138	0	584	0	155	0	877
1960	4	0	0	0	62	0	66	1996	213	0	720	0	218	0	1151
1961	1	0	0	0	106	1	108	1997	143	0	305	0	115	0	563
1962	2	0	0	0	99	0	101	1998	53	0	198	0	95	0	346
1963	3	0	0	0	63	0	66	1999	50	0	0	0	90	0	140
1964	5	0	0	0	72	0	77	2000	62	0	200	0	126	0	388
1965	16	0	0	0	89	0	105	2001	104	0	191	0	188	0	483
1966	7	0	0	0	194	0	201	2002	101	0	256	0	117	0	474
1967	6	0	0	0	325	0	331	2003	128	0	251	0	112	0	491
1968	8	0	0	0	329	0	337	2004	120	0	198	1	105	0	424
1969	12	0	0	0	303	0	315	2005	90	0	187	2	71	0	350
1970	16	0	0	0	240	0	256	2006	98	0	100	0	48	0	246
1971	22	0	0	0	335	0	357	2007	70	0	72	1	21	0	164
1972	18	0	0	0	457	0	475	2008	140	0	46	3	45	0	234
1973	25	0	0	0	426	0	451	2009	149	0	176	9	108	0	442
1974	16	0	0	1	334	0	351	2010	101	0	85	5	32	0	223
1975	19	0	0	0	14	0	33	2011	153	0	178	15	57	0	403
1976	24	0	0	0	18	0	42	2012	171	0	167	20	0	0	358
1977	21	1	0	0	15	0	37	2013	176	0	179	26	110	0	491
1978	45	2	63	0	31	0	141	2014	162	0	108	14	72	0	356
1979	60	0	165	0	35	0	260	2015	123	0	84	5	41	0	253
1980	33	0	109	0	10	0	152	2016	115	0	69	9	47	0	240
1981	66	0	212	0	12	0	290	2017	87	0	34	8	29	0	158
1982	96	0	406	1	81	0	584	2018	57	0	21	5	15	0	99
1983	108	0	298	0	85	0	491	2019	49	0	27	6	23	0	104
1984	110	0	367	0	109	0	586	2020	46	0	25	6	18	0	95
1985	117	0	164	0	66	0	347	2021	39	0	18	7	26	0	90

Table 9.2.3. Lemon sole in Subarea 4, and Divisions 3.a and 7.d. Official lemon sole landings in ICES subarea 4 by country.

Year	BEL	DNK	FRA	GER	NED	NOR	UK	Other	Total	Year	BEL	DNK	FRA	GER	NED	NOR	UK	Other	Total
1950	112	435	139	31	156	0	2855	26	3754	1973	566	478	0	73	217	16	3218	0	4568
1951	115	845	90	21	167	0	3430	42	4710	1974	486	447	0	59	269	0	2966	0	4227
1952	98	391	227	26	168	0	3953	59	4922	1975	748	521	0	83	299	0	3367	11	5029
1953	73	409	189	18	132	0	4590	29	5440	1976	493	506	0	68	308	0	3443	12	4830
1954	2	272	177	24	112	0	3368	17	3972	1977	618	321	0	71	262	0	4387	2	5661
1955	49	311	0	15	78	0	3374	9	3836	1978	760	517	28	54	231	0	4518	0	6108
1956	48	222	0	19	58	0	3034	14	3395	1979	674	876	136	41	390	0	4308	3	6428
1957	39	249	0	24	64	0	3032	11	3419	1980	484	599	102	49	303	0	4885	2	6424
1958	30	171	0	13	43	0	2835	12	3104	1981	555	605	237	39	412	0	4084	1	5933
1959	85	242	0	40	43	0	3226	11	3647	1982	879	670	419	52	759	0	4386	3	7168
1960	155	577	0	46	67	0	3178	12	4035	1983	1122	735	402	28	1009	0	4957	4	8257
1961	286	488	0	79	102	0	3934	11	4900	1984	1144	567	344	22	0	0	4850	3	6930
1962	175	501	0	54	106	0	3794	0	4630	1985	989	555	157	26	0	0	4703	5	6435
1963	365	222	0	36	71	0	3097	0	3791	1986	511	577	103	16	0	0	3839	1	5047
1964	484	358	0	62	75	0	3142	0	4121	1987	448	742	174	14	0	0	4137	1	5516
1965	562	385	0	91	93	0	3818	0	4949	1988	539	639	184	14	301	0	4220	1	5898
1966	594	548	0	98	65	0	4110	0	5415	1989	441	828	176	40	397	0	4083	2	5967
1967	601	791	0	136	61	0	4599	0	6188	1990	491	1007	208	49	0	0	4431	4	6190
1968	422	775	0	96	34	0	4943	0	6270	1991	544	1099	250	41	0	12	4666	6	6618
1969	292	639	0	80	36	0	3423	0	4470	1992	577	1149	177	30	0	13	4175	5	6126
1970	241	307	0	52	58	0	2776	0	3434	1993	525	966	240	37	0	9	4059	3	5839
1971	348	514	0	54	122	0	2929	0	3967	1994	436	597	436	27	0	11	3754	1	5262
1972	423	530	0	59	130	0	2530	0	3672	1995	588	585	412	70	0	9	3046	2	4712

Table 9.2.3 (continued). Lemon sole in Subarea 4, and Divisions 3.a and 7.d. Official lemon sole landings in ICES subarea 4 by country.

Year	BEL	DNK	FRA	GER	NED	NOR	UK	Other	Total	Year	BEL	DNK	FRA	GER	NED	NOR	UK	Other	Total
1996	592	547	534	67	0	18	2976	3	4737	2009	389	898	88	64	294	31	927	2	2693
1997	504	499	224	76	0	29	3391	4	4727	2010	375	821	32	102	323	35	935	2	2625
1998	815	796	197	149	838	23	3643	5	6466	2011	387	999	56	96	641	27	1157	2	3365
1999	662	1015	0	62	681	24	3866	6	6316	2012	406	999	34	61	587	30	0	2	2119
2000	711	1277	184	72	492	17	3222	5	5980	2013	527	649	27	67	479	16	1214	2	2981
2001	694	1281	191	77	451	22	2666	7	5389	2014	648	626	27	63	425	23	1202	3	3017
2002	604	971	190	116	402	17	1521	6	3827	2015	425	794	16	82	423	12	1116	3	2871
2003	517	1008	239	136	369	16	1399	4	3688	2016	448	1054	15	82	443	23	1196	5	3266
2004	667	1113	120	81	355	12	1192	3	3543	2017	345	1032	0	42	356	14	1028	4	2822
2005	595	1057	102	85	402	13	1188	2	3444	2018	370	815	9	52	347	14	1025	3	2635
2006	552	968	57	183	412	13	1440	2	3627	2019	467	671	8	46	473	13	1122	4	2805
2007	542	1136	65	143	367	23	1610	6	3892	2020	376	497	9	32	385	5	910	6	2219
2008	527	925	47	120	434	26	1383	4	3466	2021	338	332	2	32	422	7	637	3	1774

Table 9.2.4. Lemon sole in Subarea 4, and Divisions 3.a and 7.d. Official landings in area 3.a by country.

Year	BEL	DNK	GER	NED	SWE	Other	Total	Year	BEL	DNK	GER	NED	SWE	Other	Total
1950	0	100	1	0	206	0	307	1986	7	576	0	0	56	0	639
1951	0	74	1	0	173	0	248	1987	24	577	0	0	68	0	669
1952	0	64	0	0	179	0	243	1988	11	569	0	6	56	0	642
1953	0	35	0	0	97	0	132	1989	8	610	0	0	75	0	693
1954	0	33	0	0	95	0	128	1990	16	782	0	0	74	0	872
1955	0	29	0	0	73	0	102	1991	11	640	0	0	83	0	734
1956	0	33	0	0	63	0	96	1992	22	793	0	0	120	17	952
1957	0	27	0	0	51	0	78	1993	14	980	4	0	141	17	1156
1958	0	38	0	0	56	0	94	1994	10	648	2	0	127	16	803
1959	0	71	0	0	59	0	130	1995	27	576	2	0	91	18	714
1960	0	95	1	0	57	0	153	1996	0	513	1	0	97	24	635
1961	0	90	0	0	71	0	161	1997	0	628	2	0	115	23	768
1962	0	92	1	0	0	0	93	1998	0	743	3	0	100	22	868
1963	0	99	0	0	0	0	99	1999	0	731	3	0	88	22	844
1964	0	133	1	0	0	0	134	2000	0	722	1	0	65	15	803
1965	0	163	1	0	0	0	164	2001	0	511	1	0	53	19	584
1966	0	159	0	0	0	0	159	2002	0	457	4	0	41	20	522
1967	0	189	1	0	0	1	191	2003	0	451	6	30	35	21	543
1968	0	184	0	0	0	1	185	2004	0	472	5	82	29	19	607
1969	0	215	0	0	0	0	215	2005	0	468	5	147	38	16	674
1970	0	169	0	0	0	0	169	2006	0	321	8	40	32	16	417
1971	0	173	0	0	0	0	173	2007	0	374	5	16	18	19	432
1972	0	168	0	0	0	0	168	2008	0	239	7	3	15	12	276
1973	0	214	0	0	0	0	214	2009	0	233	4	1	15	9	262
1974	0	183	0	0	0	0	183	2010	0	286	3	35	19	7	350
1975	0	263	1	1	52	0	317	2011	0	223	0	0	12	16	251
1976	10	294	1	19	37	0	361	2012	0	446	3	0	15	18	482
1977	9	528	2	37	51	0	627	2013	0	259	3	5	10	12	289
1978	4	628	2	12	59	0	705	2014	0	276	7	12	14	6	315
1979	7	704	1	10	111	0	833	2015	0	250	4	0	9	6	269
1980	12	622	0	0	87	1	722	2016	0	265	5	16	7	6	299
1981	1	710	0	3	75	4	793	2017	0	314	5	11	6	7	343
1982	2	647	0	9	77	0	735	2018	0	252	5	14	6	2	280
1983	3	636	0	10	110	0	759	2019	0	293	1	29	5	1	329
1984	6	525	0	0	64	0	595	2020	0	288	3	44	4	1	340
1985	0	729	0	0	64	0	793	2021	0	226	2	25	3	1	256

Table 9.2.5. Lemon sole in areas 4, 7.d and 3.a. ICES estimates of landings and discards for areas 3.a, 4 and 7.d.

Year	Official landings	ICES Landings	ICES Discards	ICES Total Catch	Discard rate
1968	6792				
1969	5000				
1970	3859				
1971	4497				
1972	4315				
1973	5233				
1974	4761				
1975	5379				
1976	5233				
1977	6325				
1978	6954				
1979	7521				
1980	7298				
1981	7016				
1982	8487				
1983	9507				
1984	8111				
1985	7575				
1986	5937				
1987	6495				
1988	6798				
1989	7024				
1990	7485				
1991	7780				
1992	7442				
1993	7417				
1994	6760				
1995	6303				
1996	6523				
1997	6058				
1998	7680				
1999	7300				
2000	7171				
2001	6456				
2002	4823	4011	511	4522	11.30%
2003	4722	4575	1036	5611	18.46%
2004	4574	4394	635	5028	12.62%
2005	4468	4429	527	4955	10.63%
2006	4290	4294	1,515	5809	26.08%
2007	4488	4468	451	4919	9.18%
2008	3976	4153	898	5051	17.77%
2009	3397	3405	996	4401	22.64%
2010	3198	3234	673	3907	17.21%
2011	4019	4030	1024	5055	20.27%
2012	2959	4099	2461	6560	37.52%
2013	3761	3725	5938	9663	61.45%
2014	3688	3645	1690	5335	31.68%
2015	3393	3480	1636	5116	31.97%
2016	3805	3834	1167	5000	23.33%
2017	3323	3315	651	3966	16.41%
2018	3014	3046	331	3376	9.79%
2019	3238	3273	605	3878	15.60%
2020	2655	2653	391	3044	12.86%
2021	2121	2092	407	2589	19.18%

Table 9.3.1. Lemon sole in areas 4, 7.d and 3.a. Estimates of mean weight-at-age.

Year	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9
2005	0.0877	0.0746	0.1182	0.2229	0.3014	0.3450	0.3818	0.2153	0.2627
2006	0.0777	0.0749	0.1214	0.2246	0.3054	0.3380	0.3699	0.2349	0.2608
2007	0.0684	0.0747	0.1236	0.2249	0.3075	0.3318	0.3600	0.2551	0.2623
2008	0.0599	0.0738	0.1245	0.2237	0.3074	0.3266	0.3521	0.2749	0.2660
2009	0.0521	0.0724	0.1245	0.2213	0.3052	0.3222	0.3458	0.2945	0.2726
2010	0.0450	0.0705	0.1236	0.2175	0.3012	0.3184	0.3411	0.3133	0.2813
2011	0.0384	0.0682	0.1217	0.2119	0.2947	0.3151	0.3387	0.3333	0.2934
2012	0.0326	0.0652	0.1188	0.2054	0.2871	0.3138	0.3384	0.3515	0.3055
2013	0.0285	0.0616	0.1145	0.1977	0.2757	0.3146	0.3426	0.3722	0.3235
2014	0.0253	0.0580	0.1101	0.1880	0.2634	0.3154	0.3519	0.3937	0.3427
2015	0.0223	0.0540	0.1052	0.1795	0.2528	0.3193	0.3608	0.4102	0.3533
2016	0.0201	0.0510	0.1017	0.1717	0.2418	0.3193	0.3663	0.4163	0.3581
2017	0.0179	0.0485	0.0983	0.1643	0.2334	0.3157	0.3717	0.4153	0.3595
2018	0.0159	0.0467	0.0958	0.1571	0.2257	0.3102	0.3768	0.4085	0.3580
2019	0.0143	0.0454	0.0939	0.1504	0.2198	0.3030	0.3829	0.3961	0.3529
2020	0.0130	0.0446	0.0927	0.1441	0.2151	0.2942	0.3900	0.3783	0.3441
2021	0.0120	0.0443	0.0922	0.1383	0.2119	0.2838	0.3979	0.3552	0.3319
2022	0.0114	0.0446	0.0924	0.1332	0.2103	0.2717	0.4063	0.3265	0.3163

Table 9.3.2. Lemon sole in areas 4, 7.d and 3.a. GAM-estimated survey indices for Q1 (upper: NS IBTS) and Q3 (lower: NS IBTS + BTS). The final column for IBTS Q1 gives the empirical biomass index used in the DLS advice.

NS Lemon Sole: IBTS Q1; Last group is NOT a plus-group. Calculations made on 13/04/2022 at 13:27:15.					Biomass index
2007	2022				
1	1	0.09158074	0.09158074		
2	5				
1	132.4405	529.8477	445.033	953.7948	465.989
1	360.6327	500.37	257.8224	262.219	219.747
1	349.4405	261.3109	273.8335	113.9985	146.140
1	449.0177	683.2861	928.0366	231.1136	378.678
1	565.5265	1030.207	610.2342	540.0232	441.611
1	1803.301	2020.016	687.1781	315.361	556.314
1	563.4299	790.4599	928.3916	373.8103	402.044
1	669.1773	1310.441	923.2495	206.2037	400.058
1	389.4923	1720.876	1141.042	347.7391	488.912
1	916.2058	1661.812	991.5492	405.1585	470.777
1	643.2883	1021.305	1075.516	396.4362	392.063
1	446.711	737.6207	311.1181	300.9746	202.476
1	700.1201	1536.305	839.8822	256.945	349.965
1	767.4778	1314.459	722.1572	276.2578	309.898
1	380.5962	825.4276	1216.375	187.0898	296.070
1	905.6794	1623.911	887.4113	577.2454	418.705

NS Lemon Sole: BTS & IBTS Q3; Last group is NOT a plus-group. Calculations made on 13/04/2022 at 13:16:09										
2005	2021									
1	1	0.6202112	0.6202112							
1	10									
1	198.1394	1631.512	1865.976	1596.174	836.3528	1225.153	508.2907	348.618	531.0954	529.2395
1	132.5931	1077.952	1822.255	1506.969	1515.868	815.344	1205.625	430.7811	199.5034	965.2637
1	686.1509	1554.541	2168.778	1800.577	1511.1	1566.086	666.6084	840.6299	369.427	772.2179
1	269.928	2213.143	2229.714	1608.495	1612.786	725.2932	1092.207	418.5717	403.5415	706.6689
1	574.9186	1524.437	2563.38	1562.908	1047.772	1063.296	323.2004	687.6337	86.8001	783.3995
1	503.6096	1161.043	1910.448	1618.243	2058.563	1502.444	1402.441	568.0829	625.1119	673.4103
1	177.7114	2993.399	3483.456	1985.34	2425.084	1884.248	863.5325	1277.041	357.4645	1325.843
1	432.9287	2358.805	3268.711	2500.741	1770.664	1343.669	995.3994	717.4202	939.5227	1217.672
1	12.1321	356.2142	2022.457	3356.134	2202.666	2144.197	1851.965	1240.462	471.9077	1835.794
1	422.8282	1004.706	2483.643	3238.586	3138.829	2064.036	1049.35	899.4624	452.6558	1413.112
1	43.0335	2228.531	3687.095	3464.592	3003.79	1655.306	924.9811	852.6921	621.8049	1061.662
1	278.1376	1840.033	3105.209	2293.166	2733.047	2369.805	1457.316	734.625	723.6102	1287.611
1	52.139	1173.02	2496.612	2386.78	2602.455	2211.994	1460.993	1051.38	615.3746	829.4586
1	125.2157	1513.206	2158.514	2037.791	2357.209	1872.37	1460.757	975.9461	534.646	765.906
1	302.7345	1192.333	2555.964	2178.924	1479.27	1584.285	1557.151	1080.97	697.3062	1263.662
1	608.3402	1542.11	2354.489	2309.628	1570.995	1459.064	1301.066	989.1515	1056.422	1765.355
1	399.9037	1425.234	3422.645	2384.95	2393.161	1325.047	932.1953	926.0523	646.4829	1798.643

Table 9.4.1. Lemon sole in areas 4, 7.d and 3.a. SURBAR stock summary. Mortality Z is given as the mean total mortality over ages 3-5, while SSB and recruitment at age 1 are mean-standardised relative indices. Each estimate is given with lower and upper bounds of a 90% confidence interval.

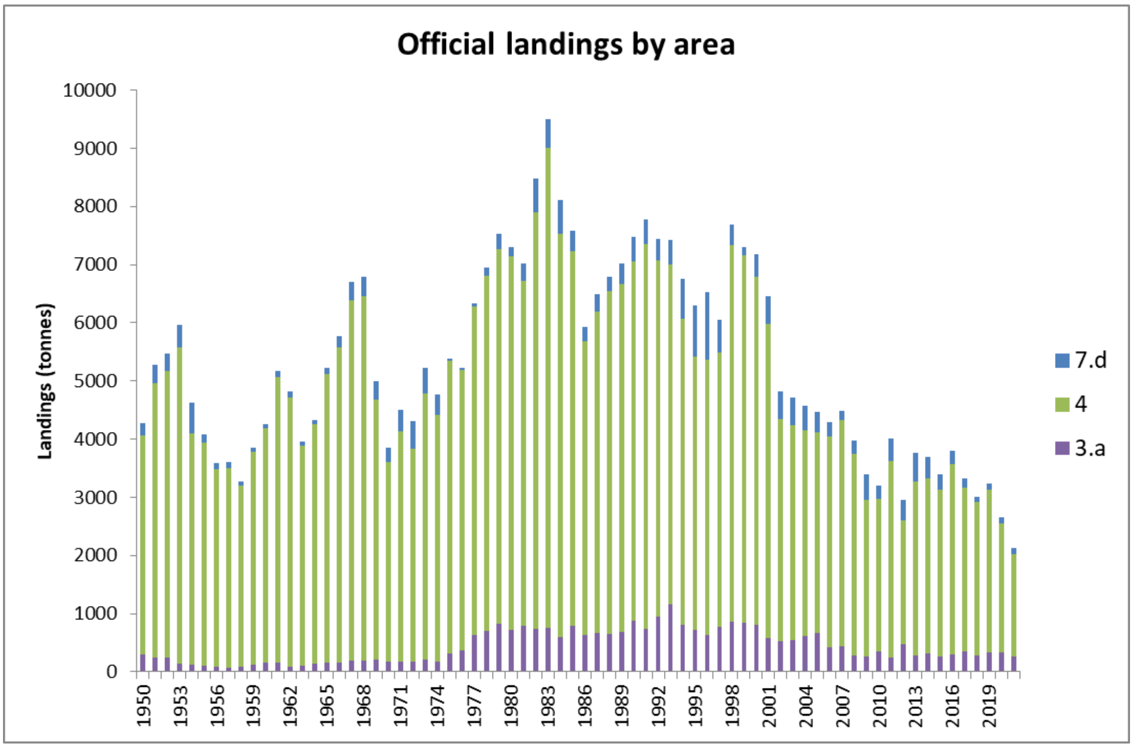
Year	z.low	z	z.high	ssb.low	ssb	ssb.high	rec.low	rec	rec.high
2005	-0.098	0.144	0.397	0.653	0.845	1.175	0.511	0.714	1.001
2006	-0.048	0.162	0.342	0.722	0.902	1.201	0.531	0.743	1.033
2007	0.136	0.349	0.559	0.767	0.924	1.211	0.730	1.030	1.437
2008	0.101	0.317	0.519	0.632	0.759	0.988	0.582	0.806	1.091
2009	-0.226	-0.022	0.158	0.524	0.636	0.838	0.653	0.894	1.200
2010	-0.177	0.003	0.187	0.724	0.864	1.097	0.890	1.199	1.562
2011	-0.090	0.113	0.298	0.901	1.081	1.379	0.901	1.217	1.634
2012	0.026	0.218	0.407	0.976	1.183	1.504	0.839	1.138	1.555
2013	0.001	0.195	0.370	0.931	1.118	1.430	0.669	0.875	1.184
2014	-0.051	0.136	0.314	0.924	1.098	1.412	0.814	1.101	1.504
2015	-0.157	0.057	0.244	0.946	1.139	1.470	0.540	0.725	0.974
2016	-0.035	0.147	0.330	1.023	1.254	1.690	0.639	0.881	1.212
2017	-0.008	0.187	0.387	0.993	1.210	1.589	0.581	0.790	1.105
2018	-0.079	0.121	0.315	0.873	1.073	1.412	0.714	1.020	1.489
2019	-0.097	0.106	0.288	0.832	1.026	1.374	0.756	1.180	1.802
2020	0.001	0.234	0.472	0.839	1.021	1.372	0.765	1.216	2.026
2021	0.050	0.154	0.251	0.680	0.870	1.178	0.615	1.471	3.411

Table 9.5.1. Lemon sole in areas 4, 7.d and 3.a. Output from LBI analyses. Green shows indicators that are met or exceeded, while red shows indicators that are not met. Length data for 2013 are missing.

	Conservation				Optimising yield	MSY
	L_c/L_{mat}	L_{25}/L_{mat}	$L_{max5\%}/L_{inf}$	P_{mega}	L_{mean}/L_{opt}	$L_{mean}/F_{F=M}$
Year	**>1**	**>1**	**>0.8**	**>30%**	**~1 (>0.9)**	**>=1**
2002	0.726	1.895	1.001	0.588	1.107	1.716
2003	1.210	1.815	0.997	0.481	1.074	1.302
2004	1.855	1.976	1.001	0.609	1.202	1.128
2005	2.016	1.976	0.910	0.383	1.126	1.001
2006	0.887	1.976	0.962	0.555	1.106	1.569
2007	0.887	1.976	0.975	0.501	1.085	1.539
2008	1.532	1.815	0.996	0.477	1.105	1.170
2009	0.565	1.815	0.994	0.479	1.064	1.819
2010	0.726	1.895	1.005	0.518	1.112	1.724
2011	0.242	1.411	0.959	0.285	0.919	1.976
2012	0.565	1.573	0.948	0.267	0.939	1.606
2013	NA	NA	NA	NA	NA	NA
2014	0.565	1.573	0.988	0.325	0.962	1.645
2015	0.242	1.653	0.995	0.284	0.963	2.070
2016	0.726	1.653	1.005	0.449	1.038	1.609
2017	0.565	1.653	1.023	0.499	1.041	1.779
2018	2.177	2.056	1.076	0.698	1.291	1.090
2019	0.565	1.573	1.024	0.433	1.032	1.764
2020	1.210	1.734	1.034	0.518	1.081	1.310
2021	1.532	1.734	1.006	0.464	1.102	1.166

Table 9.5.2. Lemon sole in areas 4, 7.d and 3.a. Empirical SSB index derived from the IBTS Q1 survey.

Year	*IBTS Q1 SSB*	*Year*	*IBTS Q1 SSB*
2007	465.9886	2015	488.9124
2008	219.7467	2016	470.7774
2009	146.1403	2017	392.063
2010	378.6778	2018	202.4758
2011	441.6112	2019	349.9651
2012	556.3142	2020	309.8977
2013	402.0442	2021	296.0699
2014	400.0579	2022	418.7047



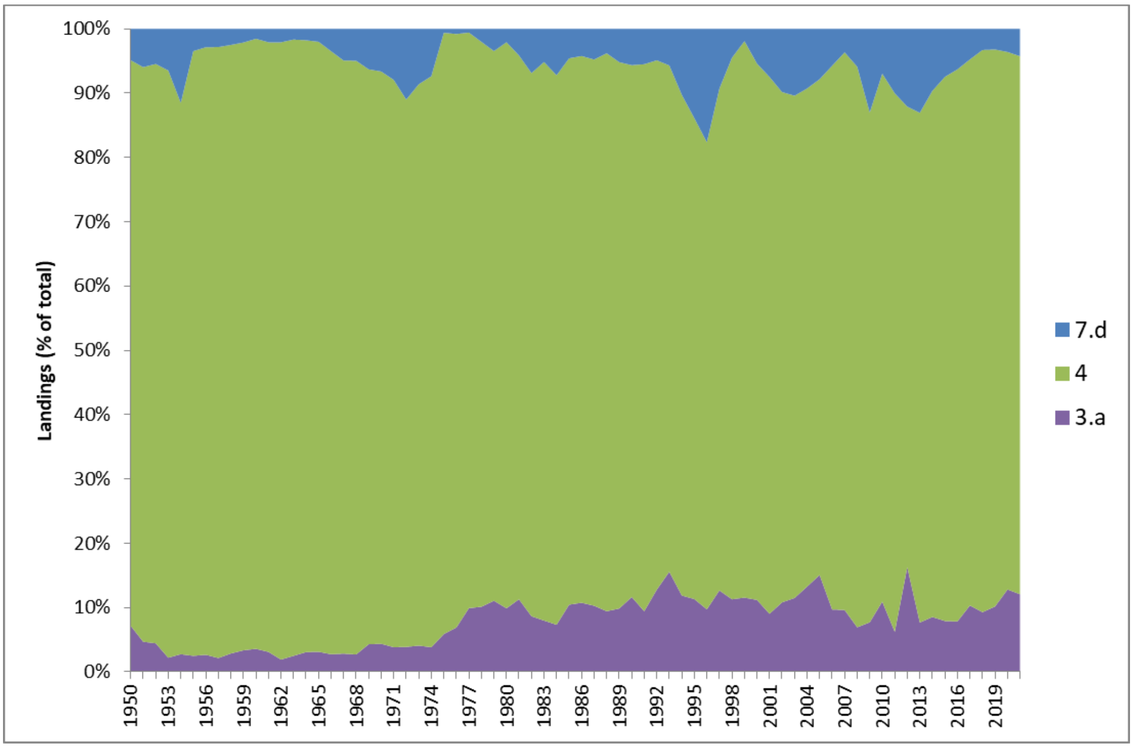
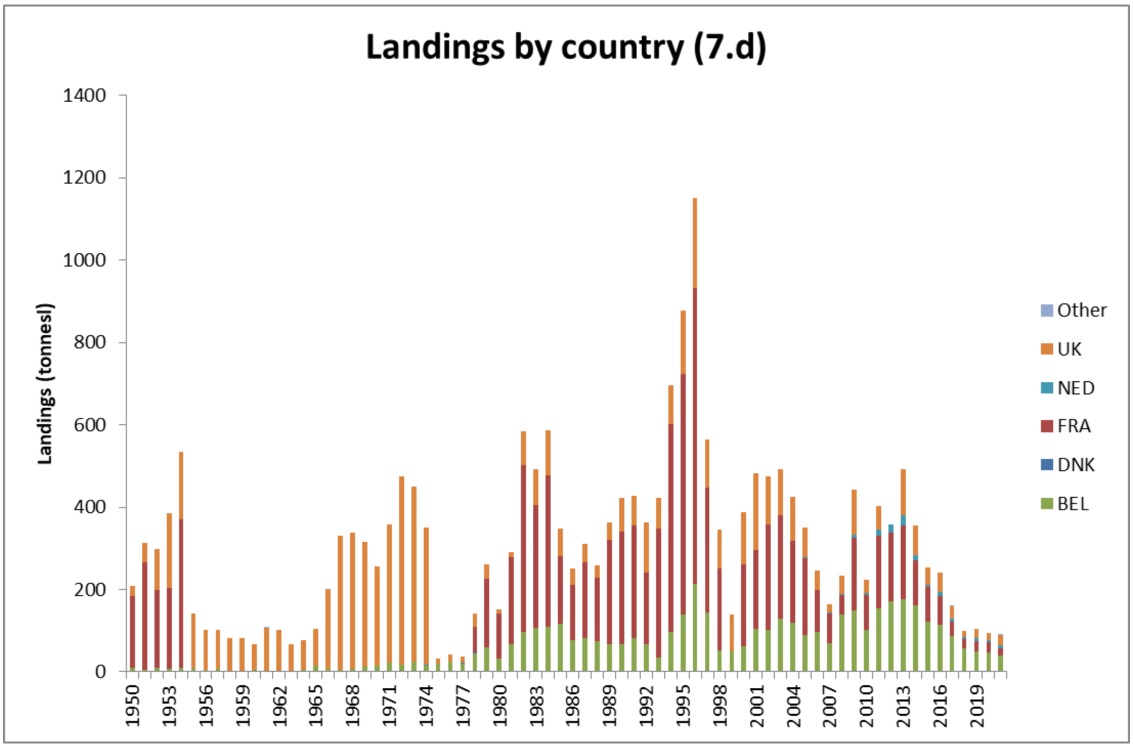


Figure 9.2.1. Lemon sole in Subarea 4, and Divisions 3.a and 7.d. Officially-reported landings of lemon sole by area in the greater North Sea. Upper plot: landings in tonnes. Lower plot: landings by area as a percentage of the full area.



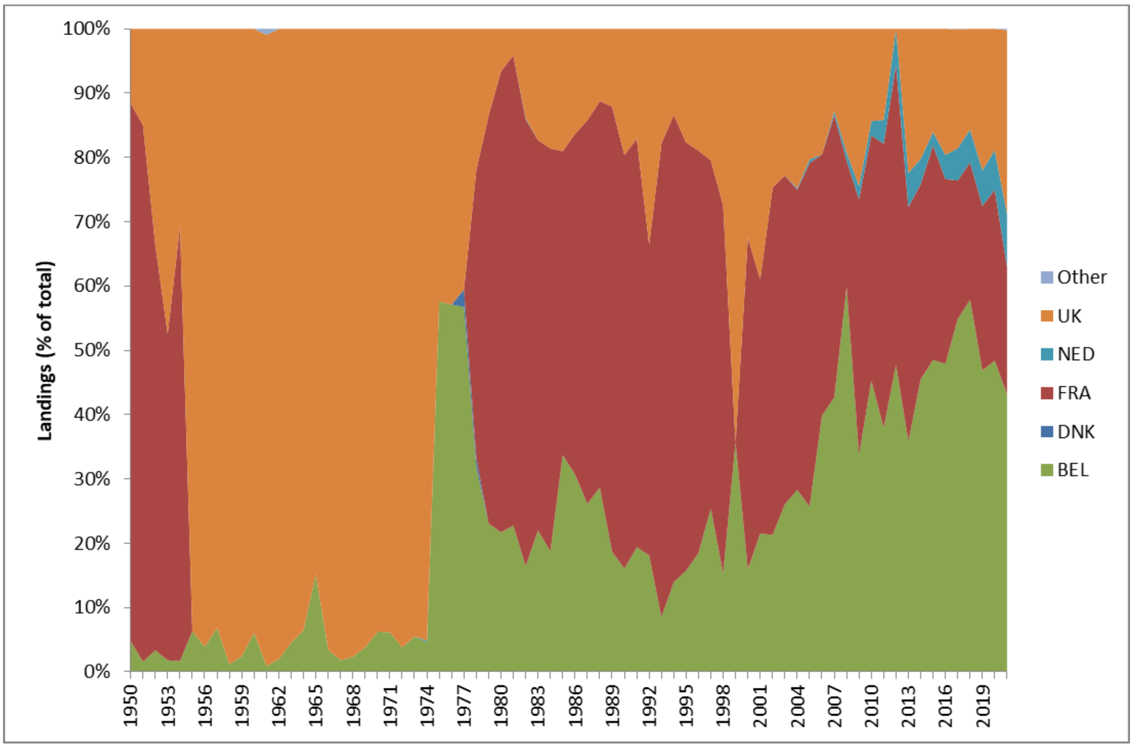


Figure 9.2.2. Lemon sole in Subarea 4, and Divisions 3.a and 7.d. Official landings of lemon sole in area 7.d by country. Upper plot: landings in tonnes. Lower plot: landings by country as a percentage of the total area 7.d landings.

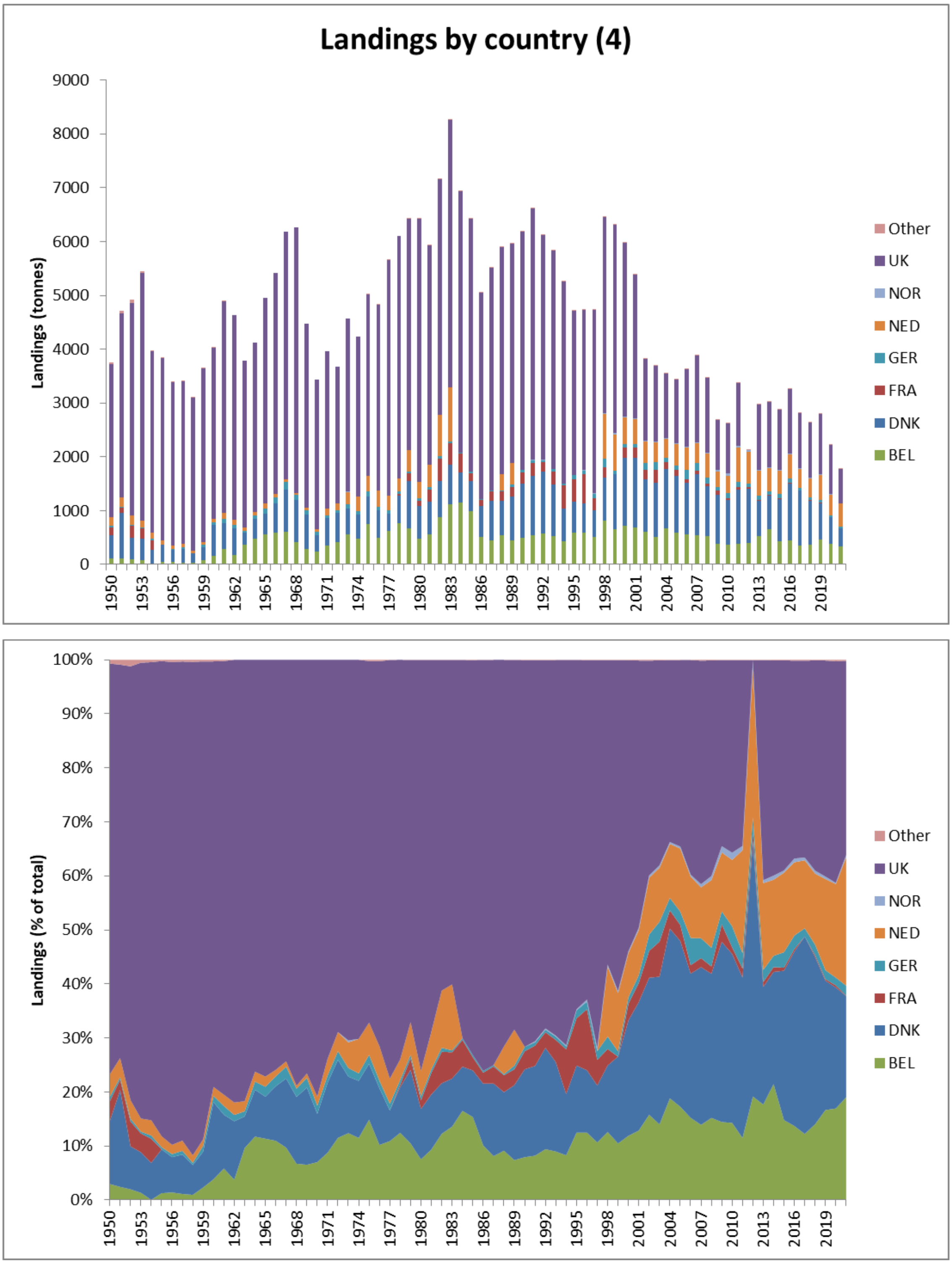


Figure 9.2.3. Lemon sole in Subarea 4, and Divisions 3.a and 7.d. Official landings of lemon sole in area 4 by country. Upper plot: landings in tonnes. Lower plot: landings by country as a percentage of the total area 4 landings.

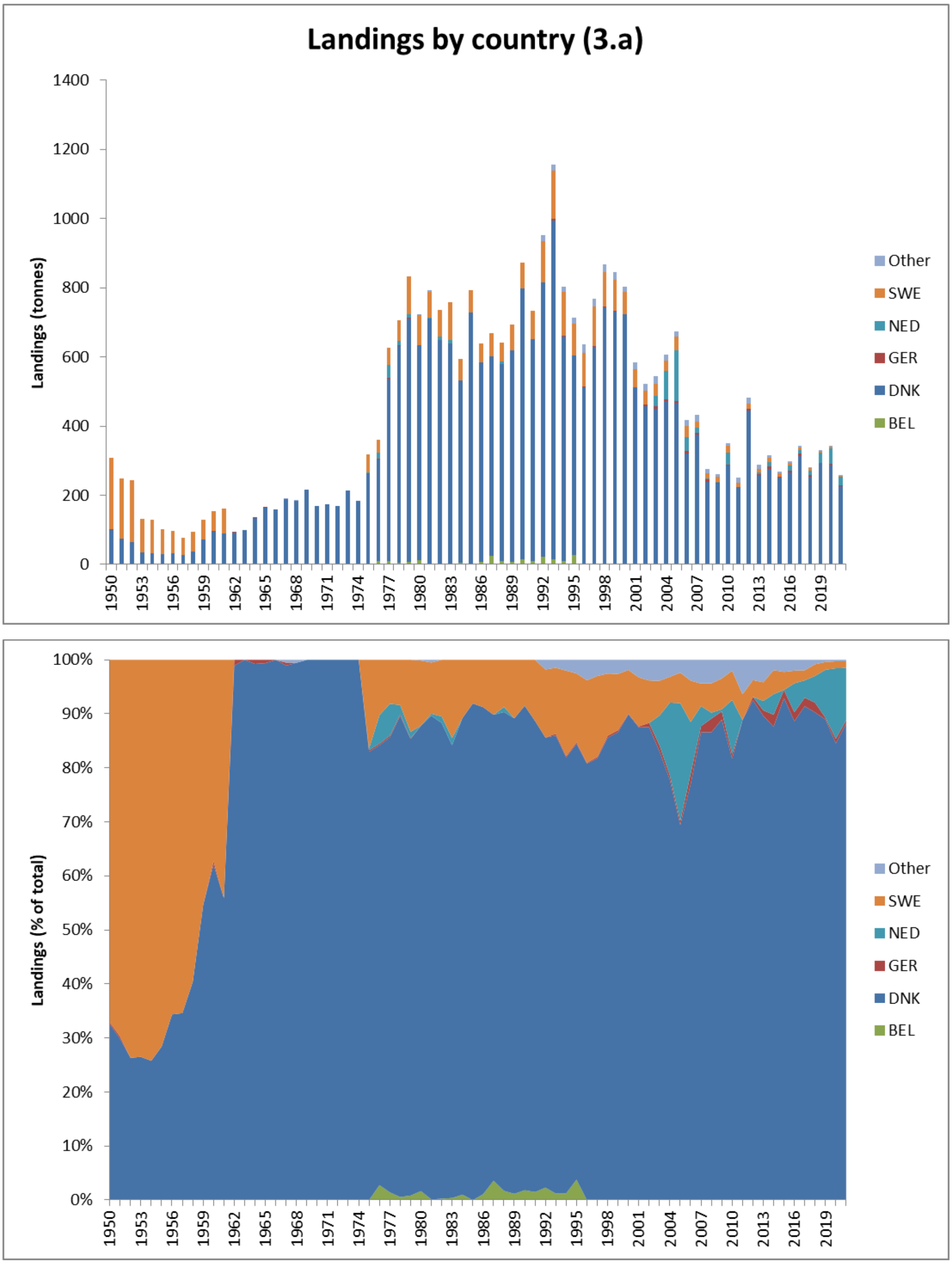


Figure 9.2.4. Lemon sole in Subarea 4, and Divisions 3.a and 7.d. Official landings of lemon sole in area 3.a by country. Upper plot: landings in tonnes. Lower plot: landings by country as a percentage of the total area 3.a landings.

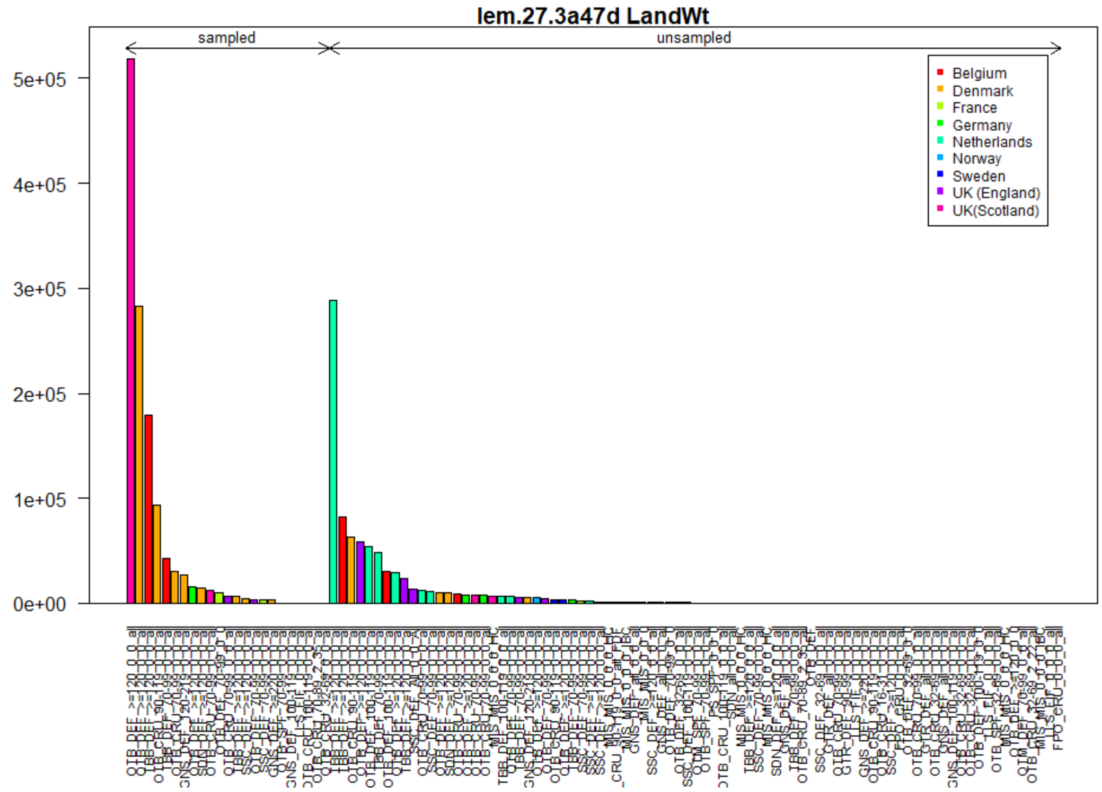


Figure 9.2.5. Lemon sole in Subarea 4, and Divisions 3.a and 7.d. InterCatch summary plots. Sampled and unsampled fleets for landings yield estimation (tonnes).

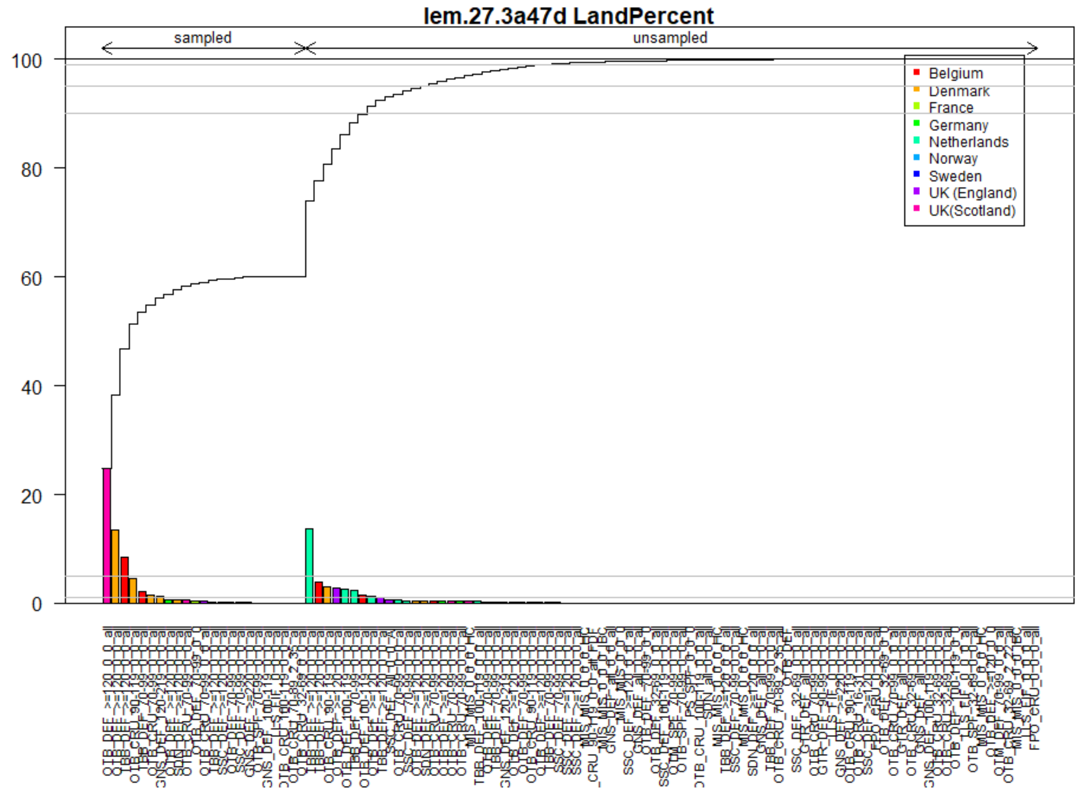


Figure 9.2.6. Lemon sole in Subarea 4, and Divisions 3.a and 7.d. InterCatch summary plots. Sampled and unsampled fleets for landings yield estimation (cumulative contribution).

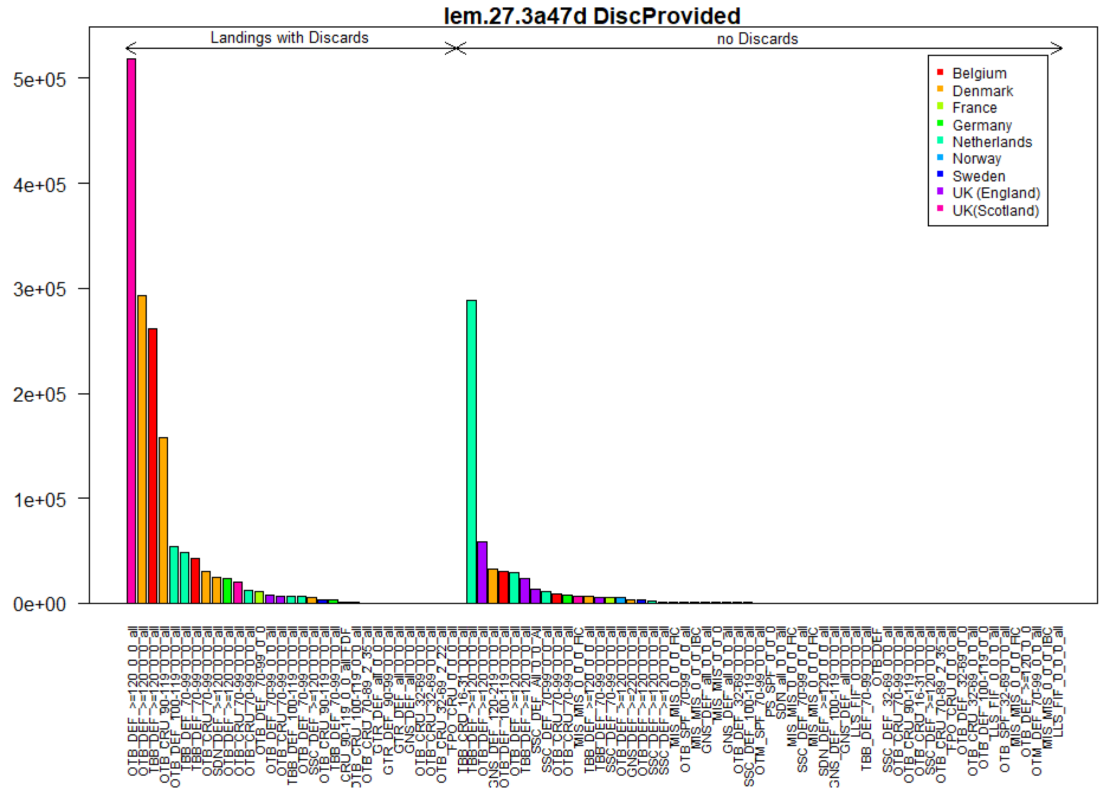


Figure 9.2.7. Lemon sole in Subarea 4, and Divisions 3.a and 7.d. InterCatch summary plots. Fleets provided with and without discard estimates.

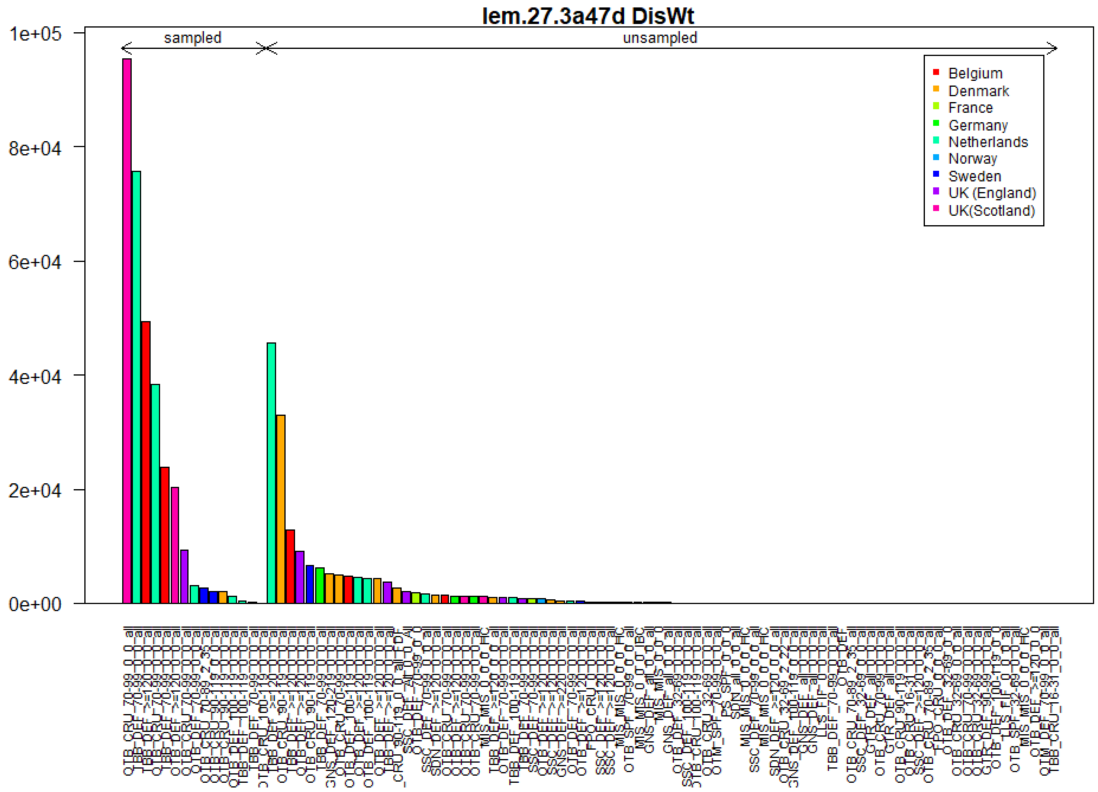


Figure 9.2.8. Lemon sole in Subarea 4, and Divisions 3.a and 7.d. InterCatch summary plots. Sampled and unsampled fleets for discard yield estimation.

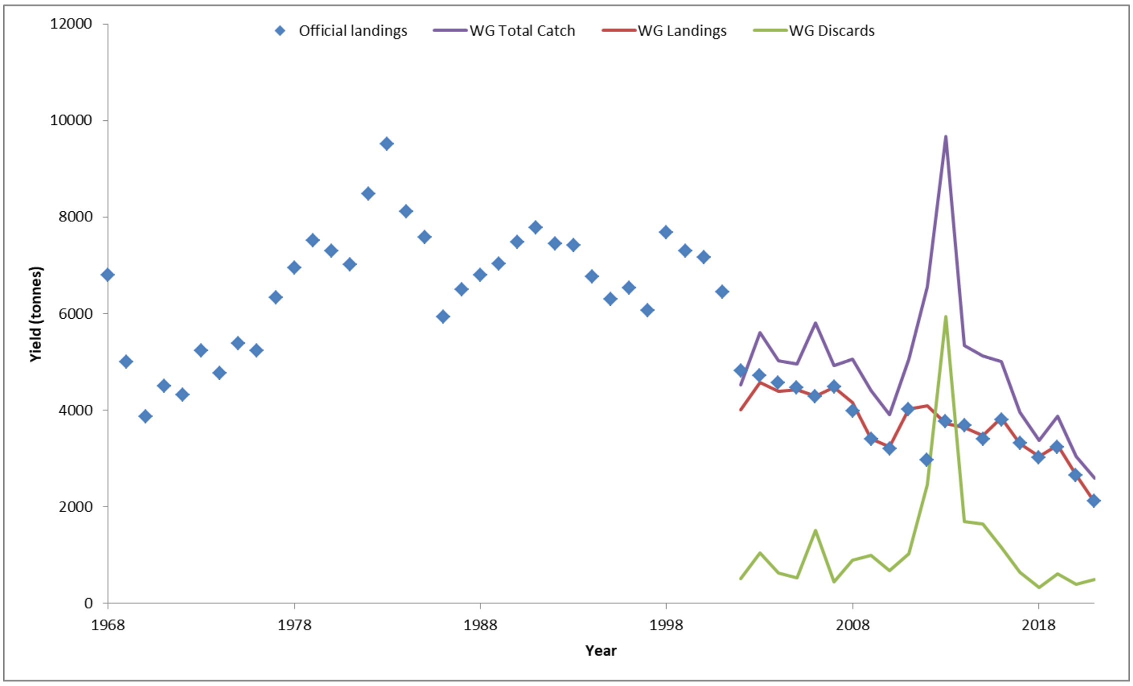


Figure 9.2.9. Lemon sole in Subarea 4, and Divisions 3.a and 7.d. Time-series of official landings (dots) along with ICES WG estimates of total catch (purple line), landings (red line) and discards (green line).

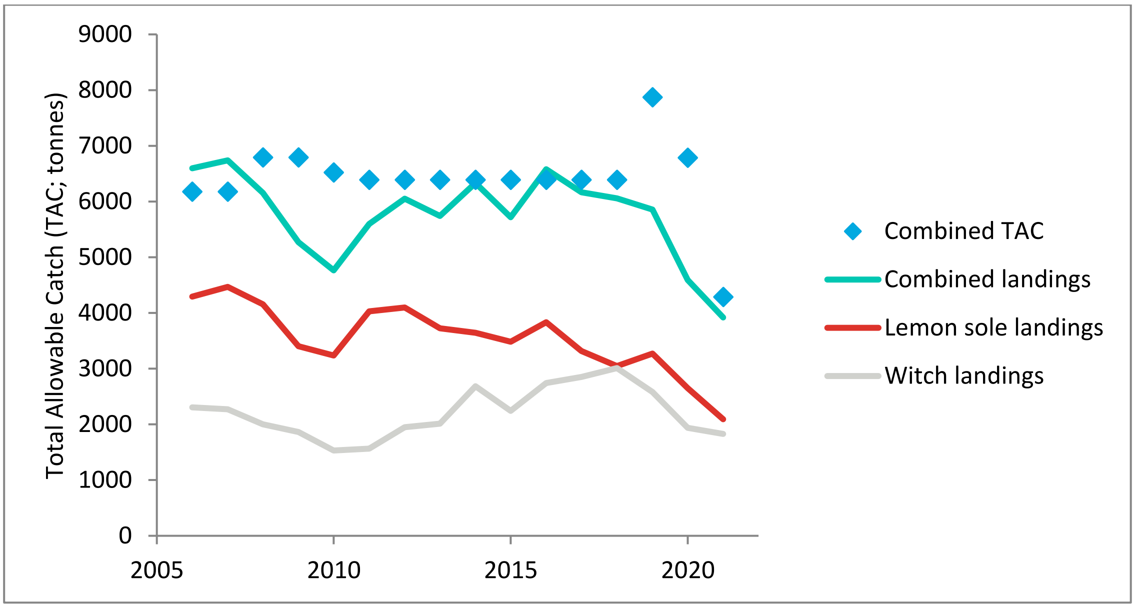


Figure 9.2.10. Lemon sole in Subarea 4, and Divisions 3.a and 7.d. Time-series of ICES WG estimates of landings for lemon sole (green line), witch (purple line) and combined (red line), along with the joint lemon sole-witch TAC (dots).

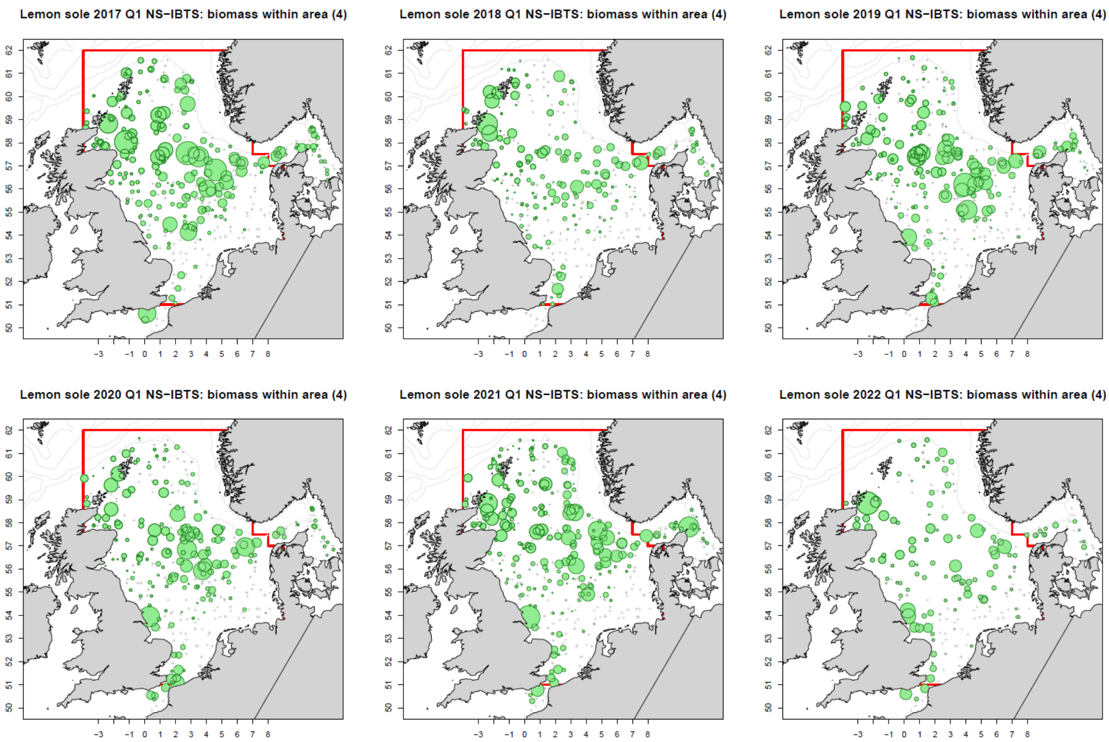


Figure 9.3.1. Lemon sole in Subarea 4, and Divisions 3.a and 7.d. Distribution of lemon sole in the North Sea derived from IBTS Q1 during 2017-2022. The sizes of the circles are proportional to the square root of the estimated weight of lemon sole caught in each haul, using a consistent scale between years.

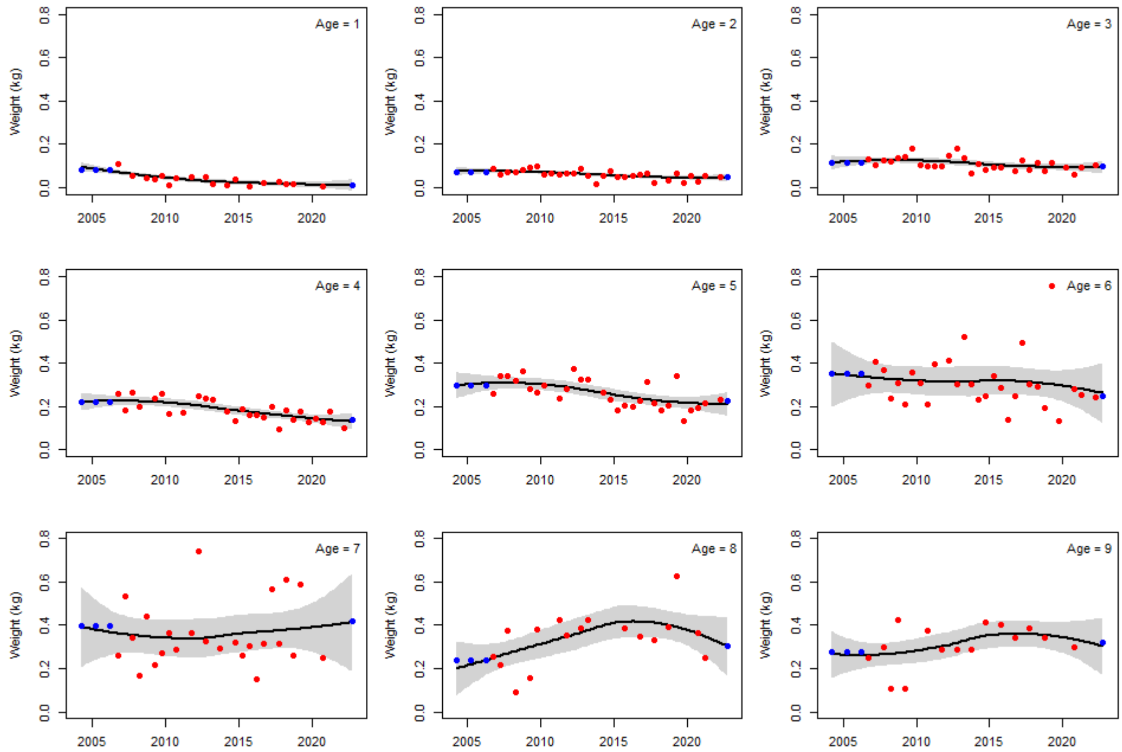


Figure 9.3.2. Lemon sole in Subarea 4, and Divisions 3.a and 7.d. Time-series of mean weight-at-age estimates (red dots) from IBTS Q1 and Q3 surveys, summarised by a loess smoother (span = 1) for each year (the grey band gives a 95% confidence interval about the loess smoother). The blue dots show averages (of either the first or last two estimates), included to allow extrapolation to the start and end point of the survey indices.

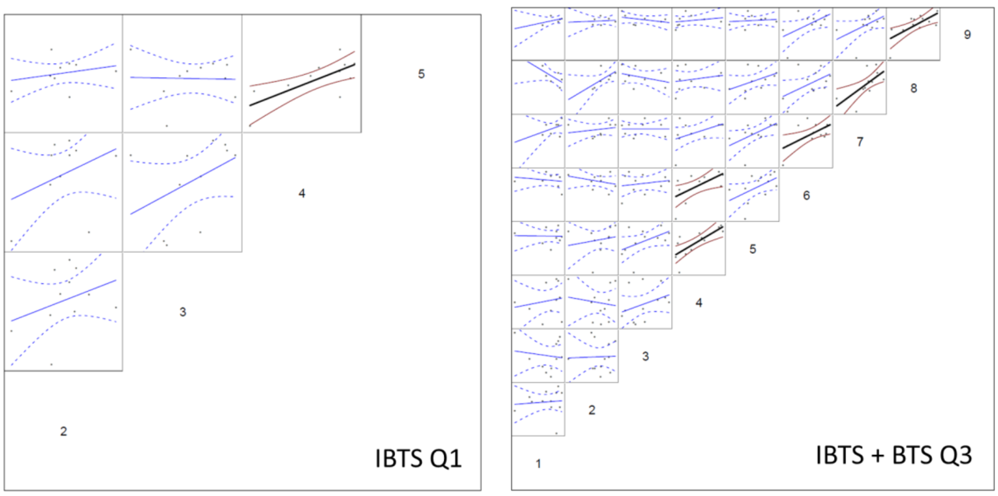


Figure 9.3.3. Lemon sole in Subarea 4, and Divisions 3.a and 7.d. Bivariate scatterplots showing consistency in cohort-strength estimation, for Q1 (left: IBTS) and Q3 (right: IBTS and BTS).

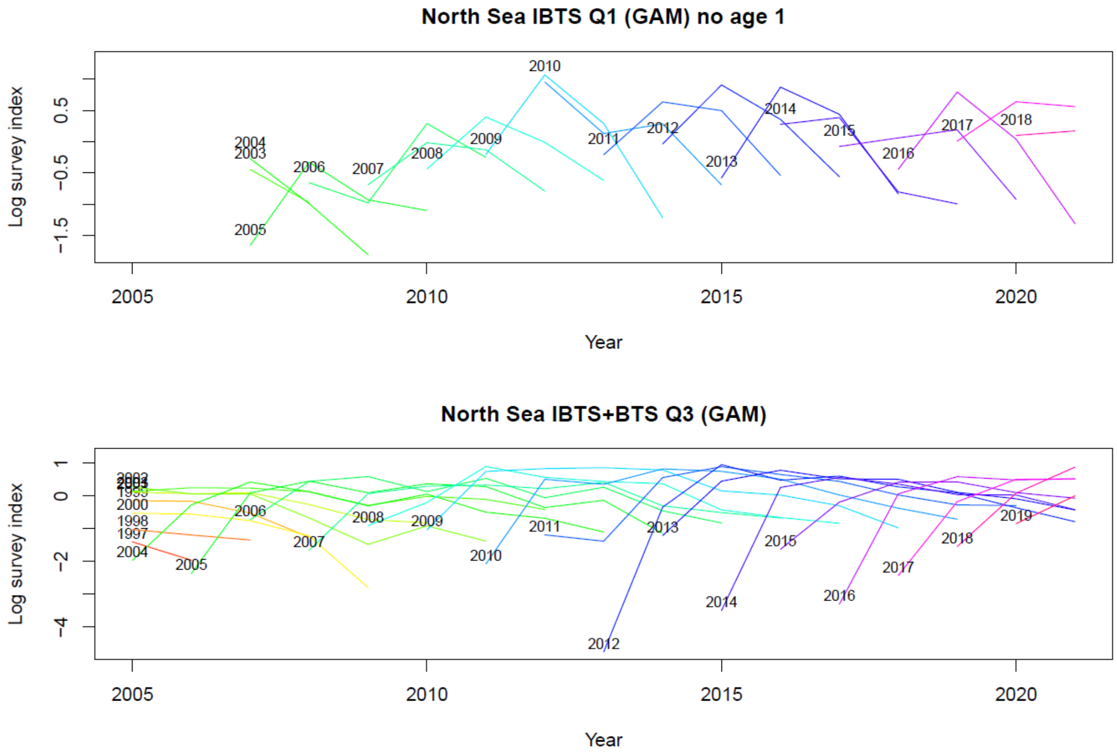


Figure 9.3.4. Lemon sole in Subarea 4, and Divisions 3.a and 7.d. Survey catch curves, for Q1 (upper: IBTS) and Q3 (lower: IBTS and BTS).

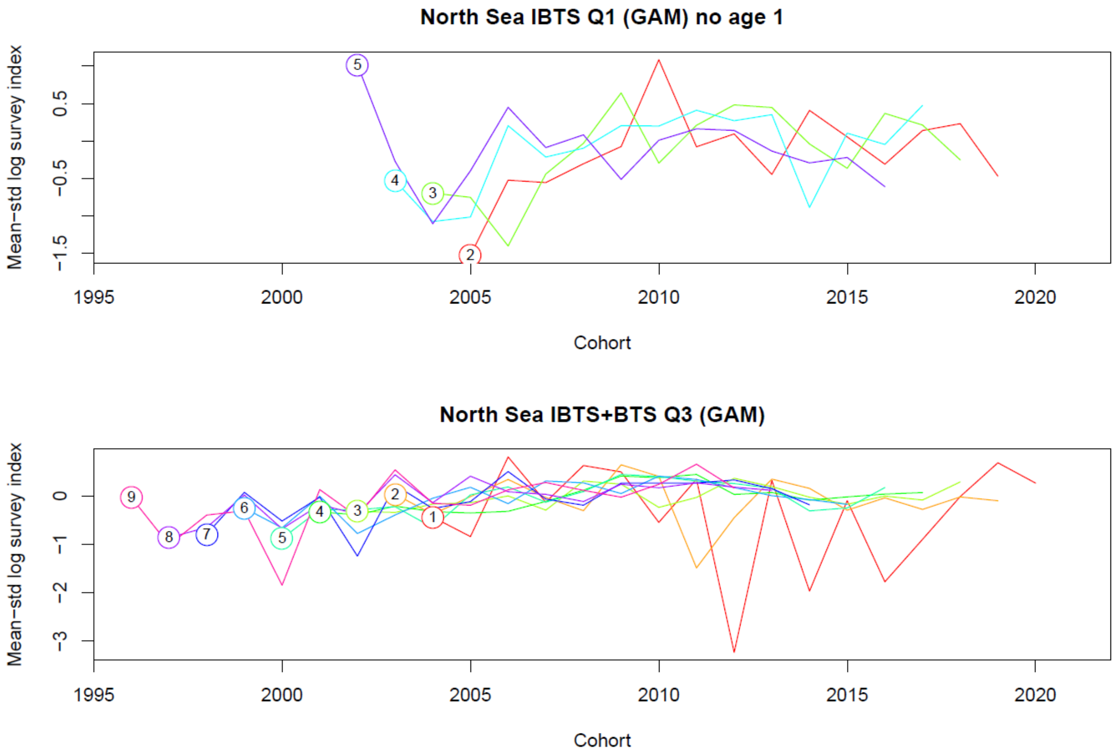


Figure 9.3.5. Lemon sole in Subarea 4, and Divisions 3.a and 7.d. Survey indices by age, cohort and year, for Q1 (upper: IBTS) and Q3 (lower: IBTS and BTS).

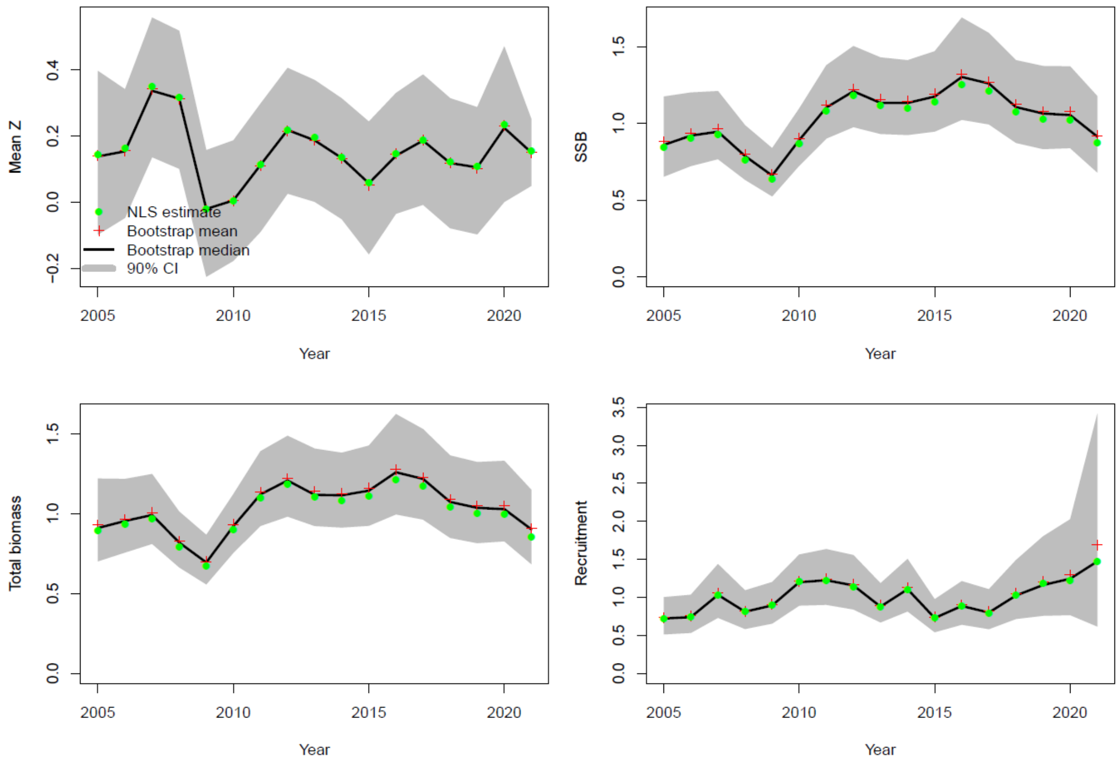


Figure 9.4.1. Lemon sole in Subarea 4, and Divisions 3.a and 7.d. SURBAR stock summary (clockwise from upper left: mean Z(3-5), relative SSB, relative recruitment at age 1, relative total biomass). In each plot, the green dots give the nonlinear least-squares estimates, the red crosses give the uncertainty-estimation bootstrap mean, the black line gives the bootstrap median, and the grey band gives a 90% confidence interval about the median.

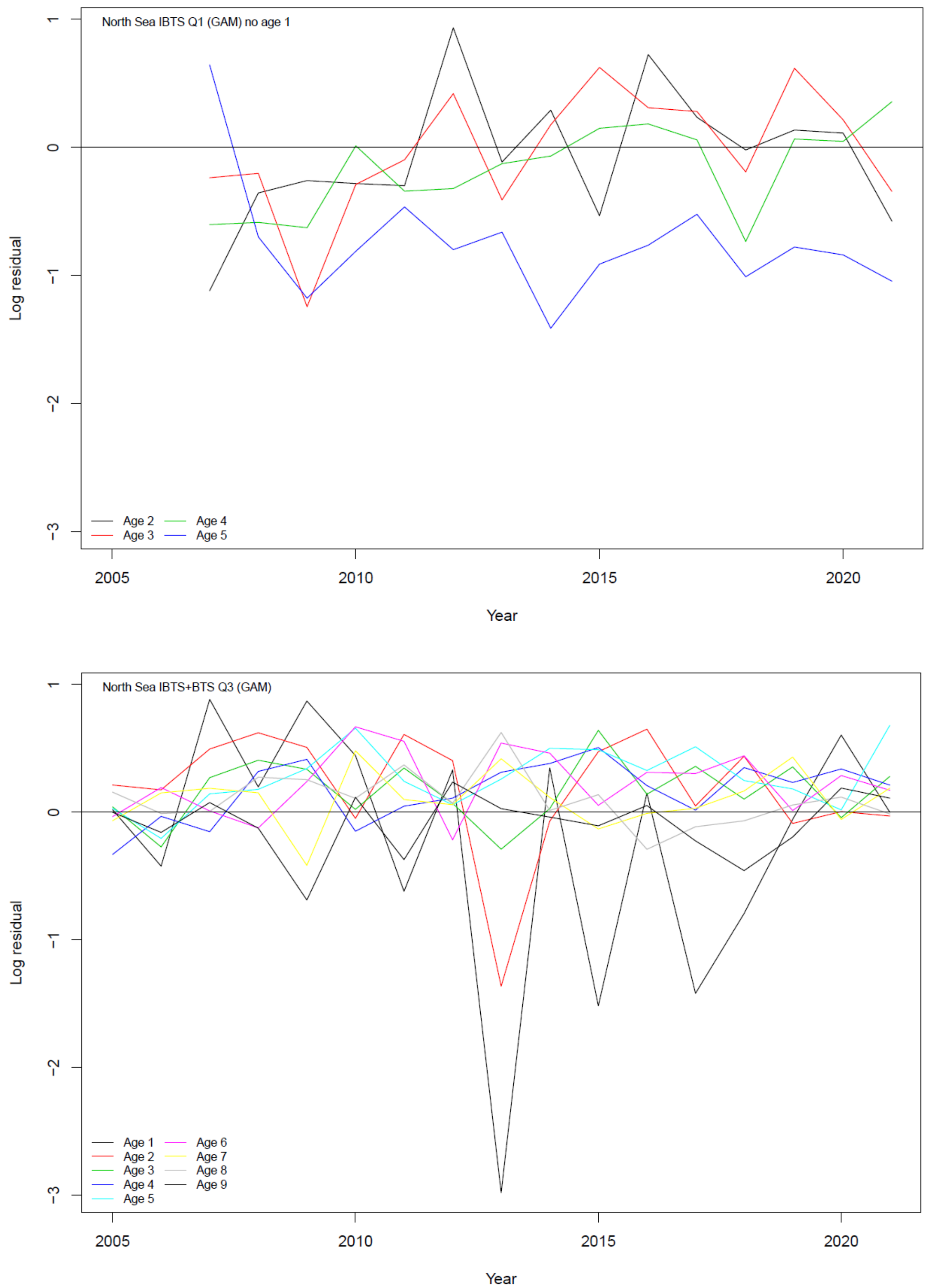


Figure 9.4.2. Lemon sole in Subarea 4, and Divisions 3.a and 7.d. Upper: Log SURBAR residuals for Q1 (IBTS). Lower: Log SURBAR residuals for Q3 (IBTS+BTS).

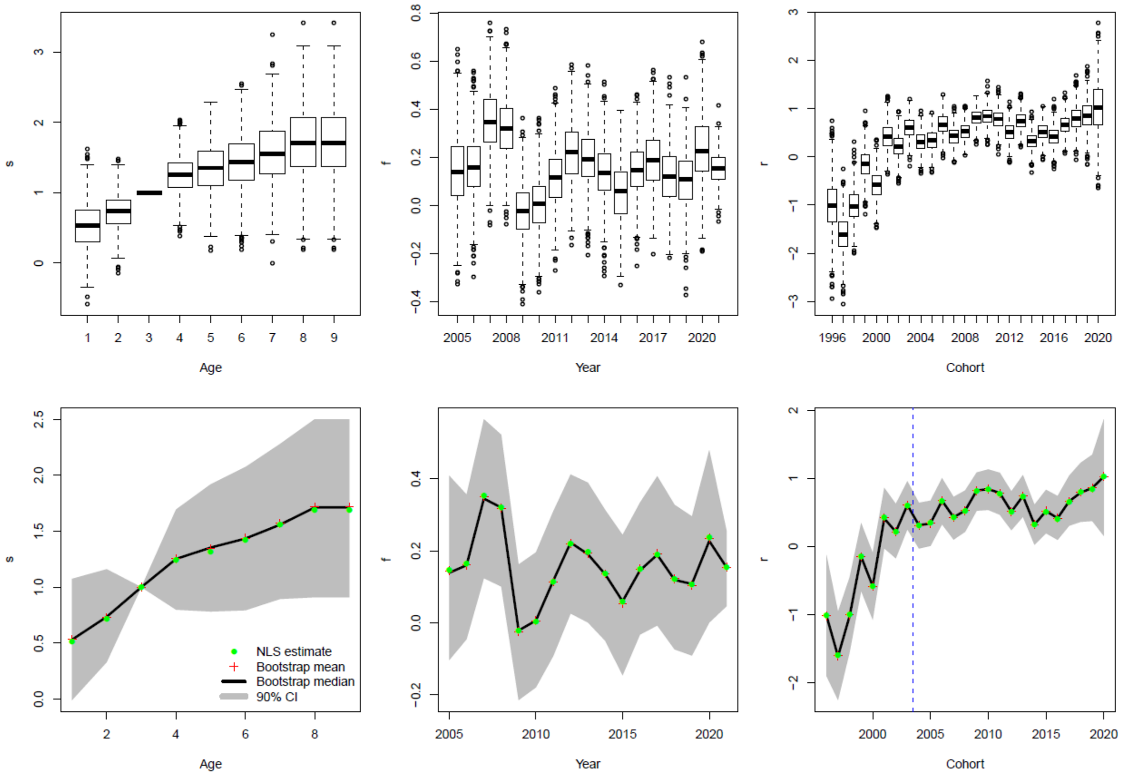


Figure 9.4.3. Lemon sole in Subarea 4, and Divisions 3.a and 7.d. Estimated SURBAR parameters: age effects (*s*) and year effects (*f*) of total mortality, and cohort effects (*r*). Upper: box-and-whisker plots of bootstrap distributions. Lower: the green dots give the nonlinear least-squares estimates, the red crosses give the uncertainty-estimation bootstrap means, the black line gives the bootstrap median, and the grey band gives a 90% confidence interval about the median.

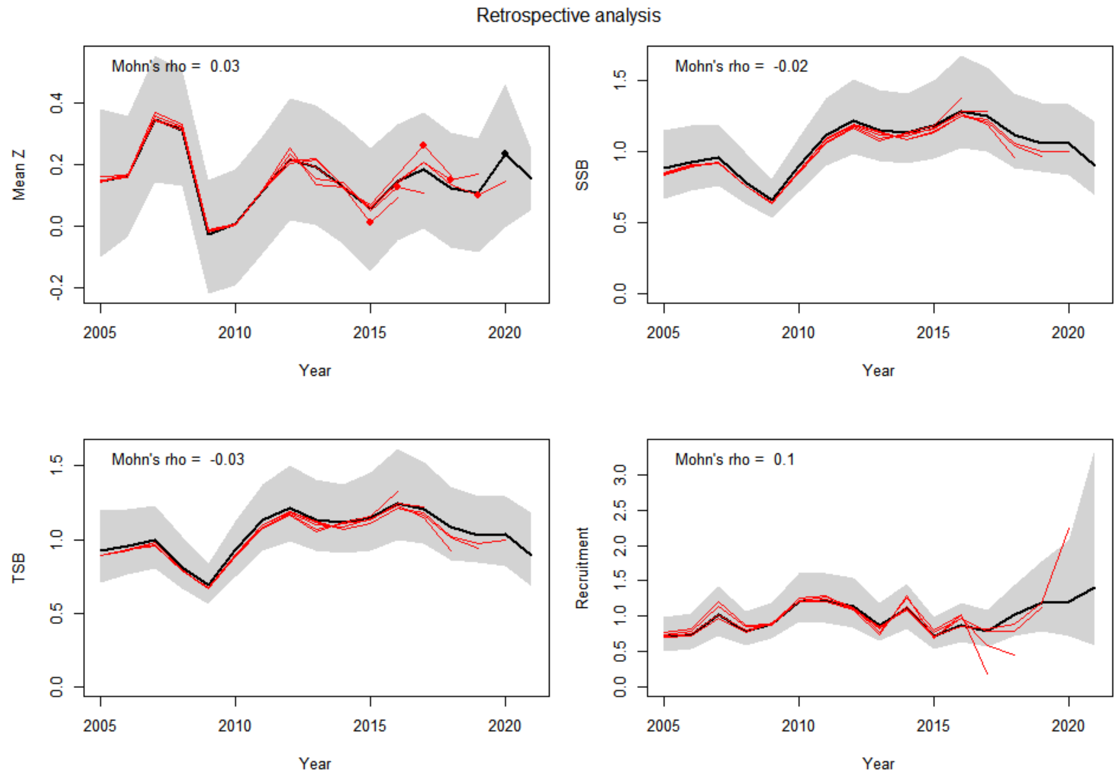


Figure 9.4.4. Lemon sole in Subarea 4, and Divisions 3.a and 7.d. Retrospective SURBAR analysis (clockwise from upper left: mean Z(3-5), relative SSB, relative total biomass, relative recruitment at age 1) with Mohn's rho included in each plot. Black lines give final-year estimates (with 90% confidence interval in grey), while red lines give the results of 5 retrospective peels.

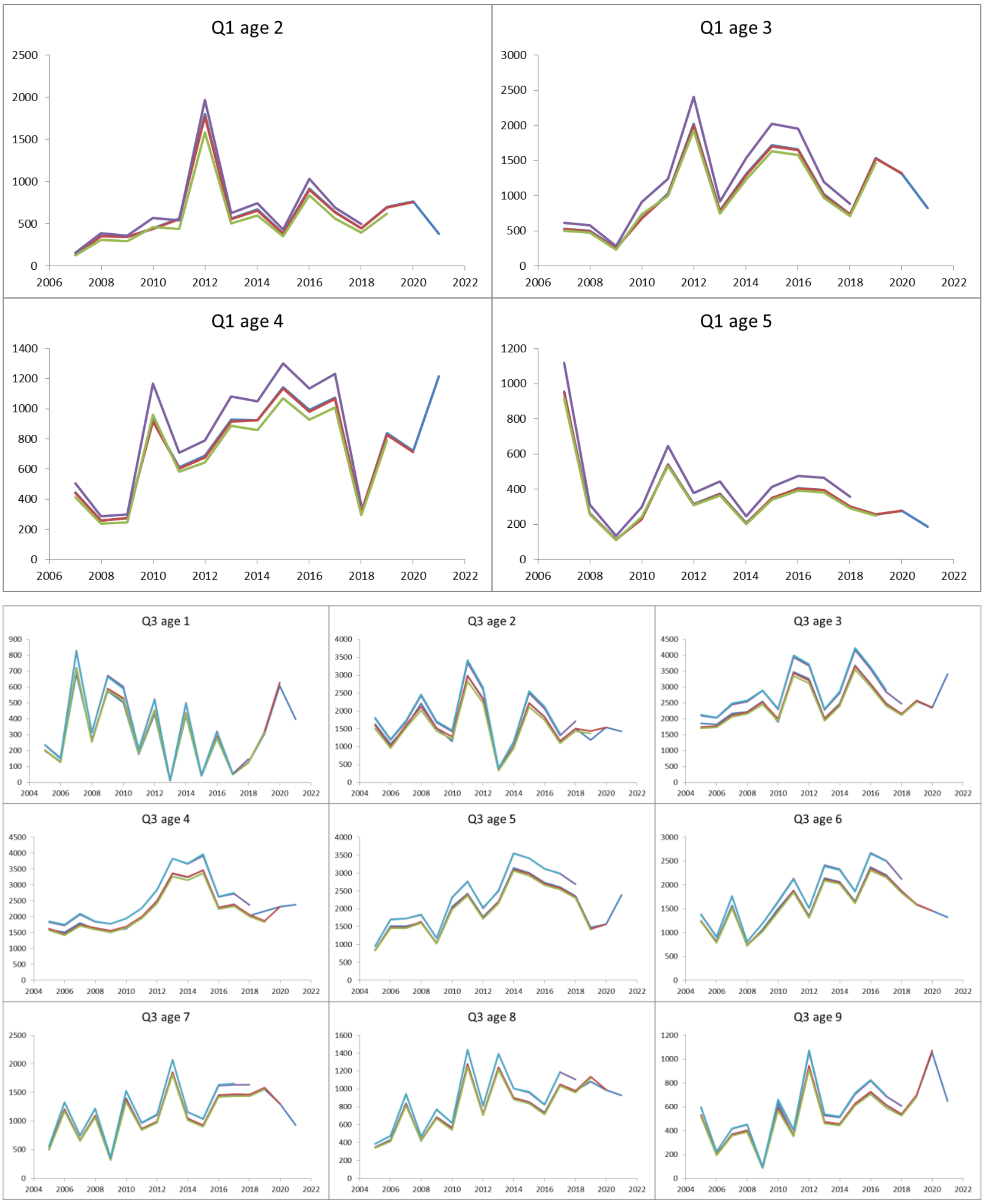
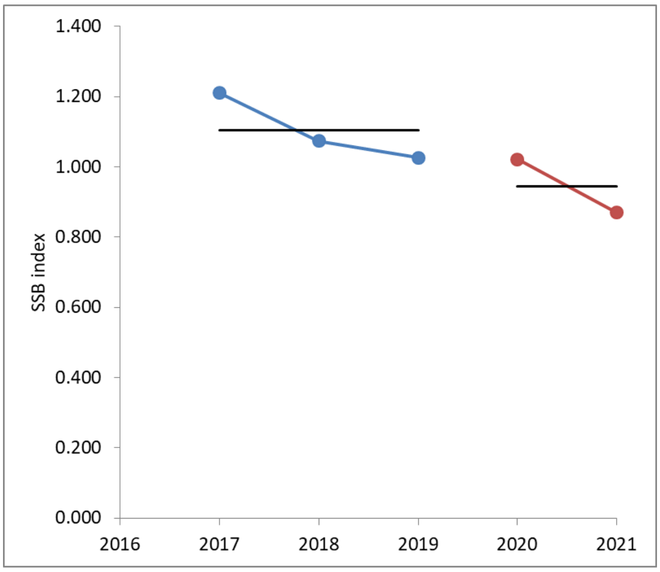


Figure 9.4.5. Lemon sole in Subarea 4, and Divisions 3.a and 7.d. Historical retrospective comparisons of relative abundance indices from IBTS Q1 (upper) and IBTS+BTS Q3 (lower). The lines show survey indices from four successive meetings of WGNSSK.



C(y)	3742
C(y+1)	3207
+20% cap	4490
-20% cap	2994

Figure 9.5.1. Lemon sole in Subarea 4, and Divisions 3.a and 7.d. Application of the previous DLS 3.2 ("2-over-3") rule, using the last five years of the relative SSB estimate given in Figure 9.4.1.

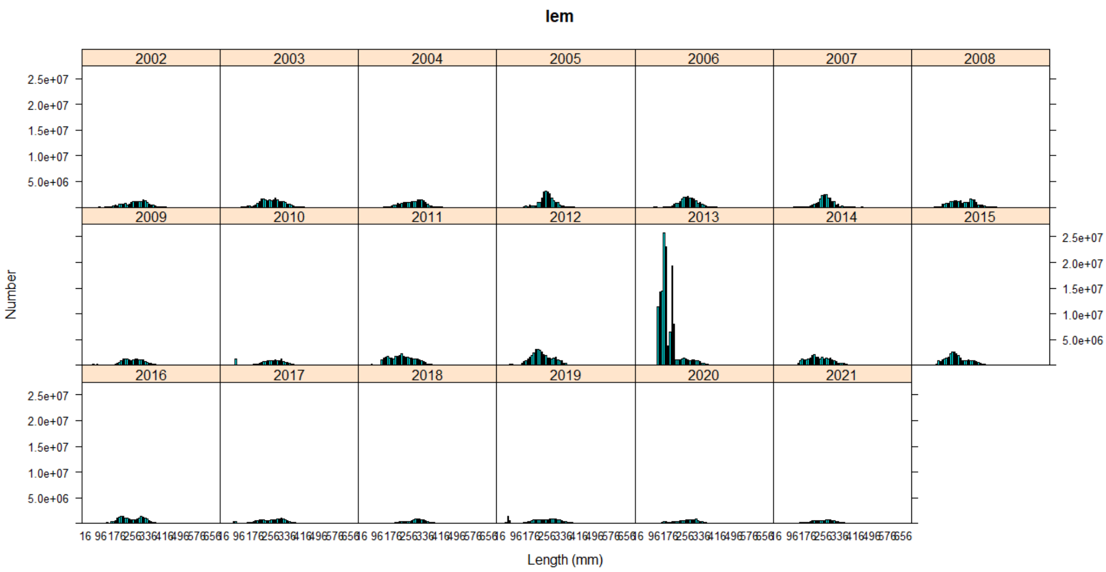


Figure 9.5.2. Lemon sole in Subarea 4, and Divisions 3.a and 7.d. Length distributions in commercial catches (landing and discards) submitted to InterCatch, by year.

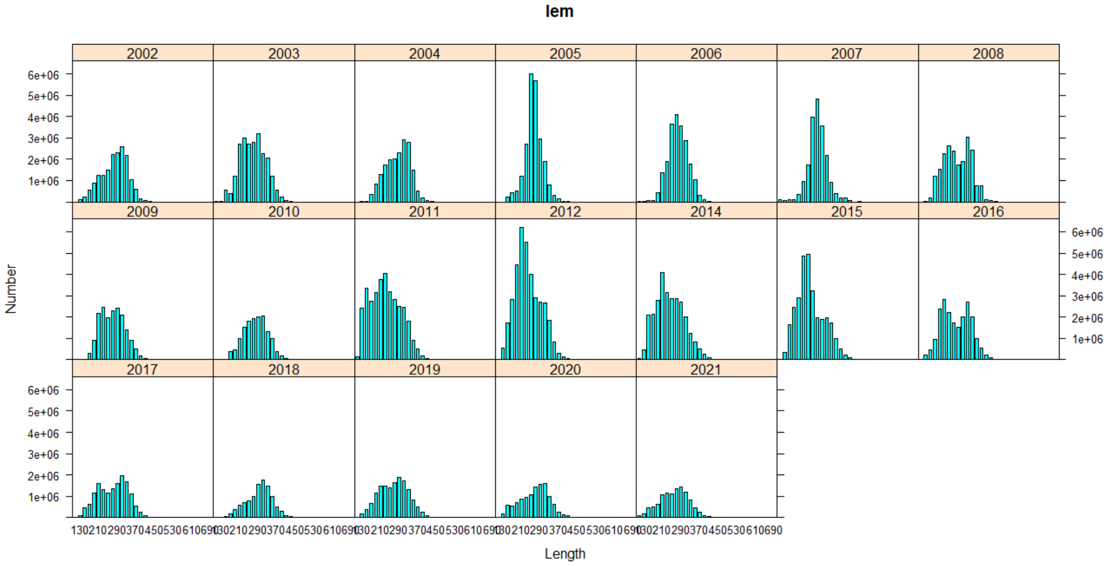


Figure 9.5.3. Lemon sole in Subarea 4, and Divisions 3.a and 7.d. Length distributions in commercial catches (landing and discards) submitted to InterCatch, by year, with 2013 data removed due to erroneous data submissions, and all fish <100 mm removed for all years.

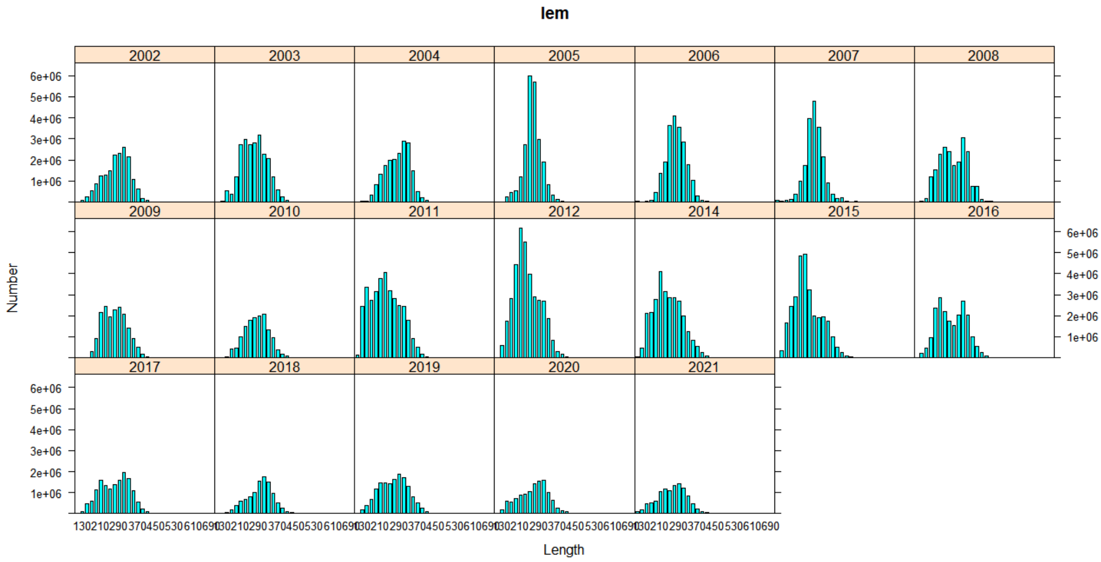


Figure 9.5.4. Lemon sole in Subarea 4, and Divisions 3.a and 7.d. As for Figure 9.6.2, with bin widths doubled (to 20 mm).

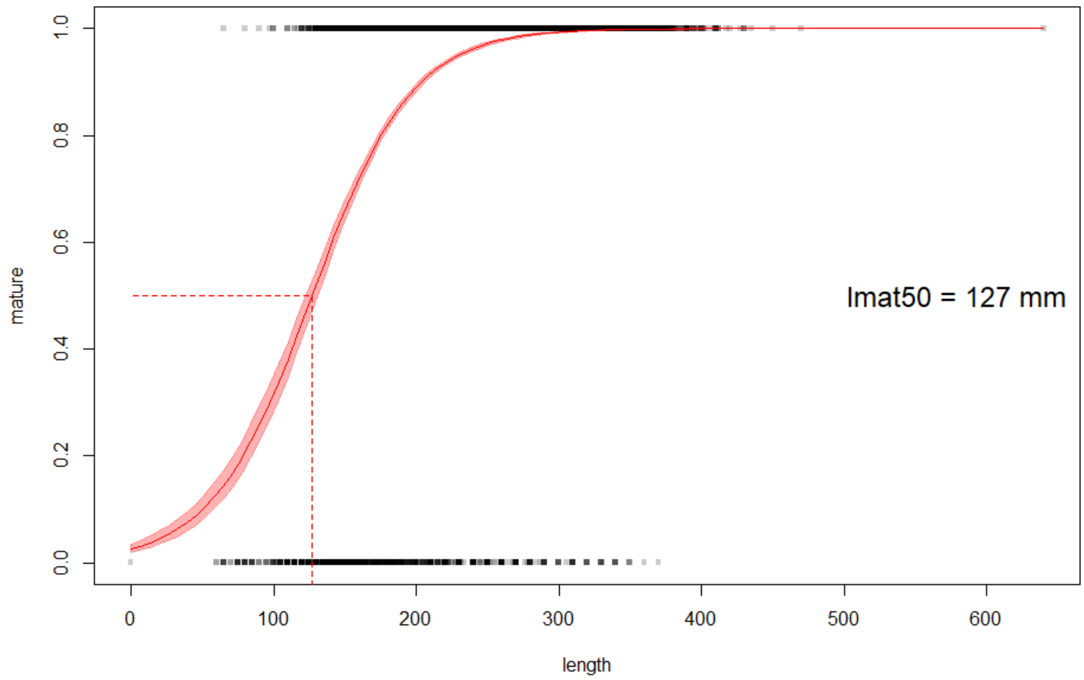


Figure 9.5.5. Lemon sole in Subarea 4, and Divisions 3.a and 7.d. Fitted maturity-at-age estimates from Q1 (IBTS) and Q3 (IBTS & BTS) survey series, using maturity-length observations from all available years (2007-2022). Maturity indices (0 = not mature, 1 = mature) are shown as shaded dots. The solid red line gives the fitted maturity ogive with 95% confidence interval (red band), while dotted red lines highlight the length of 50% maturity (L_{mat} = 127 mm)

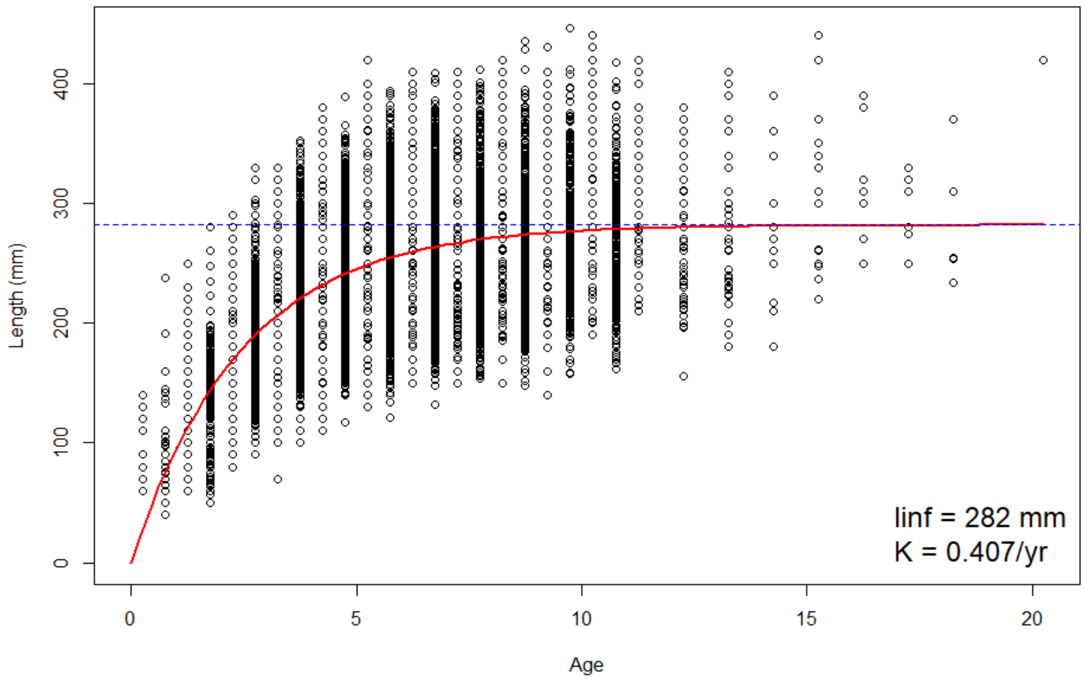


Figure 9.5.6. Lemon sole in Subarea 4, and Divisions 3.a and 7.d. Length-at-age data from Q1 (IBTS) and Q3 (IBTS & BTS) survey series, using data from all available years (2007–2021). To account for seasons, Q1 lengths are plotted at *a* + 0.25, Q3 lengths at *a* + 0.75. The red line gives a fitted von Bertalanffy growth curve (L_∞ = 282.806 mm, K = 0.4114, t_0 = 0).

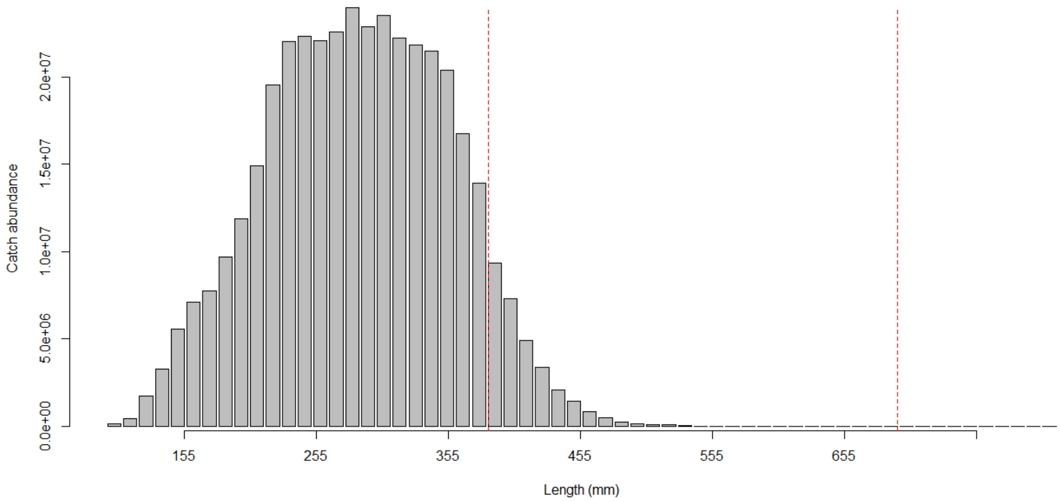


Figure 9.5.7. Lemon sole in Subarea 4, and Divisions 3.a and 7.d. Length distribution of the commercial catch data submitted to InterCatch, collated over all available years (2002–2020). The red lines give (from left to right) the 99%ile of the distribution (385 mm) and the longest observed fish (695 mm).

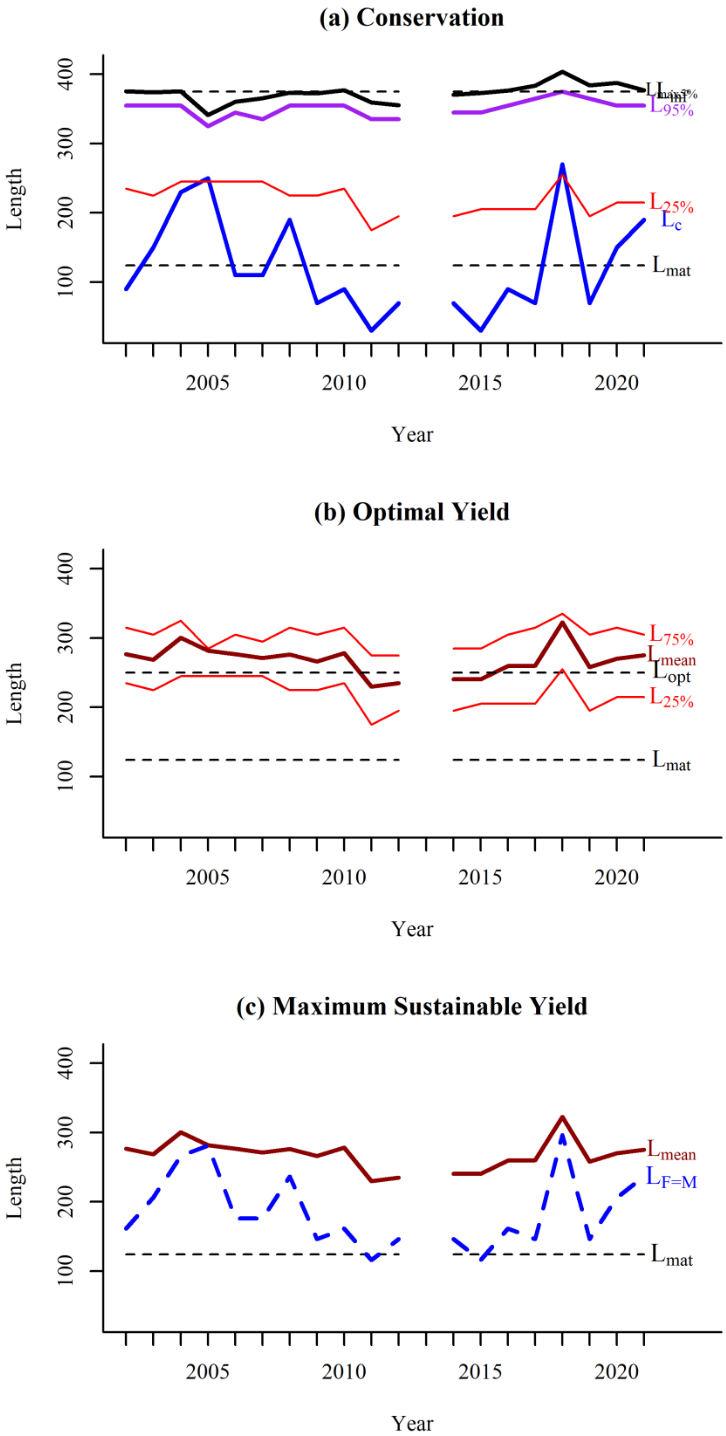


Figure 9.5.8. Lemon sole in Subarea 4, and Divisions 3.a and 7.d. Results of LBI analysis (absolute estimates).

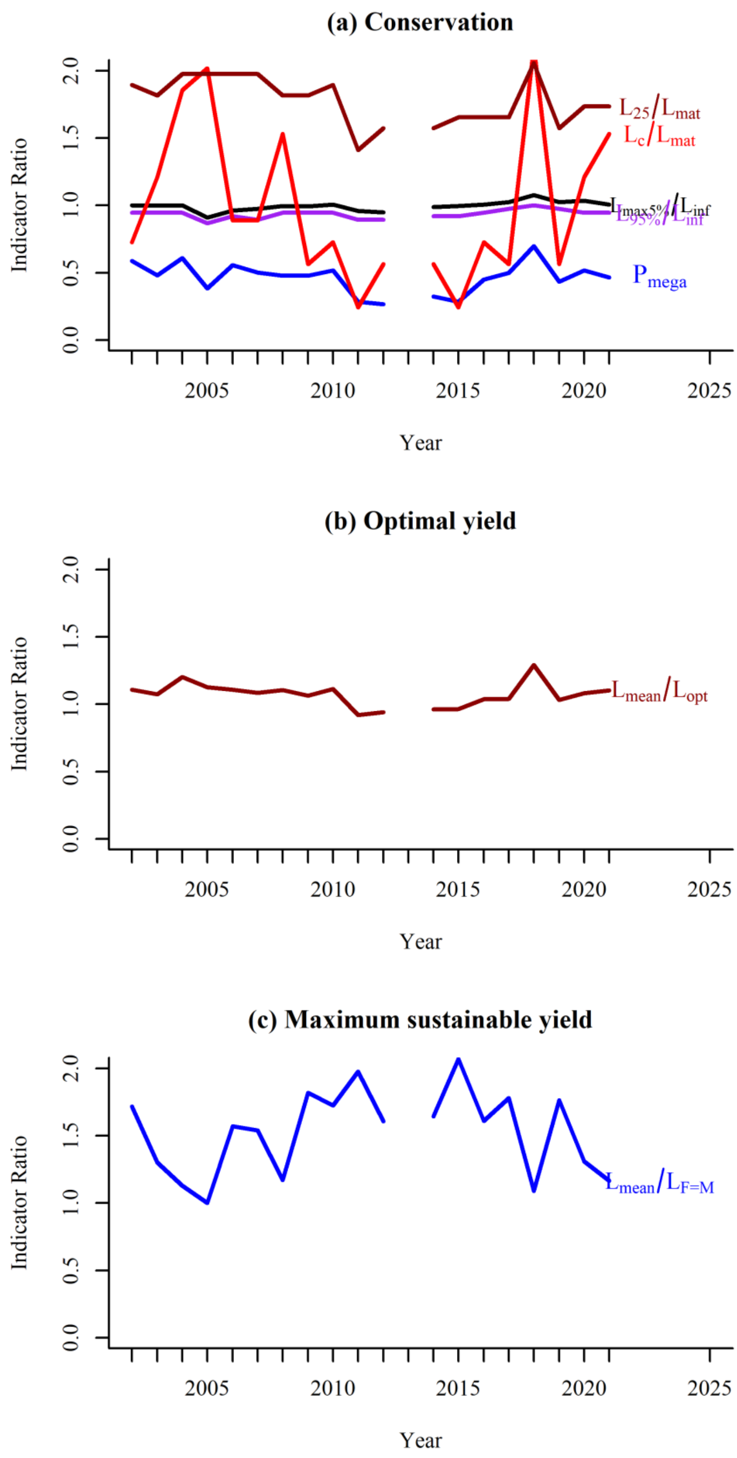


Figure 9.5.9. Lemon sole in Subarea 4, and Divisions 3.a and 7.d. Results of LBI analysis (ratio estimates).

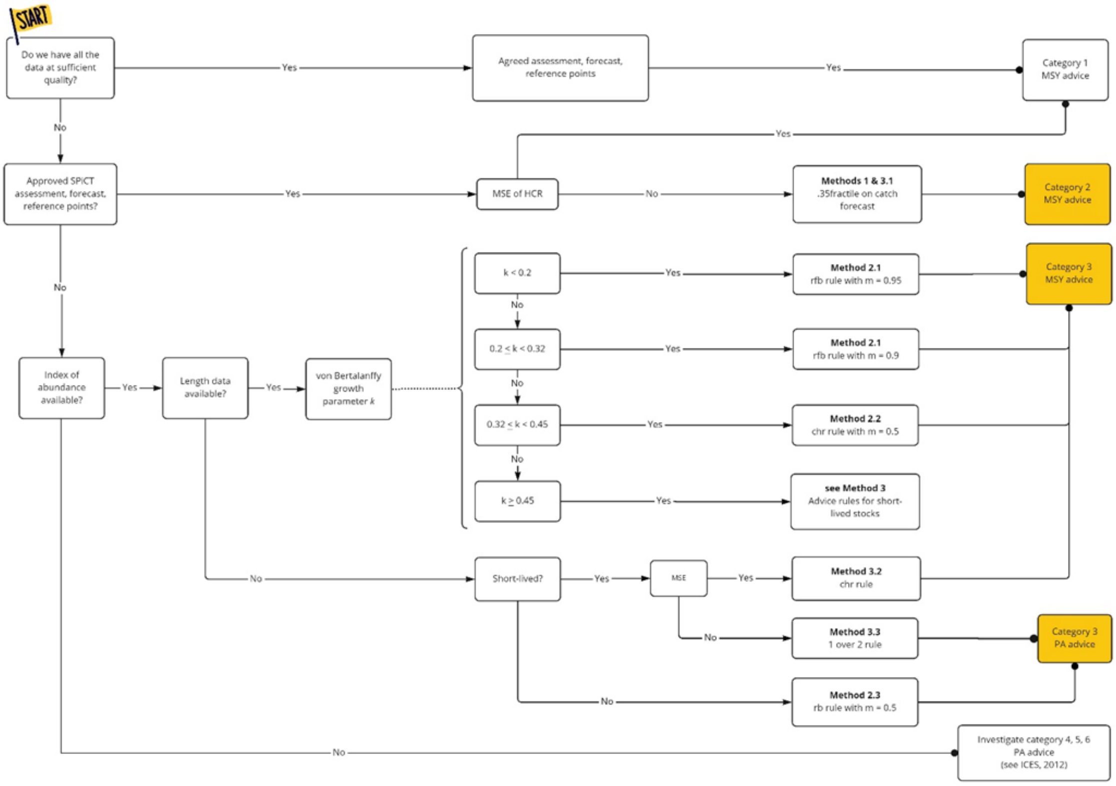


Figure 9.5.10. The WKLIFE DLS advice decision tree (ICES, 2020).

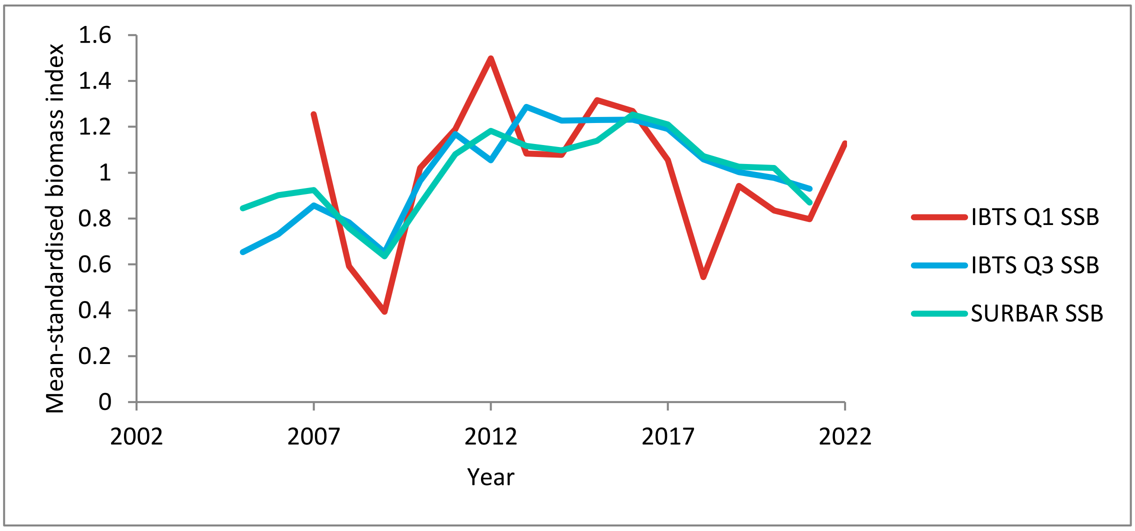


Figure 9.5.11. Lemon sole in Subarea 4, and Divisions 3.a and 7.d. Comparison of mean-standardised SSB indices from the SURBAR assessment (red), and empirical calculations based on IBTS Q1 (green) and IBTS+BTS Q3 (blue).

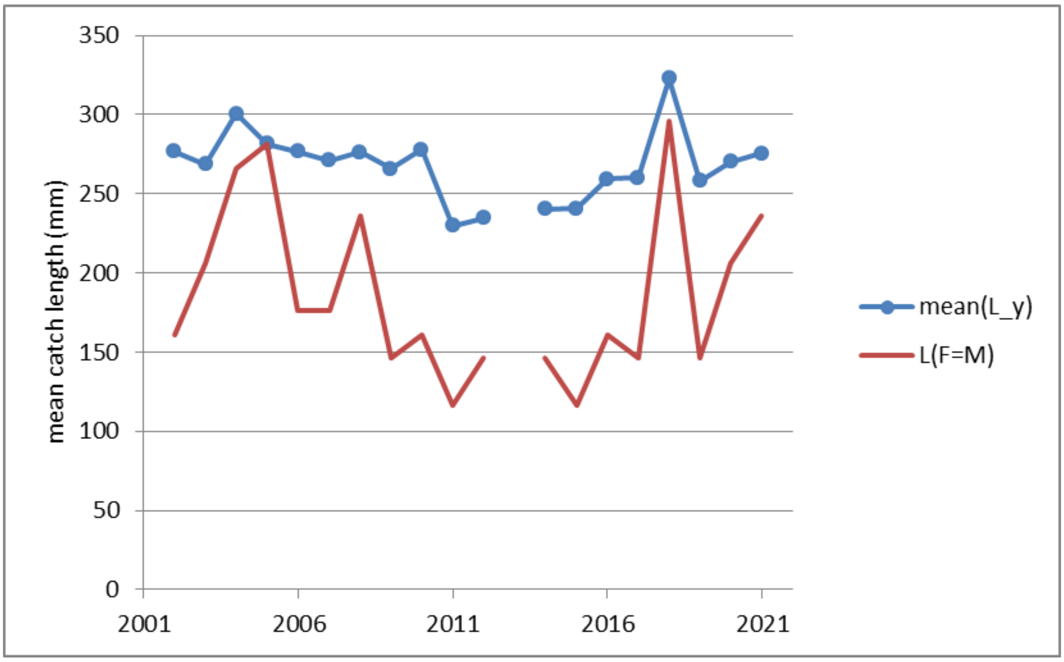


Figure 9.5.12. Lemon sole in Subarea 4, and Divisions 3.a and 7.d. Comparison of L_{mean} (blue) and $L_{F=M}$ (red) for years 2002–2021, from LBI analysis.

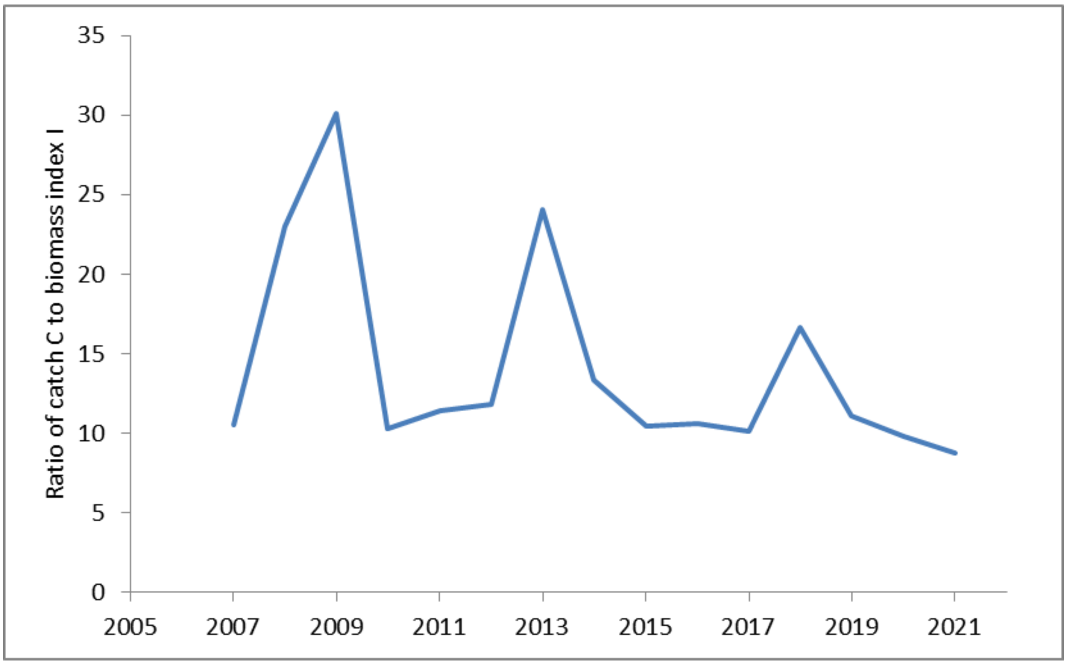


Figure 9.5.13. Lemon sole in Subarea 4, and Divisions 3.a and 7.d. Ratio of catch *C* to biomass index *I* for years 2007–2021.

10 Norway lobster (*Nephrops* spp.) in Division 3.a (Skagerrak, Kattegat)

This section was added to the report in October 2022

10.1 *Nephrops* in Division 3.a

10.1.1 General

At present, there are two functional units in Division 3.a: Skagerrak (3.a.20) and Kattegat (3.a.21). This separation was based on observed differences between Skagerrak and Kattegat regarding *Nephrops* size composition in catches in the 1980s and 1990s. However, the distribution of *Nephrops* is almost continuous from southern Kattegat into Skagerrak, and the exchange of pelagic larvae between the southern and northern areas is very likely. With the longer data series now available, it seems the differences in size composition between the two areas are more likely to be random or caused by factors from fishing operations. The assessment is therefore conducted on *Nephrops* in 3.a as one stock.

Ecosystem aspects

Nephrops live in burrows in suitable muddy sediments and is characterised by being omnivorous and emerge out of the burrows to feed. It can, however, also sustain itself as a suspension feeder in the burrows (Loo *et al*., 1993). This ability may contribute to maintaining a high production of this species in 3.a, due to increased organic production. *Nephrops* have recently been found to have a high prevalence of plastics which may have implications for the health of the stock (Murry and Cowie, 2011).

Severe depletion in oxygen content in the water can force the animals out of their burrows, thus temporarily increasing the trawl catchability of this species during such environmental changes (Bagge *et al*. 1979). An especially severe case was observed in the end of the 1980s in the southern part of 3.a in late summer, where unusually high catch rates of *Nephrops* were observed. The increasing amount of dead specimens in the catches led to the conclusion of severe oxygen deficiency in especially the Kattegat (3.a.21) in late 1988 (Bagge *et al*., 1990).

No information is available on the extent to which larval mixing occurs between *Nephrops* stocks, but the similarity in stock indicator trends between 3.a.20 and 3.a.21 for both Denmark and Sweden indicates that recruitment has been similar in both areas. These observations suggest they may be related to environmental influences.

ICES Advice

The most recent advice for *Nephrops* in 3.a was given in 2021. ICES concluded that:

'The stock size is considered to be stable. The estimated harvest rate for this stock is currently below F_{MSY}*.'*

Management for FU 3 and FU 4

The TAC for *Nephrops* in ICES area 3.a was increased from 5318 tonnes in 2015 to 11 001 tonnes in 2016, 12 715 tonnes in 2017, 11 738 tonnes in 2018, 13 733 tonnes in 2019 and 2020 and 12360 tonnes in 2021. The large increase in quota 2015 to 2016 was due to the fact that the EU shifted from providing landings advice to providing catch advice. The minimum conservation reference size (previously referred to as minimum landings size) for *Nephrops* in area 3.a was reduced in

2016 from 40 to 32 mm carapace length. The historically large MLS led to a high discard ratios (discards/(discards + landings)) around 50%, and the discard proportion 2016 was decreased to 12% of the catch (in numbers) in 3.a consisted of undersized individuals. Since 2017, the discard proportion has been around 30% (Figure 10.2.1.1). The reduction in MLS has reduced the proportion of the catch discarded considerably. Furthermore, it is expected that ongoing experimental work on improving gear selectivity will further reduce the amount discarded. A discard ban was implemented in EU waters from 1 January 2015. The discard ban became applicable to *Nephrops* from 1 January 2016, however an exemption for high survivability was introduced. New technical measures have also been agreed upon and have been implemented since 1 February 2013.

Swedish gear regulations since 2004 imply that it is mandatory to use a 35 mm species selective grid together with an 8 m full square-mesh codend of 70 mm and extension piece when trawling for *Nephrops* in Swedish national waters. Additionally, the Danish gear regulations since 2011 imply a mandatory use of either the grid or the use of the SELTRA trawl which compromise a 90 mm cod end with either a square-mesh panel (180 mm in the Kattegat and 140 mm in the Skagerrak) or 270 mm diamond mesh panel. In Article 11 in the cod recovery plan, member states may apply for unlimited number of days when using the species selective grid trawl.

10.1.2 Data available from Skagerrak (FU3) and Kattegat (FU4)

Landings

Division 3.a includes FU 3 and 4, which are assessed together. Total *Nephrops* landings by FU and country are shown in Table 10.2.1.1 and Table 10.2.1.2.

FU 3 is primarily exploited by Denmark, Sweden and Norway. Denmark and Sweden dominate this fishery, with 61 % and 35 % by weight of the landings in 2020, respectively. Landings by the Swedish creel fishery represented 13–18 % of the total Swedish *Nephrops* landings from the Skagerrak in the period 1991 to 2002. Since 2002, creel catches have been steadily increasing and have in 2009 to 2016 accounted for more than 30% of Swedish Skagerrak landings (Table 10.2.2.1). In the early 1980s, total *Nephrops* landings from the Skagerrak increased from around 1000 tonnes to just over 2670 tonnes. Until 2016 they have been fluctuating around a mean of 2500 tonnes and after that increased to around 4000 tonnes (Figure 10.2.2.1). In 2021, landings were 4031 tonnes (Table 10.2.1.1).

Both Denmark and Sweden have *Nephrops* directed fisheries in the FU 4 (Kattegat). In 2020, Denmark accounted for about 75% of total landings in FU4, while Sweden took 23 % (Table 10.2.2.5). Minor landings have been taken by Germany (~ 1%).

After a decline in the observed landings in 1994, total *Nephrops* landings from the Kattegat increased again until 1998 and have fluctuated around 1500 tonnes. However, since 2006 the landings have increased and were in 2010 the highest on record over the previous 50-year period (Figure 10.2.2.3). From 2010 till 2015, landings show a decreasing trend. Landings have increased since 2015 reaching 3149 tonnes in 2019, the maximum observed in the time series. A general trend of reduced landing of *Nephrops* during 2020 and 2021 was observed also in Kattegat with a catch in 2021 of 2511 tonnes.

Length compositions

For the Skagerrak, size distributions of both the landings and discards are available from both Denmark and Sweden for 1991–2021. In the beginning of the time series, the Swedish data can be considered as being the most complete, since sampling took place regularly throughout the time period and usually covered the whole year. Trends in mean size in catch and landings for Skagerrak are shown in Figure 10.2.2.2 and Table 10.2.2.4. Mean sizes for landings are fluctuating without trend. Mean size for undersized show an increasing trend from 2005 till 2015 but are observed to be at lower level in recent years.

For Kattegat, size distributions of both the landings and discards are available from Sweden for 1990–2021, and from Denmark for 1992–2021. The at-sea-sampling intensity has generally increased since 1999. The Danish sampling intensity was low in 2007 and 2008, but normalized in 2009 to 2019. Information on mean size is shown in Figure 10.2.2.4 and Table 10.2.2.8. Notice, that except for small mean sizes from 1993 to 1996 all categories have since been fluctuating without trend until 2016 when the minimum landing size was decreased from 40 to 32 mm carapace length.

In earlier years, the Swedish discard samples were obtained by agreement with selected fishermen, and this might have tempted fishermen to bias the samples. However, the reliability of the catch samplings was cross-checked by special discard sampling projects in both the Skagerrak and the Kattegat. In recent years, the Swedish *Nephrops* sampling has been carried out by onboard observers in both Skagerrak and Kattegat. In 1991, a biological sampling programme of the Danish *Nephrops* fishery was started on board fishing vessels in order to also cover the discards in this fishery. Due to its high cost and the lack of manpower, Danish sampling intensity in the early years was in general not satisfactory, and seasonal variations were not often adequately covered. The Norwegian *Nephrops* fishery is small and has not been sampled.

Natural mortality, maturity at age and other biological parameters

In previous analytical assessments (when Length Cohort Analyses were performed, see e.g. WGNEPH 2003), natural mortality was assumed to be 0.3 for males of all ages and in all years. Natural mortality was assumed to be 0.3 for immature females, and 0.2 for mature females. Discard survival was assumed to be 0.25 for both males and females (after Gueguen and Charuau, 1975, Redant and Polet, 1994, and Wileman *et al*. 1999).

Growth parameters are as follows:

Males:	$L\infty$ = 73 mm CL, k = 0.138.
Immature females:	$L\infty$ = 73 mm CL, k = 0.138.
Mature females:	$L\infty$ = 65 mm CL, k = 0.10, Size at 50% maturity = 29 mm CL.

Growth parameters for males were taken from Ulmestrand and Eggert (2001) and female growth parameters have been assumed to be similar to those of Scottish *Nephrops* stocks.

Data on size at maturity for males and females were presented at the ICES Workshop on *Nephrops* Stocks in January 2006 (ICES WKNEPH, 2006).

Catch and effort data–FU3

Effort data for the Swedish fleet are available from logbooks for 1978–2021 (Figure 10.2.2.1 and Table 10.2.2.2). During the period 1998 to 2005, twin trawlers shifted to targeting both fish and *Nephrops*, which resulted in a decreasing trend in LPUE during this period (Table 10.2.2.2). Since 2005, LPUE for twin trawls has increased. The LPUE for single trawls has shown and increasing trend throughout the entire time series. The long-term trend in LPUEs is similar in the Swedish and Danish fisheries (Figure 10.2.2.1). Total Swedish trawl effort shows a decreasing trend since 1992 and has been fluctuating without trend since 2003. From 2007 onwards, total Swedish trawl effort has been estimated from LPUEs from the single trawl with a grid (targeting only *Nephrops*).

Danish effort figures for the Skagerrak (Table 10.2.2.3 and Figure 10.2.2.1) were estimated from logbook data. For the whole period, it is assumed that effort is exerted mainly by vessels using twin trawls. The overall trend in effort for the Danish fleet is similar to that in the Swedish fishery. After having been at a relatively low level in 1994–1998, effort increased again in the next four years, followed by a decrease to a relatively low level in 2007 to 2017. Also, the trend in LPUE is similar to that in the Swedish single trawl fishery, however with a much more marked increase in the Danish LPUE for 2007 and 2008. This high LPUE level is likely to be a consequence of the national (Danish) management system introduced in 2007.

It has not been possible to explicitly incorporate 'technological creeping' in a further evaluation of the Danish effort data. However, since 2000 the Danish logbook data have been analysed in various ways to elucidate the effect of factors likely to influence the effort/LPUE, e.g. vessel size (Figure 10.2.2.3).

Catch and effort data–FU4

Swedish total effort has been relatively stable over the period 1978–1990. Effort increased from 1990 to 1993, followed by a decrease to 1996. During the last 20 years effort has remained relatively stable, except for 2007 and 2008 where effort increased (Figure 10.2.2.3 and Table 10.2.2.6). Figures for total Danish effort are based on logbook records since 1987. Danish effort increased from 1995 to 2001, decreased from 2002 to 2007 and has been fluctuating without trend since (Figure 10.2.2.3 and Table 10.2.2.7).

Since 2000, the Danish logbook data have been standardised to account for changes in fishing power due to changes in the physical characters of the *Nephrops* fleet. The data have been analysed in various ways to elucidate the effect of factors likely to influence the effort/LPUE, e.g. vessel size.

10.1.3 Combined assessment (FU 3 and 4)

10.1.3.1 TV survey in 3.a

In 2008 and 2009, an exploratory UWTV survey was carried out by Denmark. In 2010, the TV survey was expanded covering the main *Nephrops* grounds in the western part of Skagerrak (Subarea 1) and Northern part of Kattegat (Subarea 2). Since 2011, the TV survey has been carried out in collaboration between Denmark and Sweden and covers the main *Nephrops* fishing grounds in 3.a (Subarea 1–6). In 2014, Subarea 1 was extended to the west (Subarea 7; Figure 10.2.3.2) and in 2017 (2016 benchmark) Subarea 2 was extended east (Subarea 9). Figure 10.2.3.4 presents the distribution of stations with valid density estimates from 2011 to 2021. A similar survey design has been applied for both national surveys: a fixed grid with random stratified stations.

In order to estimate the total population numbers, the density estimates have to be raised from the survey areas to total area of the population distribution. VMS information is currently the best available proxy to estimate the *Nephrops* stock distribution in 3.a. VMS data from the Swedish and Danish fishery from 2010 were used (Figure 10.2.3.3) and are described in more detail in ICES (2011). The area estimates for each Subarea are defined in Table 10.2.3.1. Burrow counting and identification follows the standard protocols defined by WGNEPS (ICES, 2013).

Abundance indices from UWTV surveys

The number of valid stations conducted in the UWTV survey in 3.a divided into subareas Figure 10.2.3.2 is shown in Table 10.2.3.1 and Figure 10.2.3.4.

In WK*NEPH* (2009), a number of bias sources were highlighted relating to the "counted" density from the TV surveys. These bias sources are not easily estimated and are largely based on expert opinion. For the *Nephrops* stock in 3.a, it is assumed that the largest source of perceived bias is the "edge effect", due to the relatively large sizes of the burrow systems. The cumulative biases result in a correction factor to take the raw counts to absolute densities. The correction factor for 3.a was set to be 1.1, meaning that the raw TV survey is likely to overestimate *Nephrops* abundance by 10 %. TV survey results are presented as absolute values (i.e. the bias already taken into account).

FU	Area	Edge effect	Detection rate	Species identification	Occupancy	Cumulative bias
3 and 4	Skagerrak and Kattegat	1.3	0.75	1.05	1	1.1

10.1.3.2 Assessment

The assessment of the state of the *Nephrops* stock in 3.a is based on the UWTV survey from 2021. Additional used information was trends in total combined (Denmark and Sweden) LPUE, and discards (numbers) as a proxy for recruitment during the period 1990–2021.

Combined relative effort declined over the period 1990 to 2015 with a slight increase until 2021 (Figure 10.2.4.1) while combined relative LPUE shows a mostly increasing trend and is at a high level but decreased slightly in 2020 (Figure 10.2.4.2). This high level may be attributed to the change in the Danish management system (Individual Transferable Quotas) in 2007 and the change in minimum landing size in 2016. Technical creep, changes in targeting behaviour, stock size and catchability may also be responsible for some of this increase. High LPUEs attributable to sudden changes in catchability (caused by e.g. poor oxygen conditions) are known to occur but are generally of short duration.

Since the abundance of small *Nephrops* (typically discards of specimens below minimum landing size) may also be regarded as an index of recruitment, they can be used to further explain the current developments in the stock. The large amounts of discards in the periods 1993–1995 and 1999–2000 reflect strong recruitment during these years (Figure 10.2.4.3). The high levels of discards in 1993–1995 are believed to have significantly contributed to the high LPUE in 1998–1999. The high amount of discards observed in 2007, 2008 and 2009 would then indicate high recruitment in these years, as could the low amount of discards in 2014 and 2015 indicate a low recruitment. The discards in 2016 was the lowest since 1991 due to the lowered MCRS. Low discard rate may also be due to a very low recruitment and/or an increase in gear size selectivity.

MSY considerations (TV–survey)

There are no precautionary reference points defined for *Nephrops*. Under the ICES MSY framework, exploitation rates which are likely to generate high long-term yields (and low probability of stock overfishing) have been explored and proposed for Division 3.a. Owing to the way *Nephrops* are assessed, it is not possible to estimate F_{MSY} directly and hence proxies for F_{MSY} are determined. WGNSSK (2010) developed a framework for proposing F_{MSY} proxies for the various *Nephrops* stocks based upon their biological and historical characteristics, and is described in Section 1 of that report. Three candidates for F_{MSY} are $F_{0.1}$, $F_{35\%SpR}$ and F_{MAX}. There may be strong differences in relative exploitation rates between the sexes in many stocks. To account for this, values for each of the candidates have been determined for males, females and the two sexes combined. An appropriate F_{MSY} candidate has been selected according to the perception of stock resilience, factors affecting recruitment, population density, knowledge of biological parameters and the nature of the fishery (relative exploitation of the sexes and historical harvest rate vs stock status).

A decision-making framework based on the table below was used in the selection of preliminary stock-specific F_{MSY} proxies (ICES, 2010a). These proxies may be modified following further data exploration and analysis. The combined sex F_{MSY} proxy should be considered appropriate if the resulting percentage of virgin spawner-per-recruit for males or females does not fall below 20%.

When this does happen a more conservative sex-specific F_{MSY} proxy should be picked instead of the combined proxy.

		Burrow density (average burrows m⁻²)		
		Low	Medium	High
		<0.3	0.3-0.8	>0.8
Observed harvest rate or landings compared to stock status	> F_{max}	$F_{35\%SpR}$	F_{max}	F_{max}
	F_{max} - $F_{0.1}$	$F_{0.1}$	$F_{35\%SpR}$	F_{max}
	< $F_{0.1}$	$F_{0.1}$	$F_{0.1}$	$F_{35\%SpR}$
	Unknown	$F_{0.1}$	$F_{35\%SpR}$	$F_{35\%SpR}$
Stock size estimates	Variable	$F_{0.1}$	$F_{0.1}$	$F_{35\%}$
	Stable	$F_{0.1}$	$F_{35\%SpR}$	F_{max}
Knowledge of biological parameters	Poor	$F_{0.1}$	$F_{0.1}$	$F_{35\%SpR}$
	Good	$F_{35\%SpR}$	$F_{35\%SpR}$	F_{max}
Fishery history	Stable spatially and temporally	$F_{35\%SpR}$	$F_{35\%SpR}$	F_{max}
	Sporadic	$F_{0.1}$	$F_{0.1}$	$F_{35\%SpR}$
	Developing	$F_{0.1}$	$F_{35\%SpR}$	$F_{35\%SpR}$

The absolute burrow density in Division 3.a is medium (0.3–0.8/m^2), the observed harvest rate is below $F_{0.1}$ and historically the fishery is stable both spatially and temporally. This means that $F_{0.1}$ may be selected as a proxy for F_{MSY}. As the MCRS has been decreased in 2016 it is recommended to use F_{max} as a proxy for F_{MSY} as in last years. For 2021 this corresponds to a TAC of 12 067 tonnes. Under a landings obligation it may well be necessary to recalculate a harvest rate associated with F_{MSY} as total catches would be subjected to 100% mortality (current discard survival is estimated to be 25 %).

Harvest rate as proxy for F_{MSY} for 3.a from length cohort analysis 2011 (2008–2010):

	Male	Female	Combined
F_{max}	6.8%	10.0%	7.9%
$F_{0.1}$	4.9%	7.6%	5.6%
$F_{35\%SpR}$	8.1%	12.9%	10.5%

The harvest rates ((landings + dead discards)/total stock abundance) equivalent to F_{MSY} proxies are based on yield-per-recruit analyses from length cohort analyses. These analyses utilise average length frequency data taken over the 3-year period (2008–2010). All F_{MSY} proxy harvest rate values are considered preliminary and may be modified following further data exploration and analysis.

Norway lobster in Division 3.a. The catch scenarios (weight in tonnes):

Catch scenarios assuming recent discard rates

Basis	Total catch	Dead removals	Projected landings	Projected dead discards (PDD)	Projected surviving discards	% harvest rate*	% advice change
	PL + PDD + PSD	PL + PDD	PL	PDD	PSD	for PL+ PDD	
ICES advice basis							
F = F_{MSY}	12067	11574	10094	1480	493	7.90	-16.5
Other scenarios							
EU MAP^: F_{MSY}	12067	11574	10094	1480	493	7.90	-16.5**
F= MAP^ $F_{MSY\ lower}$	8554	8204	7155	1049	350	5.60	-16.5**
F = MAP^ $F_{MSY\ upper}$***	12067	11574	10094	1480	493	7.90	-16.5**
F= $F_{35\%SpR}$	16039	15383	13416	1967	656	10.50	11.0
F = F_{2021}	7766	7449	6497	952	317	5.08	-46

^ EU multiannual plan (MAP) for the North Sea (EU, 2018)
*** Calculated in numbers for dead removals.**
**** Advice basis values for 2023 relative to the 2022 advice values (MAP advice of 14 449, 10 241, and 14 449 tonnes respectively).**
***** $F_{MSY\ upper}$= F_{MSY} for this stock.**

A summary of the results from the TV survey 2021 is presented in Table 10.2.3.1. The estimated abundance index was 0.256 burrows / m2 resulting in a total abundance of 3206 million individuals. Total removals (landings + dead discards) were estimated to 163 million individuals resulting in a harvest rate of 5.1%.

Conclusions drawn from the indicator analyses

The combined logbook recorded effort has decreased by 50% since 2002 and is currently at a low level while LPUE shows an increasing trend and is at a long-term high level although a slight drop has been noted in recent years (Figures 10.2.4.1 and 10.2.4.2). Mean sizes are fluctuating without trend. There are no signs of overexploitation in 3.a.

The conclusion from this indicator-based assessment is that the stock is exploited sustainably.

10.1.4 Biological reference points

No biological reference points are used for this stock.

10.1.5 Quality of the assessment

Estimating size composition for the Swedish creel and trawl fleets for 2020 and 2021

From on-board sampling of size composition of catches, size distributions are raised to total landings. This is an important step of the stock assessment which builds on the combination of counts of individuals, and mean sizes of individuals in the population. The routine is that on-board sampling of catches is performed regularly for the Swedish and Danish trawling fleets, as well as for the Swedish creel fleet. The raising of size composition is done for the fleets separately. For German and Norwegian fleets, the combined size composition from Swedish and Danish fleets is raised to the landing.

Due to Covid-19 restrictions part of the on-board catch sampling programs could not be completed in 2020 and 2021. The Danish on-board sampling program had a wider coverage (Table 10.1.1) and was deemed feasible for use in the 2021 assessment. However, observers were only able to join a very limited number of Swedish *Nephrops* fishing trips in both Skagerrak and Kattegat (Table 10.1.1). A similar limitation occurred in 2021 although improved from 2020.

Table 10.1.1. *Nephrops* in Division 3.a. Number of observer trips on vessels targeting *Nephrops* in Skagerrak or Kattegat.

	Sweden				Denmark			
Quarter	2017	2018	2019	2020	2017	2018	2019	2020
1	15	16	11	13	20	30	25	15
2	16	14	16		20	32	27	25
3	16	15	13	1	30	30	40	29
4	13	14	15	2	17	15	21	10

Size data was available for the Swedish fleet for quarter 1 but not for the rest of the year. Available size data for other years was scrutinized to investigate if it could be applicable for 2020 circumstances and be used to make the necessary raising.

Size structure depending on discarding routines

Minimum landing size (MLS) for *Nephrops* in FU 3 and 4 was changed from 40 mmCL to 32 mmCL in 2016. However, discarding is still allowed above the MLS due to an exemption from the landing obligation because of high survival. This change in regulation had very different effects on the Danish and the Swedish trawl fleets. The Danish fleet used to discard a large proportion of it catch but changed its discarding pattern after the change in regulation (Figure 10.1.1.a). The Swedish fleet also lowered its discard rate in 2016. Since 2018, however, the Swedish fleet discard large proportions of *Nephrops*, except in quarter 2, driven in large part by market prices (Figure 10.1.1.b.) 2018 and 2019 were the two years with most stable discard patterns for both Swedish and Danish fleets.

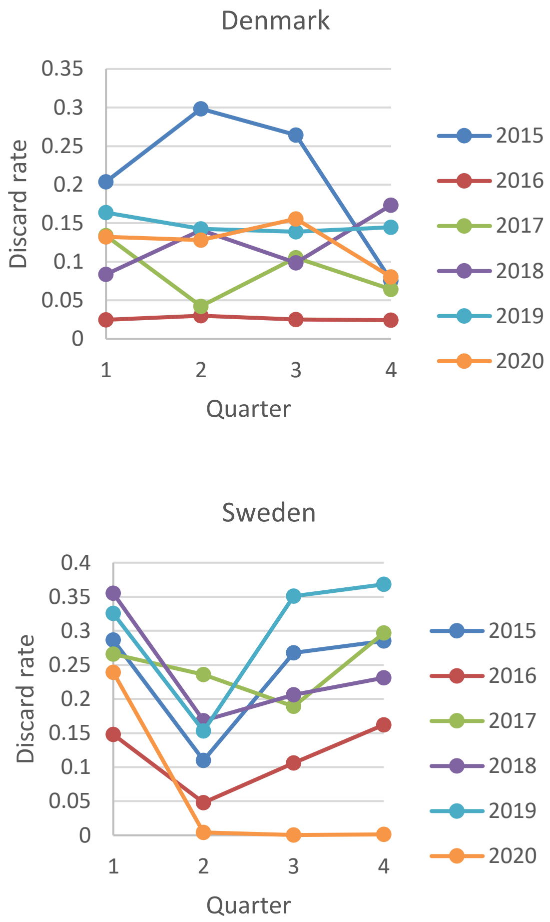


Figure 10.1.1. *Nephrops* in Division 3.a. Discard rates by weight by quarter for the a) Danish and b) Swedish trawl fleets 2015–2020, as reported to Intercatch.

The following scenarios on how to pool data for the Swedish fleets were suggested:

1. Use only 2020 size data, for each fleet separately (default routine)
2. Use Danish data for 2020
3. Use Swedish data pooled for 2019–2020
4. Use Swedish data pooled for 2018–2020
5. Use Swedish data pooled for 2017–2020
6. Use relative discard rates DK:SE to transform Danish size data for 2020 to resemble Swedish size data.

For each scenario, the data were pooled and used to raise to the total landings. The size composition was used to calculate the average size of landed and discarded individuals and the total number of dead removals. These are the main components influencing the forecast and advice of the stock.

In order to perform scenario 6 relative discard rates had to be calculated. The fleets have different discarding patterns as described above (Figure 10.1.1). Discard rates by numbers can only be done for on-board samples, but comparing discard rates by weights can be done for both Intercatch reported landings and discards as well as for the on-board sampling. Discard rates by weight by quarter for on-board sampling of 2018–2019 (Figure 10.1.2) repeats the pattern of discards between the Danish and the Swedish trawl fleets seen in the Intercatch data.

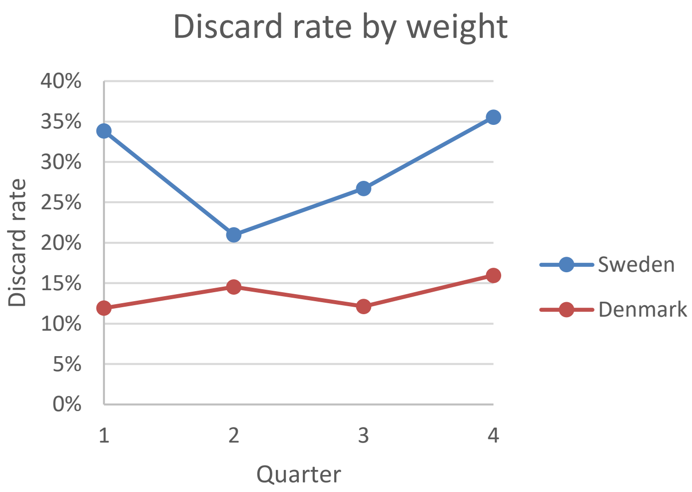


Figure 10.1.2. *Nephrops* in Division 3.a. Discard rate by weight by quarter from on-board sampling of 2018–2019.

The on-board sampling data on counts of individuals was used to calculate the relative discard rate between the Danish fleet and the Swedish fleet simply by dividing the discard rate by quarter for the Swedish fleet with the discard rate by quarter for the Danish fleet. The proportion was then used to transform the numbers of discards per size class in the sampling of the Danish fleet to resemble the discard pattern of the Swedish fleet. The resulting size composition of each fleet was then used to raise sizes to the landings data in the default manner. The resulting parameters are given in Table 10.1.2.

Through this exercise and for all scenarios the generic raising procedure for the stock was maintained. The only change between scenarios were the assumptions of input sampling data to be used for raising.

Table 10.1.2. *Nephrops* in Division 3.a. Raising factors by quarter for the transformation of size composition data from the Danish trawl fleet to the Swedish trawl fleet.

Quarter	Raising factor
1	2.32
2	1.09
3	1.69
4	1.65

Results on key parameters for the different scenarios are given in Table 10.1.3. The changes in parameters was generally small. All scenarios including Danish data for 2020 resembled each other, and the scenarios not including Danish data for 2020 resembled each other. Transforming Danish sampling data to resemble the Swedish trawl fleet discard pattern did not result in parameters similar to sampled data for the Swedish fleet from previous years.

Table 10.1.3. *Nephrops* in Division 3.a. Resulting values of mean sizes, discard rate, removals and other parameters in 2020 following the scenarios on different assumptions on data used for calculations Scenario 4 was selected for the assessment. The 3-year averages (2018–2020) are listed as weights.

Scenario	Weight Landings	Weight discard	Discard rate, by number	Removals (million)	Mean weight	Pop.num (million)	Pop.est.tonnes	Landings + Dead disc	Harvest rate	Mean weight 3-year average	Weight Landings, 3-year average	Weight Discard, 3-year average	Discard rate 3-year Average
1	54.30	23.00	27.16	142.80	45.76	3796.0	173697	6534	3.76	44.73	54.33	23.35	30.98
2	53.20	22.20	25.38	139.65	45.30	3796.0	171967	6326	3.68	44.61	54.02	23.18	30.52
3	54.20	24.60	31.53	146.93	44.85	3796.0	170232	6589	3.87	44.50	54.30	23.78	32.13
4	54.40	24.20	31.60	146.39	44.85	3796.0	170247	6565	3.86	44.50	54.37	23.65	32.15
5	54.40	23.60	32.01	147.14	44.53	3796.0	169024	6552	3.88	44.41	54.37	23.49	32.26
6	52.80	22.40	27.89	144.53	44.32	3796.0	168244	6406	3.81	44.35	53.91	23.21	31.14

It was decided that Scenario 4 was the most feasible option for two main reasons. First, not any case involving the Danish sampled data (scenario 1, 2 and 6) resembled any of the cases with only Swedish data. Secondly 2018 and 2019 showed a stabilizing trend in discard pattern following the changed regulation of MLS in 2016 (Figures 10.1.1 and 10.1.2).

Thus, for the Swedish trawl and creel fleets separately, on-board sampling data was aggregated for 2018–2020 to reflect size composition of landings and discards in 2020. To reflect size composition in 2021 on-board sampling from 2019–2021 was used with the otherwise equal methodology.

Apart from 2020 and 2021, the length and sex composition of the landings data is considered to be well sampled. Discard sampling in this fishery has been conducted on a quarterly basis for Danish and Swedish *Nephrops* trawlers since 1990, and is considered to represent the fishery adequately.

The UWTV survey has been conducted in all 8 defined subareas in 3.a during 2020–2021 and no variations due to covid has been made. A correction factor of 1.1 was used. A total weighted mean density was estimated based on density estimates from each Subarea and weighted by the size of each Subarea. The estimated F_{MSY} proxies for this stock provide a relatively low harvest rate which may be a result of the high discards ratios (27% in numbers) which occur due to an exemption of landing obligation (high discard survival) in 3.a. These removals do not increase the yield from the stock.

The Danish LPUE data used as indicators for stock development have been standardised regarding engine size. However, LPUE is also influenced by changes in catchability due to sudden changes in the environmental conditions or/and changes in selectivity, gear efficiency or a change in targeting behaviour due to the cod management plan in 3.a. Also, the changes in management systems (indicated by the broken red line in Figure 10.2.4.2), which occurred in 2007 in Denmark, caused a general increase in LPUE. In 3.a, fluctuations in catches of small *Nephrops* has been used as indicators of recruitment (Figure 10.2.4.3). This indicator will start a new series in 2016 depending on the lowered MCRS but was not updated in 2021.

10.1.6 Status of the stock

The *Nephrops* stock in Division 3.a was assessed with an UWTV survey for the eleventh year (2011–2021; new Subarea 7 only in 2014–2021 and new Subarea 9 in 2017 and 2019) and the time series of UWTV estimates is still insufficient to draw conclusions regarding stock trajectory (Figure 10.2.4.4).

The average 2016–2021 harvest rate was estimated to be relatively low (well below 7.9 % from UWTV surveys) implying the stock appears to be exploited sustainably.

The analysis of commercial LPUE and effort data indicate that the increasing trend in LPUE has changed although effort still shows a decreasing trend and the WG concludes that current levels of exploitation appear to be sustainable.

10.1.7 Division 3.a: *Nephrops* management considerations

The observed trends in effort, LPUE and discards are similar for FU 3 and FU 4. Our present knowledge on the biological characteristics of the *Nephrops* stocks in these two areas does not indicate obvious differences, and therefore the two FUs are treated as one single 'stock' in the assessment.

The UWTV-survey in 3.a suggests that the harvest rate of the stock is relatively low and the stock is exploited at a sustainable level.

The combined logbook recorded effort has decreased since 2002 and is currently the lowest level in the time series while LPUE has increased and is at a relatively high level in the last ten years (Figures 10.2.4.1 and 10.2.4.2). The increase in LPUE in 2016 is due to the lowered MCRS in 2016 from 40 to 32 mm carapace length. Mean sizes are fluctuating without trend (Figures 10.2.2.2 and 10.2.2.4). Note that the decrease in mean size for 2016 depends on the lowered MCRS. There are no signs of overexploitation in 3.a.

Given the apparent stability of the stock, the WG concludes that current levels of exploitation appear to be sustainable.

The WG encourages the work on size selectivity in *Nephrops* trawls to reduce the large amount of discarded undersized *Nephrops* in 3.a.

Mixed fishery aspects

Cod and sole are significant by-catch species in these fisheries in 3.a, and even if data on catches, including discards, of the bycatch gradually become available, they have not yet been used in the management. The WG has for many years recommended the use of species selective grids in the fisheries targeting *Nephrops* as legislated for Swedish national waters. New technical measures (Swedish grid and SELTRA trawl) have recently been agreed upon for the *Nephrops* directed fishery and have been implemented since 1 February 2013. The European Union and Norway have also agreed that a discard ban will be implemented in EU waters from 1 January 2015. The discard ban was applicable to *Nephrops* from 1 January 2016 but preliminary results indicating high discard survival has resulted in an exemption of landing obligation for *Nephrops* in 3.a during 2016 to 2021.

Table 10.1.5. Definition of *Nephrops* Functional Units in Division 3.a and Subarea 4 in terms of ICES statistical rectangles.

FU no.	Name	ICES area	Statistical rectangles
3	Skagerrak	3.aN	47G0; 46F9–G1; 45F8–G1; 44F7–G0; 43F8–F9
4	Kattegat	3.aS	44G1; 42-43 G0–G2; 41G1–G2
5	Botney Cut - Silver Pit	4.b,c	36–37 F1–F4; 35F2–F3
6	Farn Deeps	4.b	38–40 E8–E9; 37E9
7	Fladen Ground	4.a	44–49 E9–F1; 45–46E8
8	Firth of Forth	4.b	40–41E7; 41E6
9	Moray Firth	4.a	44–45 E6-E7; 44E8
10	Noup	4.a	47E6
32	Norwegian Deep	4.a	44–52 F2–F6; 43F5–F7
33	Off Horn Reef	4.b	39–41F5; 39–41F6
34	Devil’s Hole	4.b	41–43 F0–F1

Table 10.2.1.1. Division 3.a: Total *Nephrops* landings (tonnes) by Functional Unit, 1981–2021.

Year	FU 3	FU 4	Total
1981	992	1728	2720
1982	1470	1828	3298
1983	2205	1472	3677
1984	2675	2036	4711
1985	2191	1798	3989
1986	2018	1807	3825
1987	2441	1605	4046
1988	2363	1364	3727
1989	2564	1313	3877
1990	2866	1475	4341
1991	2924	1304	4228
1992	1893	1012	2905
1993	2288	924	3212
1994	1981	893	2874
1995	2429	998	3427
1996	2695	1285	3980
1997	2612	1594	4206
1998	3248	1808	5056
1999	3194	1755	4949
2000	2894	1816	4710
2001	2282	1774	4056
2002	2977	1471	4448
2003	2126	1641	3767
2004	2312	1653	3965
2005	2546	1488	4034
2006	2392	1280	3672
2007	2771	1741	4512
2008	2851	2025	4876
2009	3004	1842	4846
2010	2938	2185	5123
2011	2511	1475	3986
2012	2536	1893	4429
2013	2147	1613	3760
2014	2856	1294	4150
2015	2123	1228	3350
2016	3238	1652	4890
2017	3129	2082	5211

Year	FU 3	FU 4	Total
2018	4222	2878	7100
2019	4625	3149	7774
2020	3367	2548	5915
2021	4031	2511	6542

Table 10.2.1.2. Division 3.a: Total *Nephrops* landings (tonnes) by country, 1991–2021.

Year	Denmark	Norway	Sweden	Germany	Total landings	Total Disc.	Total Catch
1991	2824	185	1219		4228	5183	9411
1992	2052	104	749		2905	2523	5428
1993	2250	103	859		3212	8493	11705
1994	2049	62	763		2874	6450	9324
1995	2419	90	918		3427	4464	7891
1996	2844	102	1034		3980	2148	6128
1997	2959	117	1130		4206	3469	7675
1998	3541	184	1319	12	5056	1944	7000
1999	3486	214	1243	6	4949	4108	9057
2000	3325	181	1197	7	4710	5664	10374
2001	2880	138	1037	1	4056	3767	7823
2002	3293	116	1032	7	4448	4311	8760
2003	2757	99	898	13	3767	2208	5975
2004	2955	95	903	12	3965	2532	6497
2005	2901	83	1048	2	4034	3014	7048
2006	2432	91	1143	6	3672	2926	6598
2007	2887	145	1467	13	4512	6524	11036
2008	3174	158	1509	19	4860	4746	9606
2009	3372	128	1331	15	4846	6129	10975
2010	3721	124	1249	29	5123	3548	8671
2011	2937	87	945	17	3986	2847	6833
2012	2970	104	1355	0	4429	4771	9200
2013	2550	73	1134	3	3760	4010	7770
2014	2785	88	1269	7	4150	1854	6004
2015	2121	91	1138	0	3350	1038	4389
2016	3440	87	1363	0	4889	256	5145
2017	3700	81	1430	1	5211	1024	6234
2018	5133	97	1870	0	7100	1336	8435
2019	5697	112	1944	21	7774	1719	9493
2020	3977	124	1796	17	5915	1214	7129
2021	4733	120	1644	45	6542	1059	7601

Table 10.2.2.1. *Nephrops* in Skagerrak (FU 3): Landings (tonnes) by country, 1991–2021.

Year	Denmark	Norway			Sweden			Germany	Total
		Trawl	Creel	Sub-total	Trawl	Creel	Sub-total		
1991	1639	185	0	185	949	151	1100	0	2924
1992	1151	104	0	104	524	114	638	0	1893
1993	1485	101	2	103	577	123	700	0	2288
1994	1298	62	0	62	531	90	621	0	1981
1995	1569	90	0	90	659	111	770	0	2429
1996	1772	102	0	102	708	113	821	0	2695
1997	1687	117	0	117	690	118	808	0	2612
1998	2055	184	0	184	864	145	1009	0	3248
1999	2070	214	0	214	793	117	910	0	3194
2000	1877	181	0	181	689	147	836	0	2894
2001	1416	125	13	138	594	134	728	0	2282
2002	2053	99	17	116	658	150	808	0	2977
2003	1421	90	9	99	471	135	606	0	2126
2004	1595	85	10	95	449	173	622	0	2312
2005	1727	71	12	83	538	198	736	0	2546
2006	1516	80	11	91	583	201	784	0	2391
2007	1664	127	18	145	709	253	962	0	2771
2008	1745	124	34	158	675	273	948	0	2851
2009	2012	101	27	128	605	260	864	0	3004
2010	1981	105	20	125	563	266	829	4	2938
2011	1801	74	12	87	432	188	621	2	2510
2012	1516	80	24	104	592	324	916	0	2536
2013	1309	57	16	73	484	279	763	0	2146
2014	1868	68	20	88	594	305	899	0	2856
2015	1226	66	25	91	479	327	806	0	2123
2016	2260	66	21	87	604	289	892	0	3239
2017	2118	60	20	81	672	258	930	0	3129
2018	2938	71	25	97	897	290	1187	0	4222
2019	3295	86	26	112	920	298	1217	0	4625
2020	2053	84	41	124	897	292	1190	0	3367
2021	2837	84	36	120	829	245	1074	0	4031

Table 10.2.2.2. *Nephrops* Skagerrak (FU 3): Catches and landings (tonnes), effort ('000 hours trawling), CPUE and LPUE (kg/hour trawling) of Swedish specialized *Nephrops* trawlers, 1991–2021. (* Include only *Nephrops* trawls with grid and square mesh codend+ Seltra traws).

Single trawl					
Year	**Catches**	**Landings**	**Effort**	**CPUE**	**LPUE**
1991	676	401	71.4	9.5	5.6
1992	360	231	73.7	4.9	3.1
1993	614	279	72.6	8.4	3.8
1994	441	246	60.1	7.3	4.1
1995	501	336	60.8	7.8	5.2
1996	754	488	51.1	14.8	9.6
1997	643	437	44.4	14.4	9.8
1998	794	557	49.7	16.0	11.2
1999	605	386	34.5	17.5	9.3
2000	486	329	32.7	14.9	10.9
2001	446	236	26.2	17.0	10.4
2002	503	301	29.4	17.1	8.8
2003	310	254	21.5	13.9	11.4
2004*	474	257	20.1	23.6	13.4
2005*	760	339	29.7	25.6	12.7
2006*	839	401	37.5	22.4	12.2
2007*	894	314	24.1	37.0	13.0
2008*	605	264	20.0	30.3	13.2
2009*	482	285	19.6	24.5	14.5
2010*	476	286	20.7	23.0	13.8
2011*	334	198	16.8	19.9	11.8
2012*	542	238	16.0	33.8	14.9
2013*	251	137	11.3	22.2	12.1
2014*	240	157	11.0	21.7	14.2
2015*	187	133	9.5	19.6	14.0
2016*	216	188	14.9	14.4	12.6
2017*	362	232	16.9	21.4	13.7
2018*	369	265	13.5	27.3	19.6
2019*	287	224	12.7	22.5	17.6
2020*	275	215	12.0	22.9	17.9
2021*	^	222	18.3	^	12.2

^estimated catch by gear was not performed for 2021, and thus CPUE was not calculated.

Table 10.2.2.2 (cont'). *Nephrops* Skagerrak (FU 3): Catches and landings (tonnes), effort ('000 hours trawling), CPUE and LPUE (kg/hour trawling) of Swedish specialized *Nephrops* trawlers, 1991–2021. (* Include only *Nephrops* trawls with grid and square mesh codend+ Seltra trawls).

Twin trawl					
Year	**Catches**	**Landings**	**Effort**	**CPUE**	**LPUE**
1991	740	439	39.5	18.7	11.1
1992	370	238	34.1	10.9	7.0
1993	568	258	35.9	15.8	7.2
1994	444	248	34.1	13.1	7.3
1995	403	270	32.9	12.2	8.2
1996	187	121	13.0	14.4	9.3
1997	219	149	17.5	12.5	8.5
1998	254	178	16.7	15.2	10.6
1999	382	244	27.6	13.8	8.8
2000	349	237	31.3	11.1	10.1
2001	470	249	33.7	14.0	7.4
2002	392	244	33.3	11.8	7.1
2003	168	138	22.5	7.5	6.1
2004	217	118	21.7	10.0	5.4
2005	263	117	22.1	11.9	5.3
2006	253	121	19.6	12.9	6.2
2007*	248	87	5.4	45.6	16.0
2008*	139	61	3.4	41.3	18.0
2009*	211	125	7.1	29.5	17.5
2010*	165	99	5.9	27.8	16.7
2011*	202	120	7.7	26.3	15.6
2012*	544	239	12.9	42.2	18.6
2013*	423	231	13.8	30.7	16.8
2014*	484	316	16.0	30.3	19.8
2015*	328	234	11.3	28.9	20.6
2016*	471	410	20.1	23.4	20.4
2017*	667	427	17.5	38.2	24.5
2018*	851	610	21.1	40.4	29.0
2019*	847	662	23.7	35.8	28.0
2020*	851	665	23.7	35.9	28.0
2021*	^	577	24.4	^	23.7

^estimated catch by gear was not performed for 2021 and thus was CPUE not calculated.

Table 10.2.2.3. *Nephrops* Skagerrak (FU 3): Logbook recorded effort (kW days, Days at sea, and fishing days) and LPUE (kg/day) for bottom trawlers catching *Nephrops* with codend mesh sizes of 70 mm or above, and estimated total effort by Danish trawlers, 1991–2021.

Year	kW days	Days at sea	Fishing days	LPUE
1991	5501223	21043	18762	87
1992	4043742	16125	13970	82
1993	3728965	13698	11958	124
1994	3276355	12324	10778	120
1995	3024232	12070	10448	150
1996	3020019	11871	10385	171
1997	3053570	11950	10509	161
1998	3353072	12131	10899	189
1999	3967797	13767	12376	167
2000	4371006	14849	13307	141
2001	3970228	13337	11579	122
2002	4693962	16575	14197	145
2003	3476385	11589	10333	138
2004	3871974	13149	11694	136
2005	3757466	12560	11166	155
2006	3296744	10825	9725	156
2007	2424063	8026	7294	228
2008	2332056	8016	7300	239
2009	2549895	8814	8058	250
2010	2668904	9027	8338	238
2011	2666680	9767	8912	202
2012	2183682	8330	7507	202
2013	1738286	6770	6332	207
2014	2094860	8060	7653	244
2015	1592065	6337	5923	207
2016	2032034	8060	7673	295
2017	1940952	7391	7061	300
2018	2366657	8345	7936	370
2019	2666092	8980	8513	387
2020	2277212	7343	6842	300
2021	1885546	6633	7600	373

Table 10.2.2.4. *Nephrops* Skagerrak (FU 3): Mean sizes (mm CL) of male and female *Nephrops* in catches of Danish and Swedish combined, 1991–2021.

Year	Catches					
	Undersized		Full sized		All	
	Males	Females	Males	Females	Males	Females
1991	30.2	30.9	41.2	42.7	30.9	29.8
1992	33.3	32.3	43.3	44.7	33.3	32.2
1993	33.0	31.5	42.0	43.6	33.0	31.5
1994	31.7	29.6	41.7	43.6	31.7	29.6
1995	30.0	28.5	41.6	41.3	32.9	29.8
1996	33.2	31.9	42.9	44.0	37.6	37.0
1997	35.8	34.5	44.6	44.1	39.8	39.1
1998	34.8	34.4	46.1	43.9	40.7	37.3
1999	34.6	33.9	44.9	43.8	39.3	36.1
2000	30.6	30.5	45.6	45.0	32.5	34.1
2001	33.6	33.6	45.5	43.6	37.3	36.4
2002	33.9	33.7	44.0	42.5	37.2	37.3
2003	33.5	32.6	43.2	43.4	38.0	36.7
2004	34.3	33.4	44.6	45.2	38.7	36.6
2005	33.5	32.4	43.7	43.0	36.4	35.3
2006	33.2	32.9	44.7	42.7	37.1	36.1
2007	32.6	31.9	44.4	42.4	34.9	33.5
2008	33.6	32.3	44.0	42.7	36.5	34.5
2009	35.0	33.8	45.3	42.8	39.8	35.9
2010	34.2	33.8	46.2	44.8	38.9	36.6
2011	33.8	33.1	44.5	43.3	38.4	36.5
2012	34.8	34.1	44.2	42.5	38.2	36.2
2013	35.1	34.8	45.0	42.9	38.6	36.9
2014	35.7	35.3	45.5	43.7	41.7	39.1
2015	35.5	36.2	47.2	44.1	43.6	41.1
2016	32.0	31.8	43.5	41.0	42.2	39.9
2017	32.3	31.5	42.4	41.7	39.1	39.0
2018	31.1	30.7	41.6	41.1	38.7	37.6
2019	32.5	31.8	42.1	41.7	38.8	38.5
2020	32.6	31.5	41.7	40.5	39.0	37.6
2021	31.9	31.3	41.5	40.4	38.8	37.9

Table 10.2.2.5. *Nephrops* Kattegat (FU 4): Landings (tonnes) by country, 1991–2021.

Year	Denmark	Sweden		Sub-total	Germany	Total
		Trawl	Creel			
1991	1185	119	0	119	0	1304
1992	901	111	0	111	0	1012
1993	765	159	0	159	0	924
1994	751	142	0	142	0	893
1995	850	148	0	148	0	998
1996	1072	213	0	213	0	1285
1997	1272	319	3	322	0	1594
1998	1486	306	4	310	12	1808
1999	1416	329	4	333	6	1755
2000	1448	357	4	361	7	1816
2001	1464	304	6	309	1	1774
2002	1240	219	5	224	7	1471
2003	1336	287	5	292	13	1641
2004	1360	270	11	281	12	1653
2005	1175	303	8	311	2	1488
2006	916	347	11	358	6	1280
2007	1223	491	15	505	13	1741
2008	1429	561	16	577	19	2025
2009	1360	450	16	467	15	1842
2010	1740	403	17	420	25	2185
2011	1136	308	16	324	15	1475
2012	1454	406	33	439	0	1893
2013	1241	341	27	368	3	1612
2014	917	335	34	369	7	1294
2015	895	301	31	333	0	1228
2016	1180	436	34	470	0	1650
2017	1581	468	31	500	1	2082
2018	2195	649	33	683	0	2878
2019	2401	694	33	726	21	3149
2020	1924	606	26	632	17	2574
2021	1896	540	31	571	45	2511

Table 10.2.2.6. *Nephrops* Kattegat (FU 4): Catches and landings (tonnes), effort (‘000 hours trawling), CPUE and LPUE (kg/hour trawling) of Swedish *Nephrops* trawlers, 1991–2021 (* Include only specialized *Nephrops* trawls with grid and square mesh codend + Seltra trawls).

Single trawl					
Year	**Catches**	**Landings**	**Effort**	**CPUE**	**LPUE**
1991	66	39	10.3	6.4	3.7
1992	44	28	11.6	3.8	2.4
1993	128	58	14.9	8.6	3.9
1994	95	53	16.2	5.7	3.2
1995	79	53	9.6	7.8	5.5
1996	207	134	13.7	15.1	9.8
1997	269	183	18.0	15.0	10.2
1998	181	127	13.1	13.8	9.7
1999	146	93	8.1	17.9	11.4
2000	114	77	8.5	13.4	9.1
2001	117	62	7.6	15.4	8.2
2002	42	25	3.7	11.2	6.7
2003	49	40	4.6	10.7	8.7
2004	70	44	4.3	16.2	10.1
2005	147	100	12.3	11.9	8.1
2006	234	154	15.1	15.5	10.2
2007*	107	51	4.1	25.7	12.3
2008*	121	57	4.4	27.6	13.0
2009*	157	81	5.1	30.9	16.1
2010*	181	102	7.6	23.8	13.4
2011*	75	45	3.8	20.0	12.0
2012*	80	45	3.4	23.5	13.3
2013*	44	26	2.3	19.5	11.6
2014*	35	25	2.2	15.8	11.6
2015	43	29	2.6	16.6	11.0
2016*	50	47	5.4	9.4	8.7
2017*	65	45	4.0	16.2	11.2
2018*	84	63	4.1	20.4	15.4
2019*	92	71	4.6	20.0	15.5
2020*	61	48	3.4	18.0	13.9
2021*	^	46	4.0	^	11.6

^estimated catch by gear was not performed for 2021, and thus CPUE was not calculated.

Table 10.2.2.6 (cont'). *Nephrops* Kattegat (FU 4): Catches and landings (tonnes), effort ('000 hours trawling), CPUE and LPUE (kg/hour trawling) of Swedish *Nephrops* trawlers, 1991–2021 (* Include only specialized *Nephrops* trawls with grid and square mesh codend + Seltra trawls).

Twin trawl					
Year	Catches	Landings	Effort	CPUE	LPUE
1991	93	55	8.8	10.6	6.2
1992	101	65	14.2	7.1	4.6
1993	187	85	17.8	10.6	4.8
1994	138	77	14.2	9.7	5.4
1995	125	84	11.0	12.2	7.7
1996	97	63	7.5	13.0	8.4
1997	183	124	12.7	14.3	9.7
1998	215	151	15.0	14.4	10.1
1999	306	195	20.1	15.2	9.7
2000	330	224	24.5	13.5	9.1
2001	353	187	25.1	14.1	7.4
2002	256	153	23.2	11.0	6.6
2003	222	181	24.8	8.9	7.3
2004	253	158	16.5	15.4	9.6
2005	198	135	15.3	12.9	8.8
2006	183	121	12.7	14.4	9.5
2007*	112	54	3.6	30.9	14.8
2008*	164	78	4.8	34.1	16.1
2009*	309	161	11.0	28.2	14.6
2010*	297	167	9.2	32.2	18.1
2011*	266	159	9.7	27.3	16.3
2012*	406	231	12.4	32.8	18.6
2013*	354	210	15.0	23.7	14.0
2014*	282	206	14.4	19.6	14.4
2015	262	173	11.3	23.2	15.4
2016*	404	378	19.4	20.9	19.5
2017*	603	418	17.5	34.4	23.8
2018*	774	586	18.7	41.4	31.3
2019*	760	589	20.0	38.0	29.4
2020*	682	528	20.0	34.1	26.4
2021*	^	485	23.2	^	21.0

^estimated catch by gear was not performed for 2021 and thus was CPUE not calculated.

Table 10.2.2.7. *Nephrops* Kattegat (FU 4): Logbook recorded effort (kW days, Days at sea, and fishing days) and LPUE (kg/day) for bottom trawlers catching *Nephrops* with codend mesh sizes of 70 mm or above, and estimated total effort by Danish trawlers, 1991–2021.

Year	kW days	Days at sea	Fishing days	LPUE
1991	4223351	23040	16770	71
1992	3689413	20184	14240	63
1993	2827025	15392	10598	72
1994	2480847	13989	10985	68
1995	2330909	13023	10028	85
1996	2707363	14856	11688	92
1997	2807943	14389	11558	110
1998	2957280	15264	12380	120
1999	3417242	16734	13536	105
2000	3642120	18307	14661	99
2001	3826693	18764	15294	96
2002	3258819	16568	13325	93
2003	3173969	15345	12507	107
2004	2929407	14229	11289	120
2005	2452852	11814	9337	126
2006	2147461	10431	8467	108
2007	2022910	9883	7897	155
2008	2148132	10538	8469	169
2009	2219200	11120	8726	156
2010	2438736	12055	9707	179
2011	2009409	10286	8099	140
2012	2292229	11800	9661	150
2013	2221959	11669	9226	135
2014	1908170	10393	7865	117
2015	1847763	10094	7704	116
2016	1899286	10249	7815	151
2017	1939311	10074	7703	205
2018	2204244	12294	9035	243
2019	2477989	12294	9587	250
2020	2367713	11680	8977	214
2021*	2790207	12946	11510	165

Table 10.2.2.8. *Nephrops* Kattegat (FU 4): Mean sizes (mm CL) of male and female *Nephrops* in discards, landings and catches, 1991–2021. Since 2005 based on combined Danish and Swedish data.

Year	Catches					
	Discards		Landings		All	
	Males	Females	Males	Females	Males	Females
1991	30.7	31.1	42.4	42.5	32.5	32.9
1992	33.0	30.3	44.4	43.2	36.7	34.9
1993	30.5	29.3	42.3	43.1	31.3	30.1
1994	29.7	28.3	40.8	40.2	31.2	28.9
1995	30.8	30.5	42.4	42.0	33.7	33.2
1996	32.7	31.3	42.0	44.0	36.7	37.3
1997	33.6	33.2	45.0	44.5	37.1	35.0
1998	34.2	33.2	45.6	44.1	41.3	36.8
1999	32.9	33.8	45.3	40.9	37.8	34.9
2000	35.1	35.2	45.7	42.1	40.4	36.9
2001	32.2	33.0	44.1	41.9	35.9	36.5
2002	34.4	33.3	44.4	43.8	37.2	36.2
2003	33.0	33.2	43.5	42.2	37.1	36.0
2004	34.7	34.2	45.1	43.2	39.9	37.5
2005	33.5	33.9	45.8	43.1	38.7	38.7
2006	33.2	33.6	45.1	42.8	37.9	37.4
2007	33.9	33.2	44.8	43.5	37.2	35.5
2008	32.6	32.4	44.0	43.9	37.5	35.9
2009	33.8	33.1	44.7	44.1	36.8	35.2
2010	34.6	33.8	45.9	44.5	39.8	36.9
2011	33.7	32.9	44.7	43.3	38.1	35.5
2012	33.8	33.2	44.3	42.9	37.1	35.7
2013	34.4	34.6	44.8	42.9	38.0	36.5
2014	35.0	34.8	45.6	42.9	40.4	37.4
2015	34.5	34.8	45.6	42.7	40.9	38.3
2016	30.1	29.8	45.1	40.6	43.4	38.5
2017	30.1	30.6	42.6	40.6	38.6	36.7
2018	32.1	31,5	42.7	40.5	39.8	36.9
2019	32.6	32.2	43.6	41.0	37.8	34.7
2020	31.5	30.9	42.7	40.2	40.0	37.2
2021	31.5	31.6	41.6	40.1	39.0	37.9

Table 10.2.3.1. *Nephrops* in Division 3.a. Summary output of the TV-survey in 3.a from 2021.

Subarea	Area (km^2)	Number of stations	Absolute mean density	Population numbers (mill.)
1	2575	32	0.187	481.65
2	1958	41	0.385	753.71
3	2613	23	0.242	631.38
4	962	13	0.237	227.68
5	996	19	0.395	393.13
6	1719	27	0.218	375.44
7	1295	8	0.141	182.64
8		6	0.045	
9	385	4	0.416	160.08
Total	12503	173	0.256	3205.71
Harvest rate				0.0509
Removals 2021 (landings + dead discards**)				163.25

*** In millions**

**** The survival rate of discard is estimate to be 25% (Wileman *et al*., 1999)**

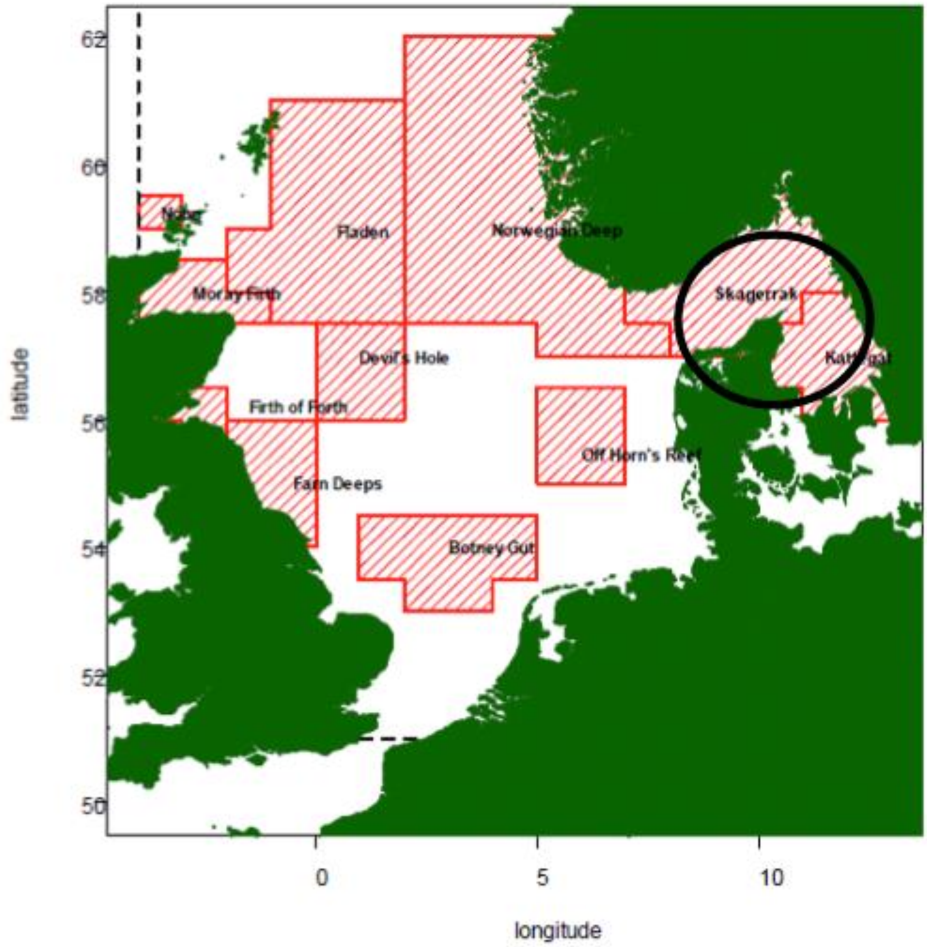


Figure 10.1.1. ***Nephrops*** **Functional Units in the North Sea and Skagerrak/Kattegat region.**

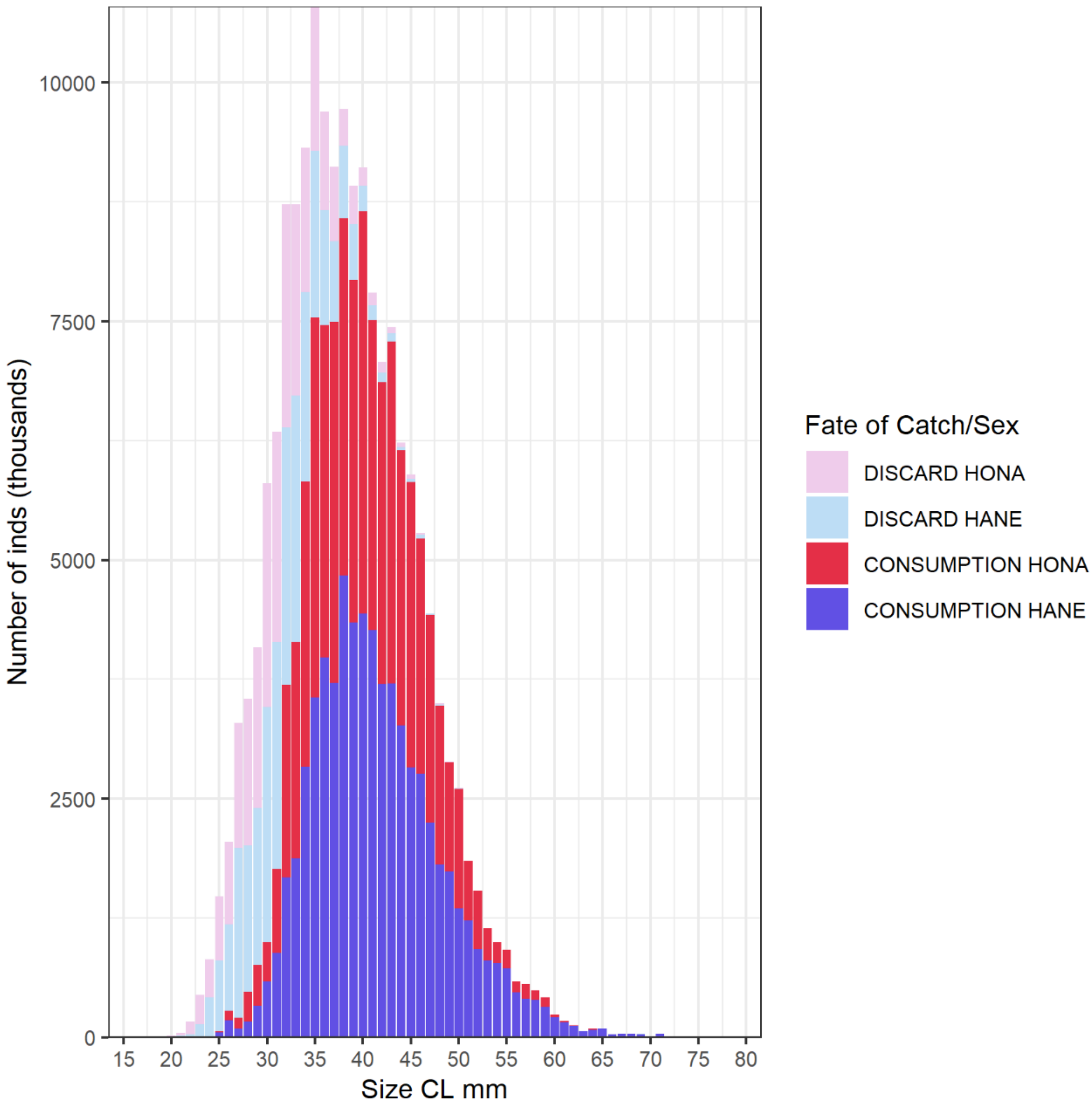


Figure 10.2.1.1. *Nephrops* Skagerrak (FU 3) and Kattegat (FU4): Length frequency distributions of *Nephrops* catches in number of individuals, split by catch fraction (landings and discards) and sex. Data for Denmark and Sweden combined for 2021.

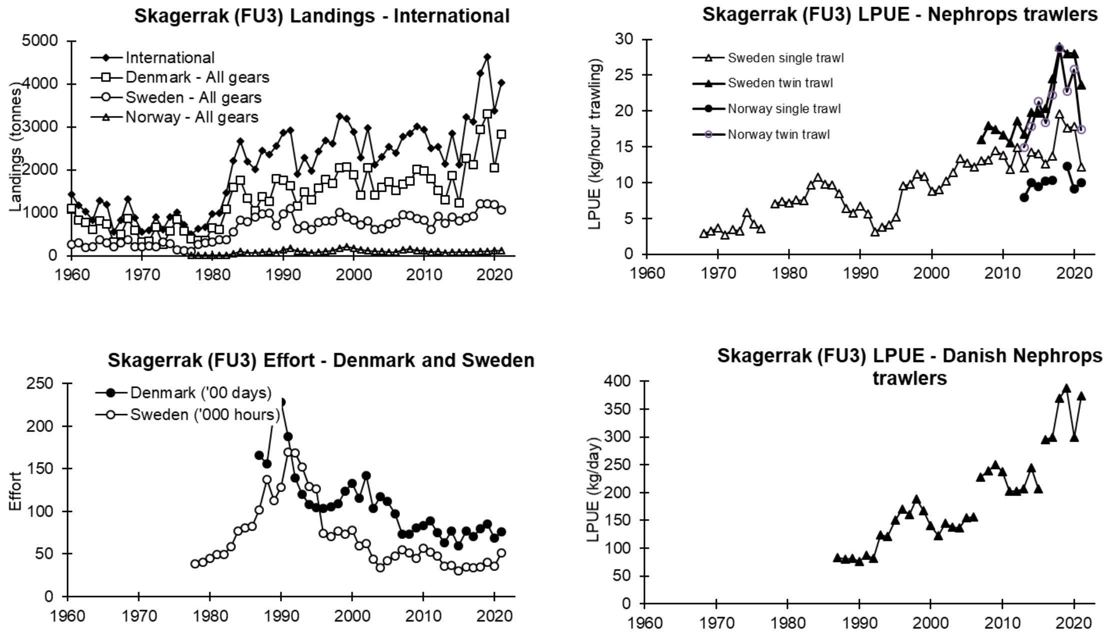


Figure 10.2.2.1. *Nephrops* Skagerrak (FU 3): Long-term trends in landings, effort, and LPUEs.

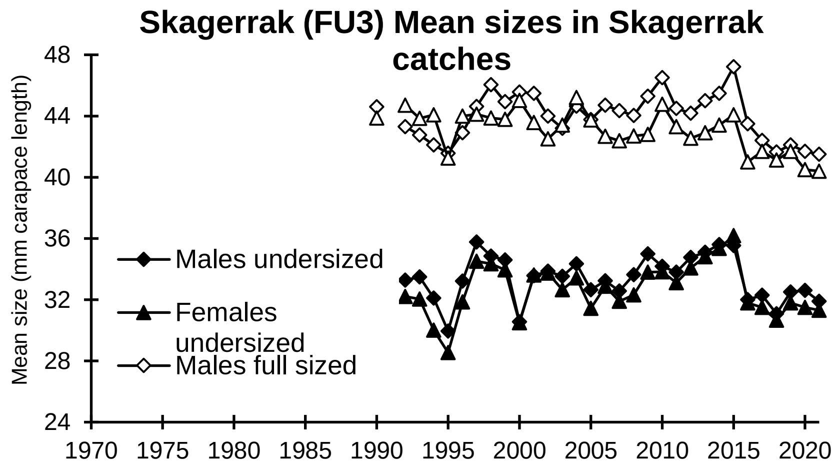


Figure 10.2.2.2. *Nephrops* in FU 3. Mean sizes in the catches.

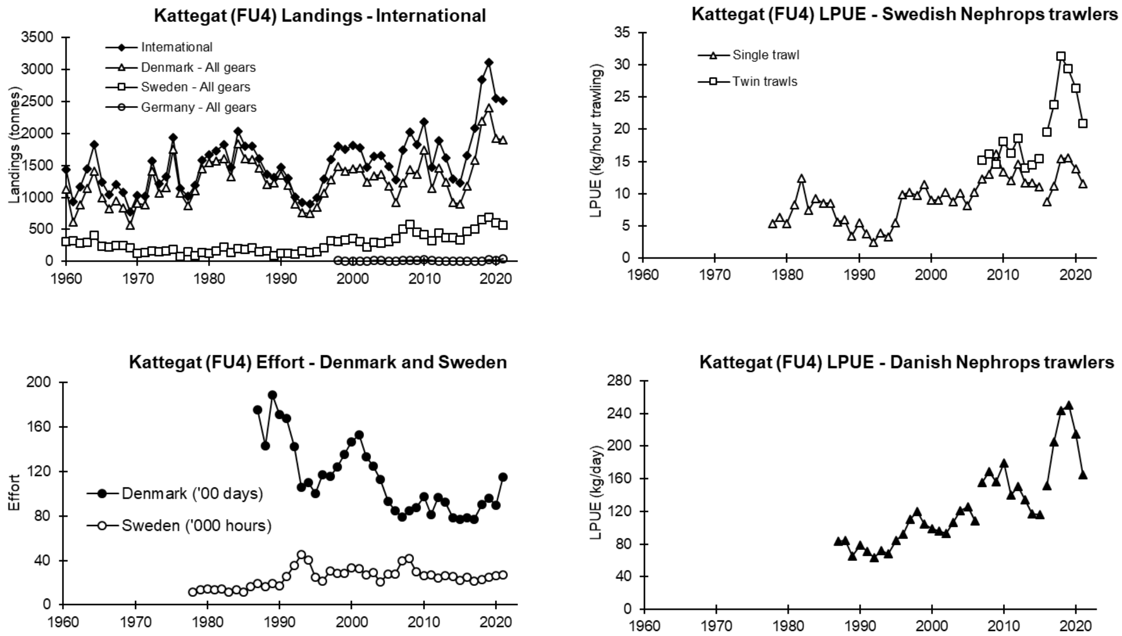


Figure 10.2.2.3. *Nephrops* Kattegat (FU 4): Long-term trends in landings, effort and LPUEs.

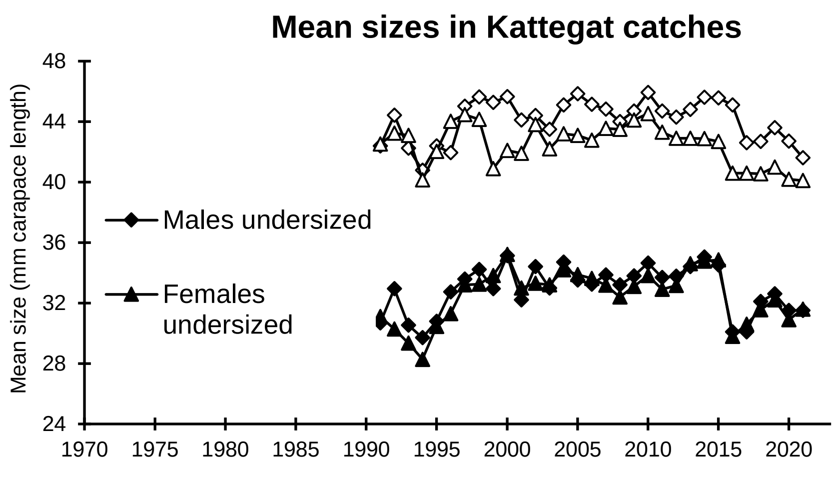


Figure 10.2.2.4. *Nephrops* in FU 4: Mean sizes in the catches.

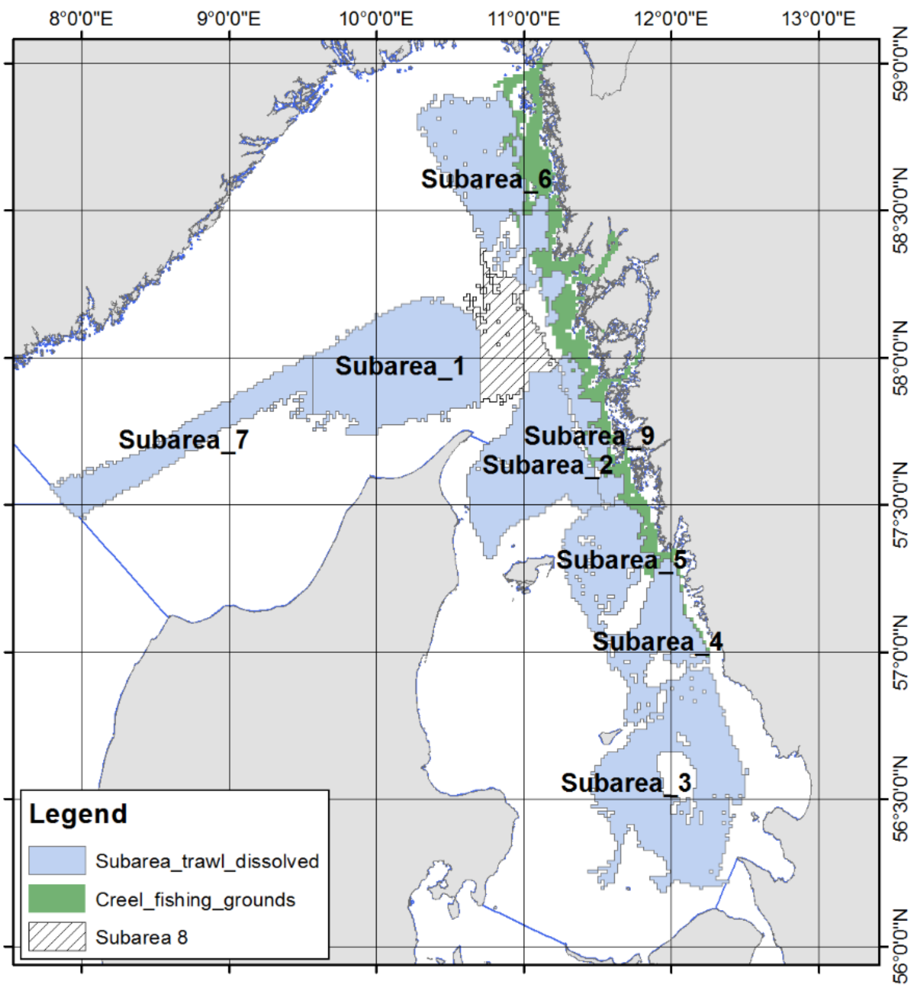


Figure 10.2.3.2. The defined subareas of the *Nephrops* stock in Division 3.a.

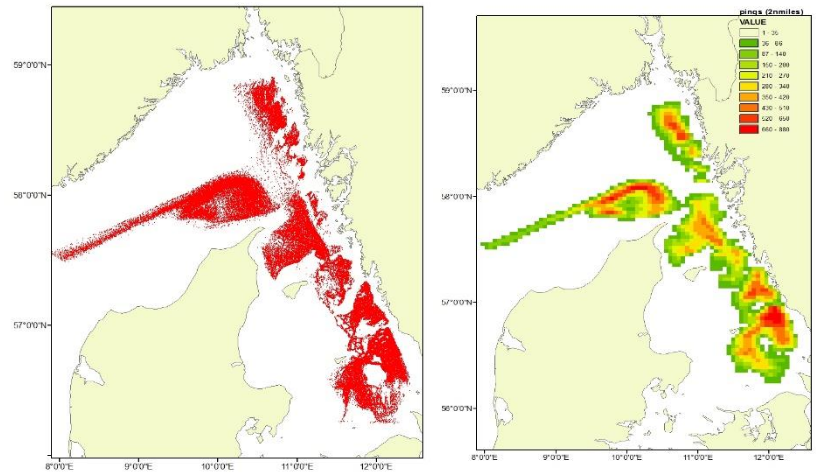


Figure 10.2.3.3. *Nephrops* stock in Division 3.a. The spatial distribution of the Danish and Swedish *Nephrops* fishery in 2010: Left map shows VMS pings and the right map shows density of VMS pings.

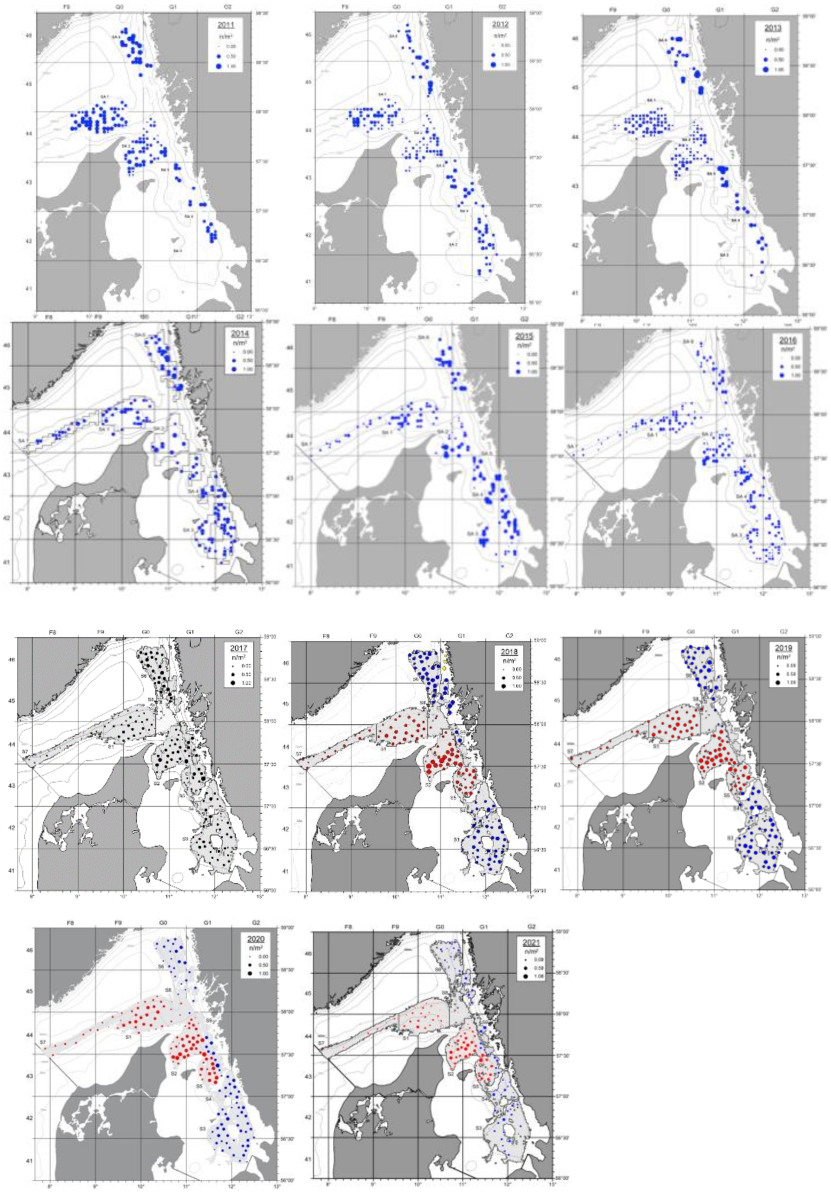


Figure 10.2.3.4. ***Nephrops*** **stock in 3.a. Sampling locations and** ***Nephrops*** **burrow density in the UWTV survey in the Skagerrak and Kattegat (FU 3 and 4) in 2011 (146 stations), 2012 (166 stations), 2013 (157 stations), 2014 (154 stations), 2015 (154 stations), 2016 (176 stations), in 2017 (171 stations), 2018 (177 stations), 2019 (173 stations), 2020 (176 stations) and 2021 (167 stations).**

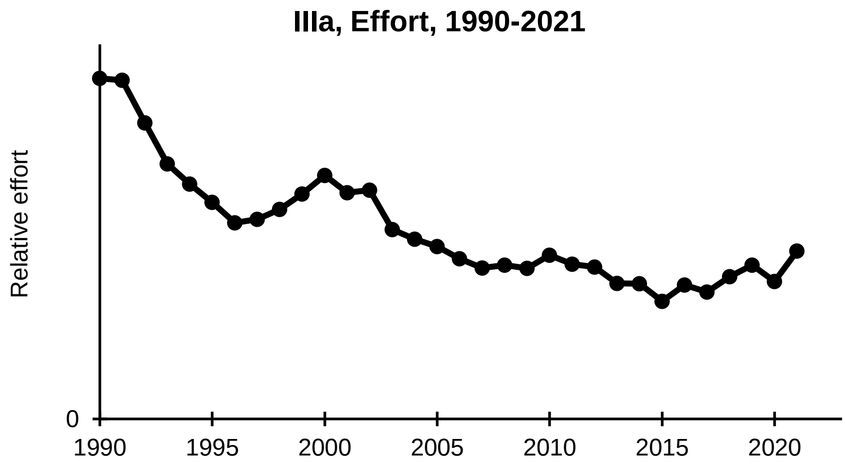


Figure 10.2.4.1 *Nephrops* in Division 3.a. Combined Effort for FU 3 and 4.

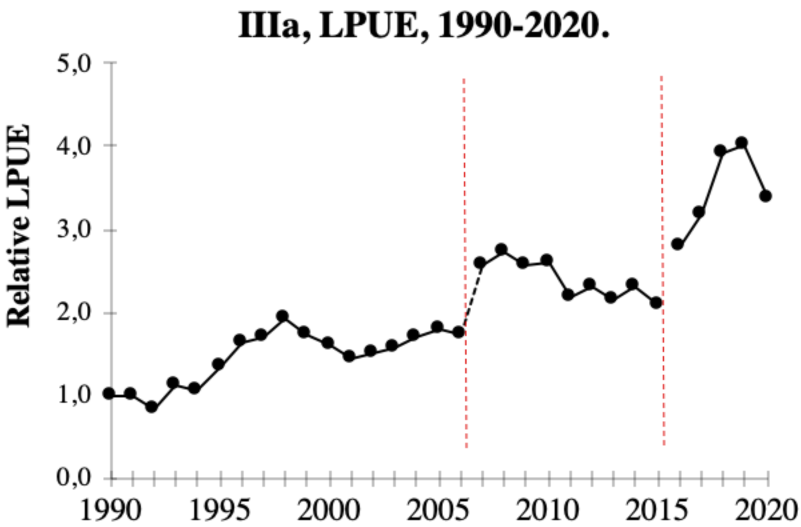


Figure 10.2.4.2 *Nephrops* in Division 3.a. Combined LPUE for FU 3 and 4. Red dotted line shows the year at the shift in Danish management system and, to the right, change in MCRS.

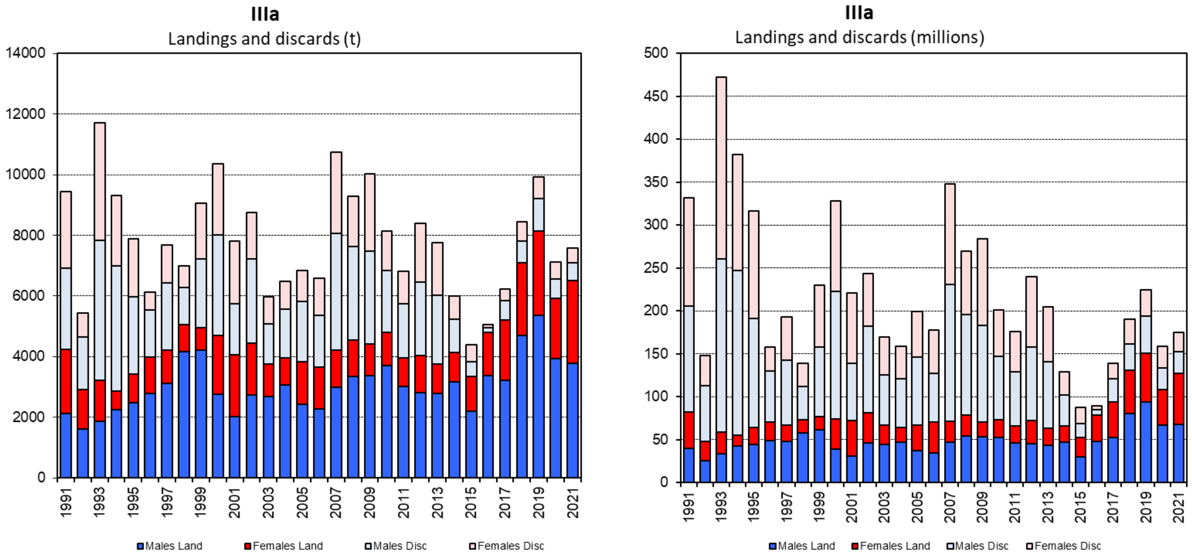


Figure 10.2.4.3. *Nephrops* in Division 3.a. Catch by sex and size category in biomass and numbers.

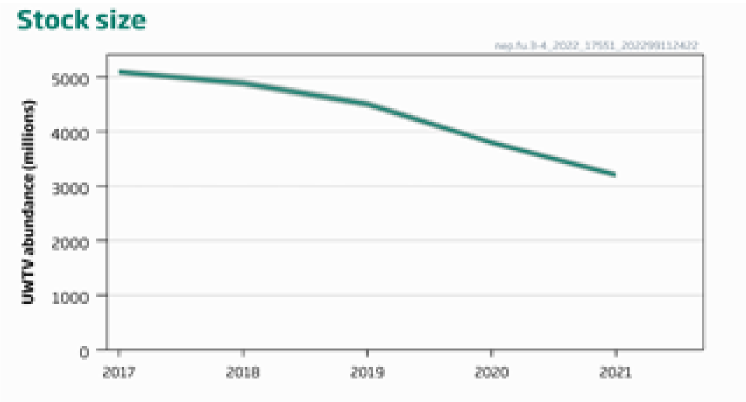


Figure 10.2.4.4. *Nephrops* stock in 3.a. Mean abundance by year: Error bars indicate the 95% confidence intervals.

11 Norway lobster (*Nephrops* spp.) in Subarea 4 (North Sea)

This section was updated in October 2022

11.1 General comments relating to all *Nephrops* stocks

See Section 10.1.

11.2 *Nephrops* in Subarea 4

Subarea 4 contains nine FUs 5, 6, 7, 8, 9, 10, 32, 33 and 34. Management is applied at the scale of ICES Subarea through the use of a TAC and an effort regime. FU 34 (The Devil's Hole) is a relatively new functional unit having been designated in 2010 (SGNepS, 2010).

Management at ICES Subarea Level

The 2018 EC TAC for *Nephrops* in ICES Subarea 2.a and 4 was 24 518 tonnes in EC waters (plus 800 tonnes in Norwegian waters). For 2019 and 2020, EC TAC, this was decreased to 22 103 tonnes in EC waters and 600 tonnes in Norwegian waters. For 2021 the EC TAC in Norwegian waters was further decreased to 200 tonnes. COUNCIL REGULATION (EU) 2022/515 of 31 March 2022 (amending Regulation (EU) 2022/109 fixing for 2022 the fishing opportunities for certain fish stocks and groups of fish stocks applicable in Union waters and for Union fishing vessels in certain non-Union waters) sets a TAC for 2022 of 24 268 tonnes for Subarea 2.a and 4, of which 21 021 tonnes are assigned to the UK, and 3 247 tonnes are assigned to the EU. The biggest share of the EU allowance is for Belgium and Denmark, with 1 269 tonnes each.

A major change in the management of *Nephrops* fisheries in ICES Subarea 4 since 2016 has been the introduction of the landing obligation for *Nephrops* fisheries in the 80–99 mm trawl fisheries. A *de minimis* exemption for catches below the Minimum Conservation Reference Size (MCRS) of up to 6% was permitted for the fishery in Subarea 4. The application of this exemption was not clear (i.e. whether the 6% applied at a trip level or to the total annual catch). Because there was no evidence presented to the Working Group that the introduction of the landing obligation had caused any change to discarding practices for the 2017 and 2018 fishery, the catch options have been estimated assuming discarding continues according to historic patterns.

The minimum landings size (MLS) for *Nephrops* in Subarea 4 (EC) is 25 mm carapace length. Denmark and Sweden applied a national MLS of 40 mm up to 2015 but this was changed to 32 mm from 1 January 2016. Norway still has a MLS of 40 mm.

Days-at-sea regulations and recently introduced effort allocation schemes (kW*day) have reduced opportunities for directed whitefish fishing. STECF 2010 stated that the overall effort (kW*days) by demersal trawls, seines and beam trawls shows a substantial reduction since 2002. However, there have also been substantial changes in the usage of the different mesh size categories by the demersal trawls. In particular there has been a sharp reduction in usage of gears with a mesh size of between 100 mm and 119 mm (targeting whitefish), but only a gradual decline in the effort of *Nephrops* vessels (TR2).

UK legislation (SI 2001/649, SSI 2000/227) requires at least a 90 mm square mesh panel in trawls from 80 to 119 mm, where the rear of the panel should be not more than 15 m from the cod-line. The length of the panel must be 3 m if the engine power of the vessel exceeds 112 kW, otherwise a 2 m panel may be used. Under UK legislation, when fishing for *Nephrops,* the cod-end, extension and any square mesh panel must be constructed of single twine, of a thickness not exceeding 4 mm for mesh sizes 70–99 mm, while EU legislation restricts twine thickness to a maximum of 8 mm single or 6 mm double. The UK introduced emergency technical measures for UK vessels targeting *Nephrops* in the Farn Deeps in 2016 (see Section 11.4).

Under EU legislation, a maximum of 120 meshes round the cod-end circumference is permissible for all mesh sizes less than 90 mm. For this mesh size range, an additional panel must also be inserted at the rear of the headline of the trawl. UK legislation also prohibits twin or multiple rig trawling with a diamond cod end mesh smaller than 100 mm in the North Sea south of 57°30'N.

Official catch statistics for Subarea 4 are presented in Table 11.2.1. The preliminary officially reported landings in 2021 are 18 723 tonnes (including 16 tonnes of BMS landings), 37% higher than in 2020 (13 687 tonnes), 14% lower than in 2019 (21 808 tonnes), and 24% lower than the peak observed in 2009 (24 597 tonnes). The main contributing countries increased their landings in 2021 compared to 2020. The UK remains the main producer country (reporting 83.0% of the total landings in 2021), followed by Netherlands (6.8%), Belgium (3.9%) and Denmark (2.1%).

Table 11.2.2 shows landings by FU as reported to the WG for 2021. The most productive functional units are 7 (51% of the total landings), followed by 6 (11%), 8 (10%) and 33 (7%). A small but significant proportion of the landings from Subarea 4 come from outside the defined *Nephrops* FUs. This value increased to nearly 10% of the total in 2009 and as a response, a new Functional Unit at the Devil's Hole (FU 34) was designated in 2011. Landings from outside the Functional Units exceeded 1000 tonnes in 2017 but have been below 800 tonnes since then.

11.3 Botney Cut (FU 5)

11.3.1 The fishery in 2021

Nephrops Functional Unit 5 is an offshore stock that encompasses an area of 1850 km² in Division 27.4.b (Central North Sea) and Division 27.4.c (Southern North Sea).

There is no creeling in the area, and *Nephrops* are caught through trawling by five countries: Netherlands is the main producer, in recent years usually followed by the Belgium, Germany, and the UK. Danish landings have been negligible between 2015 and 2020. However, in 2021, Danish landings exceeded UK landings, which have been decreasing since 2016. Although *Nephrops* are caught throughout the year, the main activity takes places during the summer (predominantly Q3).

The highest landings from FU 5 were reached in 2016, with a value on record of 2535 tonnes (Figure 11.3.1). The landings in 2017 were also high at 2109 tonnes, but decreased in 2018 to a more representative value of 1004 tonnes, primarily due to a 76% decrease in UK landings compared with 2017. In 2019, especially Dutch and German landings increased again, with total annual landings of 1172 tonnes. The total international landings in 2020 were 540 tonnes, the lowest recorded value since 1994, most likely due to the restrictions and reduced market during the Covid-19 pandemic. In 2021, international landings almost doubled compared to the previous year, with a total of 1067 tonnes.

ICES advice in 2020

FU 5 is assessed every two years, with the last advice given in 2020:

"ICES advises that when the precautionary approach is applied, catches in each of the years 2021 and 2022 should be no more than 1570 tonnes, assuming recent discard rates.

To protect the stock in this functional unit (FU) from continued overexploitation, management should be implemented at the functional unit level."

11.3.2 Data Available

Commercial landings

Landings by country for FU 5, including Belgium, Denmark, Germany, Netherlands, and the UK, are available since 1991 (Table 11.3.1 and Figure 11.3.1). Landings increased from around 800 tonnes in the early 1990s to around 1200 tonnes in the early 2000s, reaching 1443 tonnes in 2001. Then followed a period of general decline, with a low of 729 tonnes in 2009. From there, landings have increased again to over 2000 tonnes in 2016 and 2017. In 2018, 2019, and 2021, landings decreased again to more long-term representative values of 1004, 1172, and 1067 tonnes, respectively. In 2020, landings were uncharacteristically low due to the Covid-19 pandemic.

Between 1991 and 1995, the Belgian fleet took more than 75% of the international *Nephrops* landings from this functional unit. Since then, Belgian landings have declined drastically, and since 2006 there has been no directed *Nephrops* fishery by Belgian operated vessels. Some Belgian owned vessels operating as Dutch vessels have a directed fishery and increased the landings between 2010 and 2017 by a factor of 7.5. Danish landings have been sporadic since 2006, with almost no landings between 2015 and 2020. In the most recent years, the Netherlands and the UK have accounted for most of the landings from this functional unit, the large increase in 2014–2015 being driven entirely by these two fleets. The sharp jump in landings in 2016 was dominated by increases from the UK, Belgium and Germany, with lesser increases from the Netherlands. Since 2017, the UK reduced their participation in the fishery, catching only 2.4% of the total landings in 2020, and 1.1% in 2021. The strong decline in landings in 2020 was mainly due to reduced landings by the Netherlands, Germany, and the UK, while Belgian landings remained the same at just over 190 tonnes. In 2021, landings returned to the more typical level of 2018 and 2019.

Length composition

The length composition of landings by sex has been provided by The Netherlands since 2004. Data were not available for 2013 as the sample rate was considered insufficient to raise the distributions. Since 2015, Netherlands has also provided the unsexed length composition of their discards.

The intensity of the Dutch catch sampling programme is highly variable (Figure 11.3.2). In 2015 and 2017, the number of animals measured in landings were 4000 and 5600 individuals per year, respectively. In the other years since 2016, the annual number of length measurements has been at or below 2000, with no landings sampling in 2020. Annual length measurements in discards have been at least 4000 since 2015, with the exception of 2020, when 1500 animals were measured.

The proportion of Dutch landings that is represented by the Dutch catch sampling programme is also highly variable (Figure 11.3.3). Overall, the best sampling year was 2015, where a relatively high number of measurements represented 62% of the landings. By contrast, the even higher number of measurements in 2017 only represented 7% of the landings. In 2019, 32% of the landings were represented by just below 2000 measurements, and in 2021, 90% of the landings were represented by 2000 measurements. As there were no length measurements in landings in 2020, the individual mean weight in landings for this year's advice update is calculated based on 2019 and 2021 sampling.

Natural mortality, maturity at age and other biological parameters

In previous analytical assessments (see e.g. WGNEPH, 2003), natural mortality was assumed to be 0.3 for males of all ages and in all years. Natural mortality was assumed to be 0.3 for immature females, and 0.2 for mature females. Discard survival was assumed to be 0.25 for both males and females (after Gueguen and Charuau, 1975; and Redant and Polet, 1994).

Growth parameters are as follows:

Males:	$L\infty$ = 62 mm CL, k = 0.165.
Immature females:	$L\infty$ = 62 mm CL, k = 0.165.
Mature females:	$L\infty$ = 60 mm CL, k = 0.080, Size at 50% maturity = 27 mm CL.

Growth parameters have been assumed to be similar to those of Scottish *Nephrops* stocks with similar overall size distributions of the landings (see e.g. WGNEPH, 2003). Female size at 50% maturity was taken from Redant (1994).

Commercial effort data

Until the previous advice update in 2020, *Nephrops* directed effort was calculated for all English and Welsh vessels landing outside the UK, together with all UK vessels (including also Scottish and Northern Irish vessels) landing into England and Wales. This was done because, in this functional unit, more detailed information about *Nephrops* targeting vessels is available for the English and Welsh fleet, than for the fleets of other nations.

The relative contribution of UK landings to the total international landings has fluctuated over time and has generally decreased from the highest value of 53% in 2008, to the lowest value of 12% in 2019 (ignoring the unusual situation during the Covid-19 pandemic in 2020 and 2021; Table 11.3.1 and Figure 11.3.1). The UK landings component during recent years has not been high enough to be able to calculate an effort or LPUE measure that would be representative of the entire fleet targeting this functional unit. Therefore, until the UK component increases again, an estimate of annual directed effort will be determined based on the data uploaded to InterCatch.

Nephrops directed effort is estimated by taking into account only the OTB_CRU_70-99_0_0_all metier. For all countries, except the Netherlands, this is equivalent to TR2 gear. The TR2 class is defined as containing Otter trawl gears (codes OT (unspecified), OTB (bottom trawls), OTT (twin trawls)), as well as *Nephrops* bottom trawls (TBN), with mesh sizes of 70–99 mm. The Netherlands associate TR2 landings either with a crustacean (CRU), or with a demersal fish (DEF) target assemblage, depending on the catch composition.

Although the total international effort in 2021 has increased slightly compared with 2020, it remains low compared with previous years (Figure 11.3.4). The main changes were significant increases in Dutch and Belgium effort, and a decrease in German effort.

UWTV survey

There were no new surveys in FU 5 since 2012. Details of the 2010 and 2012 surveys are given in the 2013 WGNSSK report.

11.3.3 InterCatch

The ICES InterCatch database has been used as the main data submission tool for *Nephrops* from 2011 onwards, whereby all countries participating in the fishery within a particular functional unit submit at least quarterly landings by fleet.

Annual discard data have been available since 2015 from the Dutch self-sampling program. Discard data were available for the Belgian *Nephrops* fleet for the period 2002–2005, but in the absence of a directed fishery since 2006, there has been no data collection from the Belgian *Nephrops* landings. In addition, the Netherlands has provided length distributions for landings and discards by fleet where available. As discussed in Section 11.3.2, the Dutch sampling effort is highly variable from one year to the next. However, the sampling in 2019 and 2021 is deemed sufficient to update mean individual weights and discard rates for the calculation of the most recent harvest rate, which is required for the advice update.

11.3.4 Quality of assessment

The data available to assess FU 5 are limited, and consequently the assessment is not robust enough to determine the status of the stock.

The assessment is based upon the assumptions that the length composition of catch, and the discard pattern, are the same for all fleets and are sufficiently well estimated by Dutch sampling. The 2012 survey estimate considered in this advice (0.7 burrows m^{-2}) is relatively high compared with most Norway lobster stocks in the North Sea. However, the large interannual variability in density that is seen in neighboring functional units, such as FU 6, indicates that a single survey is insufficient to provide a reliable abundance estimate. For the advice given in 2022, it was therefore decided to downgrade this functional unit from a Category 4 to a Category 5 stock.

11.3.5 Status of stock

The status of this stock is uncertain, although there are signs that the fishing yield of this stock has decreased over the years. The number of UK vessels fishing in FU 5 has generally decreased over time. Due to the small contribution of UK vessels to the total international landings, and in the absence of detailed information about the other national fleets, an LPUE estimate has not been calculated since 2018. Pooled landings and discards length distributions were determined for 2019 and 2021. No landings samples are available for 2020.

Following the procedure outlined in Section 10.1.2, an estimate of all *Nephrops* grounds was used to give a likely envelope for the total abundance of *Nephrops* in this functional unit, and to estimate the harvest rate. Discard survival was set to zero in line with the protocol for data limited *Nephrops* stocks. The 2012 survey shows that density is relatively high on this ground at 0.7 burrows per m^2. Estimating the harvest rate since then is associated with two main sources of uncertainty. One is the inevitable change in abundance, the other is the lack of adequate sampling data to establish reliable estimates of individual mean weights in landings. Therefore, to increase confidence in at least the qualitative evolution of recent harvest rates, two different scenarios were considered (Figure 11.3.5). For both scenarios, the individual mean weights in landings and discards from 2018, 2019 and 2021 were used. For the years 2017–2021, discard rates by number were calculated as three-year averages ending in a given year. In the first scenario, the abundance was assumed to be constant since 2012. In the second scenario, the abundance from FU 6 was used, scaled to the FU 5 abundance in 2012. Based on both scenarios, the harvest rate steadily declined between 2017 and 2020. In 2021, it increased again but remains well below the precautionary MSY proxy of 7.5%. The qualitative changes in harvest rate are predominantly driven by changes in landings, rather than the abundance.

11.3.6 Short term forecasts

The short-term forecasts and the quota advice for this stock are updated every two years. Catch and landing predictions for 2023 and 2024 were estimated for WGNSSK 2022 and are given in the table below when the ICES framework for Category 4 *Nephrops* stocks was applied. This assumes that the absolute abundance estimate made in 2012 is relevant to the stock status for 2023 and 2024.

However, at the ADGNEPH 2022, it was decided that due to the lack of recent survey estimates or trends to downgrade this stock from category 4 to category 5. There is no indication of harvest rate relative to proxies, stock size in relation to reference points is unknown and there are no marked positive trends for this FU. Therefore, catch advice for 2023 and 2024 are based on the latest catch advice and a precautionary buffer of -20% was applied. Based on the advice approach, catches in 2023 and 2024 should be no more than 1256 tonnes, assuming recent discards rates (50.5%, average in 2019, 2019, 2021)

***Nephrops* FU 5. Category 4 advice catch options assuming discarding continues at recent average. All weights are in tonnes. Harvest rates in percent are calculated for a range of densities, with values above the MSY proxy of 7.5% highlighted in grey.**

Basis	Total Catch	Projected landings	Projected discards	Range of potential densities (*Nephrops* m^{-2})								
				0.05	0.1	0.2	0.3	0.4	0.5	0.6	0.7 *	0.8
0.5 x average landings (2019–2021)	709	463	246	24.3	12.1	6.1	4.0	3.0	2.4	2.0	1.7	1.5
0.5 x average landings (2012–2021)	1045	683	362	35.8	17.9	8.9	6.0	4.5	3.6	3.0	2.6	2.2
Advice for 2021 and 2022 -20%	1212	792	420	41.5	20.8	10.4	6.9	5.2	4.2	3.5	3.0	2.6
Average landings (2019–2021)	1418	926	492	48.6	24.3	12.1	8.1	6.1	4.9	4.0	3.5	3.0
Advice for 2021 and 2022	1578	1031	547	54.1	27.0	13.5	9.0	6.8	5.4	4.5	3.9	3.4
Advice for 2021 and 2022 +20%	1894	1237	657	64.9	32.4	16.2	10.8	8.1	6.5	5.4	4.6	4.1
Average landings (2012–2021)	2089	1365	724	71.6	35.8	17.9	11.9	8.9	7.2	6.0	5.1	4.5
Average landings (2012–2021) +20%	2507	1638	869	85.9	43.0	21.5	14.3	10.7	8.6	7.2	6.1	5.4
MSY proxy harvest rate	3064	2002	1062		52.5	26.3	17.5	13.1	10.5	8.8	7.5	6.6
Maximum landings	3880	2535	1345		66.5	33.2	22.2	16.6	13.3	11.1	9.5	8.3

*** Density assumed for this stock.**

11.3.7 Issues for a future benchmark

The lack of updated abundance estimates since 2012 significantly reduces the reliability of estimates of the current harvest rate. This makes it difficult to determine whether the landings advice can be increased from the previous year, according to the advice rules for Category 4 *Nephrops* stocks. Currently, there are no UWTV surveys planned within FU 5. It might therefore become necessary to re-classify this functional unit as a Category 5 stock and provide landings only advice, as for the outside-FU parts of Subarea 4.

At that time, it could also be considered whether the area covered by FU 5 should be redefined, possibly in connection with the introduction of a new functional unit. This is suggested by an analysis of the spatial distribution of recent landings from the outside-FU area (for a description, see Section 11.12).

11.3.8 Management considerations for FU 5.

The North Sea TAC is not thought to be restrictive for the fleets exploiting this stock, as the landings between 2014 and 2017 were significantly higher than the catch advice. Although since then landings have been broadly in line with the advice, given the paucity of metrics available for assessing stock development, the exploitation of this stock should be monitored closely.

11.4 Farn Deeps (FU 6)

11.4.1 Fishery in 2020 and 2021

Nephrops Functional Unit 6 is situated in Division 27.4.b (Central North Sea), off the northeast coast of England.

Since the beginning of the time-series, the UK fleet has accounted for virtually all landings (≥ 98%) from the Farn Deeps (Table 11.4.1 and Figure 11.4.1). The Farn Deeps fishery is essentially a winter fishery commencing in September and running through to March. The most recent data from 2021 therefore comprise the end of the 2020–2021 fishery and the start of the 2021–2022 fishery.

The total international landings in 2021 were 2022 tonnes, significantly lower than the unusually high landings of 4364 tonnes in 2019, and within the range of landings during the 2016–2018 period and in 2020 (Table 11.4.1 and Figure 11.4.1). While the combined relative contribution to total international landings from English, Welsh, and Northern Irish vessels has continued to increase from 79% in 2019 to 89% in 2021, the contribution from Scottish vessels has decreased from 20% to 11%.

The discard rates (estimated as percentage of biomass) during 2017—2019 were between 9.1—9.4%. During the years of the Covid-19 pandemic, they increased to 14.0% in 2020 and 17.2% in 2021. As described in Section 11.4.4, there is a greater uncertainty around the estimation of discards in 2020 and 2021, due to the reduced sampling at sea.

In 2016, the UK implemented a suite of technical measures in response to the continued poor state of the stock. The measures commenced in April 2016 for UK vessels fishing in Farn Deeps (99% of the fleet in the stock unit). These measures were as follows:

- A minimum mesh size of 90 mm using single twine of 5 mm.
- Only single-rig vessels of 350 kW (476 hp) or less are permitted to fish within 12 nm of the coast.
- Multi-rig vessels (vessels with three or more rigs) are prohibited from operating within the Farn Deeps. Twin rig vessels are permitted to operate outside 12 nm.

- No vessel can use gear with more than one cod end per rig

ICES updated advice in November 2021

"ICES advises that when the MSY approach is applied, and assuming that discard rates and fishery selection patterns do not change from the average of the years 2018–2020, catches in 2022 should be no more than 1940 tonnes.

To ensure that the stock in Functional Unit (FU) 6 is exploited sustainably, management should be implemented at the functional unit level. Any substantial transfer of the current surplus fishing opportunities from other FUs to FU 6 could rapidly lead to overexploitation."

Management of the fishery is at the ICES Subarea level as described in Section 10.1.

11.4.2 Assessment

Review of the 2022 assessment

"The forecast has been performed correctly with no deviations from the standard procedure for this stock."

11.4.3 Data available

Landings and discards sampling

The two types of sampling on *Nephrops* in FU 6 are the UK vessel observer programme, determining the sex-specific length distributions in landings and discards, and the Cefas shore sampling programme, determining sex-specific length distributions in unsorted catches. The catch length distributions from the shore sampling programme are separated into landings and discards by means of a sigmoidal discard probability curve that is fitted to the vessel observer size-dependent discard rates. For the years 2006—2019, the results are shown in Figure 11.4.2. Due to the Covid-19 pandemic, in 2020 and 2021, there were too few observer trips during which both landings and discards were sampled. For those two years, length distributions are primarily based on data from the shore sampling programme.

Discarding practice varies considerably between vessels in any given period, but there are no significant trends in the two fitted parameters of the discard probability curve (Figure 11.4.2). A fixed discard probability curve has therefore been used since 2002 to separate catch samples into landings and discards.

The Benchmark meeting in 2013 concluded that the historical assumption of 0% discard survival was no longer applicable, as a significant proportion of catch sorting now takes place at sea. For day-boats, the first haul of the day will generally be sorted on the fishing grounds, whilst the second haul will be sorted whilst steaming back to port (and therefore passing over habitat unsuitable for *Nephrops)*. Discarding practice for multi-day boats will generally result in discards returning to suitable sediment. The conclusion was therefore that although the full 25% survival assumed in other FUs was not likely to be applicable, a 15% survival rate was a reasonable estimate for this functional unit.

Changes in length distribution

There is a clear change in length frequencies around 2007, with much lower contributions from the smaller (discarded) size classes (Figure 11.4.3). This may reflect an improvement in selectivity by the fleet. A bi-modal length frequency distribution for landed females was observed between 2009–2014, becoming more pronounced throughout that period. This could be the result of a large year class, but a similar phenomenon is not observed in the male part of the population. In fact, the mean size in the males decreased in 2012 and 2013 (Table 11.4.2). Additionally, the mean annual increment of the larger female mode of around 2 mm is considerably lower than the annual growth that would be expected based on the growth parameters available for this stock. A high year class strength is therefore unlikely to be the cause of this phenomenon. The predominance of large females in the catches means they were foraging for food, at a time when they would be expected to be brooding within their burrows. Given that there are very few males of similar size appearing in the catches, it is possible that there is a physical size differential constraint in mating patterns of *Nephrops*. This may either be an inability of the males to successfully transfer spermatophores, or alternatively large females may be able to resist the (usually quite aggressive) approaches of the smaller males when they try to mate with large females.

The reduction in the bi-modal nature of the female length distribution since 2015 implies a lower relative availability of females at larger sizes and may indicate a better spawning success. The high abundance observed in the UWTV survey in 2018 and 2019 (continuing the increase since 2015), and the small animals observed in the catch for those years, support this hypothesis (assuming that recruits enter the fishery between age 3 and 4, and they are seen in the survey from age 2).

The mean carapace length of large females (≥ 35 mm) in the landings have gradually increased over the period 2000–2017 (Figure 11.4.1). Since 2017, the mean length of large females as declined again. For large males, the mean length increased over the period 2002–2013, and has generally decreased since, although there was an increase in 2021. The mean lengths of small females and males (< 35 mm) in the landings do not show any clear temporal pattern.

Effort and LPUE

The way in which data regarding both landings and effort were collected within the UK changed in 2006, when the "Buyers & Sellers" legislation from 2005 came into effect, which resulted in a noticeable change in the level of reported metrics. A comparison between the periods before and since 2006 is therefore inadvisable.

Historically the fishery has been prosecuted by a combination of local English boats (smaller vessels undertaking day–trips) and larger vessels from Scotland with occasional influxes of Northern Irish vessels. The total number of vessels in the fishery (which land into England and Wales) has fluctuated between ~100 and ~250 since 2006 (Figure 11.4.4), but overall the fleet size declined until 2018. A temporary increase in 2019, resulting in more than doubling of the landings of the previous year, was then followed by a decline in the active fleet size in 2020, back to the 2018 level. The fleet size increased again in 2021, due to an increase in the number of small and intermediate vessels, while the number of vessels longer than 15 m continued to decline. Generally, however, most of the fluctuation in fleet size is due to changes in the above 15 m fleet, which experienced an influx of vessels from Scotland and Northern Ireland for the period between 2011–2014, and again in 2019. In contrast, the size fleet for the 10–15 m sector has remained fairly constant since 2006, with the exception of a temporary increase in the number of active Scottish vessels in 2019. The size of the under-10 m sector has generally declined since 2006.

Directed effort is calculated taking into account only TR2 gear, with a *Nephrops* catch component of ≥ 25%. The TR2 class is defined as containing Otter trawl gears (codes OT (unspecified), OTB (bottom trawls), OTT (twin trawls)), as well as *Nephrops* bottom trawls (TBN), with mesh sizes of 70–99 mm. On the basis of available data for this functional unit, effort is calculated for all English and Welsh vessels landing outside the UK, together with all UK vessels (including also Scottish and Northern Irish vessels) landing into England and Wales. The unit of fishing effort is kWd.

Fishing effort calculated in this fashion for vessels ≤ 15 m has been fairly consistent since 2006 (Figure 11.4.1). The main changes in total landings – including the sharp decline between 2006–2008, the intermittently high values in 2012–2014, and the high value in 2019 – were driven primarily by fluctuations in the fishing effort of the > 15 m fleet (Figure 11.4.1). Directed effort is highest in quarters one and four, without a consistent relative fishing intensity between these quarters (Figure 11.4.5). A notable exception is the relatively high effort in the summer (Q3) of 2016. Landings per unit effort (LPUE) of males tend to be highest during the winter months, whereas LPUE of females is typically highest in quarter three.

The use of LPUE as an index of stock abundance is confounded by changes in availability of *Nephrops* to fishing gears, depending upon environmental factors such as tide and light levels, plus changes to emergence behaviour induced by mating and predator avoidance. Therefore, the temporal trend of LPUE can only be used as an indicator of trends of abundance, if the catchability of *Nephrops* is assumed to be constant over the years.

LPUE for the entire directed *Nephrops* fleet, as defined above, has fluctuated between 0.6–1.0 kg/kWd since 2006, without any consistent trends over periods of more than 3 years (Table 11.4.3).

Traditionally, males tend to predominate the landings, averaging about 70% (with a range of 64%–79%) by biomass in the period 1992–2005. Towards the end of the fishing season (February–March) there is usually an increase in female availability as mature females emerge from their burrows having released their eggs. There has been a marked change in the seasonal pattern of sex-ratio (in catches by number) for Farn Deeps *Nephrops* since the winter of 2005. Prior to this, the ratios were generally steady, with small (~10%) seasonal fluctuations. Since then, there have been significant interannual swings, with whole years being dominated by landings of females (2006, 2010, 2013–2014, Figure 11.4.6). The sex ratio since 2015 returned to a generally male dominated fishery, which can be explained by the lack of large females in catches (Figure 11.4.3). However, in 2019, for the first time since 2013, a larger number of females was caught in the fourth quarter, followed by an even larger proportion in the first quarter of 2020. Due to the poor sampling situation since then, sex-ratios in landings are uncertain. However, based on the available data, quarter one and four landings in 2021 had a high proportion of males.

UWTV

Underwater TV (UWTV) surveys of the Farn Deeps grounds have been conducted at least once in each year from 2001 onwards.

A time series of indices is given in Table 11.4.4 and Figure 11.4.7. The procedure used to work up the UWTV survey has been changed in 2007. The original survey design was a random-stratified design, where the ground was split into regular boxes with stations randomly placed within. At a later stage, additional stations were inserted into areas of high density to better define them. However, this was not accounted for in the process of estimating overall abundance, and therefore the higher density of stations in high-density *Nephrops* areas biased the estimate upwards. In addition, the distance covered by the UWTV sledge was determined by assuming a straight-line between the start and finish positions of the vessel. Since 2007, GPS logging of the position of the vessel and the sledge (via a Hi-Pap beacon) at short intervals (~5 seconds) has enabled the determination of a considerably more robust estimate of viewed distance. The abundance estimate is now obtained through a geostatistical procedure, in which the burrow density estimates are first fitted by a semi-variogram model. Then, an interpolated surface of burrow density is created using Kriging on a 500 m by 500 m grid. Uncertainty estimation of the overall abundance estimate is performed by bootstrapping the counts, re-fitting the semi-variogram, and re-estimating the surface. Uncertainty estimates are typically 2%, much lower than the previous estimates which ignored spatial structure to a large degree. Since 2013, the survey takes place during the summer instead of the autumn, in order to avoid the fishing vessels working in the area and disturbing the sediment.

The total abundance at the beginning of the time series was higher than 1000 million of individuals, reaching 1685 million in 2001. From 2008 to 2015, the abundance gradually declined, attaining the lowest value of 578 million in 2015. The UWTV survey in 2009 was hampered by a period of poor weather and low visibility, which coincided with the surveying of the areas traditionally associated with the highest densities. From 2015 until 2019, mean density and total abundance have increased again, with values of 0.37 individuals per m^2 (a total of 1163 million individuals, ±26 million 95% CI) in 2019. However, the UWTV surveys since then indicate that total abundance has steadily decreased to a value of 878 million individuals (±20 million 95% CI) in 2022, with a density of 0.28 individuals per m^2. The lower bound of the confidence interval is now at the MSY biomass trigger point of 858 million. The turning point in the abundance trend coincides with the unusually high landings in 2019.

The spatial pattern of burrow density is similar through time with the highest density ground running along the western edge of the mud-patch (Figure 11.4.8).

11.4.4 InterCatch

In 2021, landings data by fleet were provided via the ICES InterCatch database by England, Scotland, the Netherlands, Belgium, Denmark, and Sweden. Discard data were provided by England and Scotland. Length distributions for landings and discards by fleet and quarter were provided by England and Scotland. There were no reported BMS landings.

As in previous years, unreported discards for the reported landings were calculated in InterCatch based on the UK discard ratios. Following this procedure, 282 tonnes of discards were raised for 2021, which was unusually high compared with the 137 tonnes of reported discards. The reason for the high raised discards is the lack of discard data for Q1 in 2021. However, the total discards of 419 tonnes (reported plus raised) are between the values of 2019 (453 tonnes) and 2020 (310 tonnes).

The length distributions imported by England and Scotland for 2021 represented 34% of the landings, which is less than half the proportion of sampled landings for the period 2015--2020. The main reason for that is the lack of samples in Q1 of 2021. All reported discards were sampled. Length frequencies for unsampled landings, or strata without reported discards, were generated from the pooled sampling data. Strata are defined by quarter and metier.

11.4.5 Biological parameters

Biological parameter values, such as natural mortality and maturity at age, are included in the Stock Annex which was updated at the 2013 benchmark.

11.4.6 Exploratory analyses of RV data

A comprehensive review of the use of UWTV surveys for *Nephrops* stock assessment was undertaken by WKNeph (ICES, 2009). This covered the range of potential biases resulting from factors including edge effects, species mis-identification, and burrow occupancy. The cumulative bias-correction factor estimated for FU 6 was 1.2, meaning that the raw counts from the UWTV survey are likely to overestimate densities of *Nephrops* by 20%. The correction factor is therefore applied to the raw counts to arrive at the absolute abundance index. Estimates of absolute burrow density and total abundance estimates (with confidence estimates) are given in Table 11.4.4.

For the purposes of advising on management for the next year, the UWTV survey from the assessment year is assumed to be representative of the fishing opportunities for the forecast year. The UWTV survey for FU 6 is typically undertaken between late May and July and is therefore available for the updated advice in autumn. The validity of using the UWTV survey to determine advice for the following year was explored by looking at how the UWTV survey predicts metrics such as catch rate and landings in the following year. Significant relationships exist between UWTV abundances and LPUE, Effort and Landings in the following year (Figure 11.4.9), whereas there are no significant relationships when using the UWTV survey in the same year as the fishery metrics. This suggests that, for FU 6, the UWTV survey is a valid predictor of fishery activity the following year.

Final Assessment

The estimated abundance in 2022 was 878 million individuals (±20 million 95% CI, Table 11.4.4), a 10.6% decrease from 2021, and the lower bound of the confidence interval is at the 2007 estimate of 858 million, which is used as MSY $B_{trigger}$. The estimated harvest rate for 2021 was 11.9% (up from 9.6% in 2020; Table 11.4.5) and therefore remains above the MSY proxy level of 8.1%.

11.4.7 Historical stock trends.

The time series of UWTV surveys covers the time period from 2001 onwards, although the new geostatistical method has only been applied retrospectively to 2007. Whilst a small over-estimation of abundance using the previous technique is expected, it is likely that the reduction in stock abundance observed between the two periods of estimation procedure is real.

Estimates of historical harvest rate (the proportion of the stock which is removed) range from 5.9% in 2008 to 24.3% in 2006 (Table 11.4.5, Figure 11.4.10). The harvest rate jumped from around 11% in 2004–2005 to the historical maximum in 2006, when the new reporting legislation came into effect. Since 2001, the harvest rate has only been below the MSY level once, during the historical minimum in 2008.

11.4.8 MSY considerations

Considerations for setting harvest rates associated with proxies for F_{MSY} for *Nephrops* are described in ICES, WGNSSK, 2010, Section 10.1.

- Average density in the stock is at a medium level, above the level of FU 7, but below that of FU 8.
- Density has varied through time but does not appear to undergo large scale interannual fluctuations. Spatially, there is a good degree of consistency in the pattern of high and low density between the years.
- Estimated growth rates are at a moderate level, although the data supporting them are quite old. Natural mortality estimates are standard.
- The fishery in the Farn Deeps is a winter fishery (October–March) with typically male dominated catches. The intra-annual pattern of sex ratio in the catches has fluctuated widely between 2005 and 2014, with periods of high female catch ratios during the winter. This might be due to sperm limitation or ovary resorption, leading to more mature but unfertilised females becoming available to the fishery.
- Although the time series of observed harvest rates is relatively short, there has been a fair degree of fluctuation (6–24%). The observed harvest rate is, of course, confounded by the change in reporting levels considered to have occurred around 2006.

The following table shows the mean F, implied harvest rate and resulting spawner per recruit values (expressed as percentage of a virgin stock) for the range of F_{MSY} proxies suggested for *Nephrops*. These values were last recalculated in 2013 using a length cohort analysis model (SCA, see ICES, WKNEP 2009) on the combined length frequencies for 2010–2012. The model fit to the data (Figure 11.4.11) is reasonable, but the increasing bi-modality of the length frequency observed in the females for 2009–2014 does violate model assumptions, and the model under-predicts the landings of larger females.

		F_{bar} 20–40 mm		Harvest Rate	% Virgin Spawner per Recruit (SpR)	
		Female	Male		Female	Male
F0.1	Comb	0.09	0.09	8.7%	47.52%	32.11%
F0.1	Female	0.16	0.16	14.0%	32.63%	18.26%
F0.1	Male	0.07	0.07	7.1%	53.02%	38.50%
F35%	Comb	0.12	0.12	11.1%	39.98%	24.50%
F35%	Female	0.17	0.17	15.2%	34.82%	16.64%
F35%	Male	0.16	0.16	8.1%	57.17%	34.88%
Fmax	Comb	0.17	0.17	15.3%	34.58%	16.48%
Fmax	Female	0.29	0.29	21.6%	22.22%	9.47%
Fmax	Male	0.12	0.12	11.6%	44.70%	23.73%

The default harvest rate suggested for *Nephrops* is the combined sex F35%SpR. The effects of sperm limitation appear to have been a factor in the recent development of this stock. There are signs that this stock may have been in a period of lower productivity for a number of years, and so a harvest rate which gives greater protection to the spawning potential of males would be advisable. The Working Group adopted the F_{MSY} proxy to be the harvest rate equivalent to F35% on males for this stock (8.1%).

WGNSSK suggests the absolute abundance index of 858 million individuals from the 2007 UWTV survey (i.e., the first year when the stock was considered to be depleted in the recent series) should become a proxy for $B_{trigger}$.

11.4.9 Short term forecasts

Catch and landing predictions for 2023 are given in the table below. These predictions include the latest abundance estimate from the 2022 UWTV survey.

In November 2016, ICES advised on fishing opportunities assuming that discarding would only occur below the minimum conservation reference size (MCRS). Observations from the fishery since then indicate that discarding above the MCRS continues, and practices have not changed markedly (Figure 11.4.3). Consequently, ICES has provided advice based on average discard rates observed over the last three years, which is considered to be a more realistic assumption than zero discards above MCRS. A table with the catch and landing predictions assuming zero discards is also presented for comparison.

A deviation from the normal procedure was agreed during WGNSSK 2021, to address the reduced sampling level in quarters two to four of 2020 due to Covid-19 restrictions. For *Nephrops* stocks, the adopted procedure calculates the average mean individual weights in landings and discards during the period 2017–2019, scaled such that the quarter one values of the three-year reference period are identical to those in quarter one of 2020. In FU 6, the commercial activity in 2019 was unusual not only by the magnitude of annual landings, but also by uncharacteristically high discard rates by weight in quarters two and three. As the unusual discarding practice in 2019 might have affected the length sampling for FU 6, in contrast with the other *Nephrops* stocks, it was decided to calculate averages for the reference period 2016–2018 and scale those to quarter one values in 2020. As usual, discard rates by number were calculated from landed and discarded numbers, given by the total landed and discarded weights divided by the respective mean individual weights.

In 2021, discard and length sampling data were only available for Q4. Despite reduced sampling during the two years of the pandemic, discards in 2020—2021 were within the range of values of the ten years preceding the pandemic (Table 11.4.5). Also, a comparison between quarterly mean weights of females and males in landings and discards has shown that the values in 2020—2021 are not outliers (Figure 11.4.11). An adjustment of discards and mean weights, as in the previous year, was therefore not deemed to be necessary. This would require a deviation from the stock annex, would have to be done outside of InterCatch, would therefore reduce transparency and potentially introduce more uncertainty into the results.

The ICES MSY approach dictates that, where the stock status is above the trigger point, the maximum advised fishing rate should be the MSY rate. Applying this approach, catches in 2023 that correspond to MSY are 1604 tonnes. This value is considered precautionary when applying the ICES advice rule.

***Nephrops* in FU 6. The basis for the catch scenarios**

Variable	Value	Notes
Stock abundance	878	Underwater TV survey 2022; individuals in millions
Mean weight in projected landings	25.53	Average 2019–2021; grammes
Mean weight in projected discards	10.82	Average 2019–2021; grammes
Projected discard rate (total)	26.7	Average 2019–2021; percentage by number of the total catch
Discard survival rate	15	Percentage by number of the discards
Dead projected discard ratio	23.7	Percentage by number of the total catch

***Nephrops* in FU 6. Catch options assuming discarding continues at recent average. All weights are in tonnes.**

Basis	Total catch	Dead removals	Projected landings	Projected dead discards	Projected surviving discards	% harvest rate*
	PL + PDD + PSD	PL+PDD	PL	PDD	PSD	for PL+PDD
MSY approach	1604	1572	1390	183	32	8.12
$F_{MSY\ lower}$	1383	1355	1198	157	28	7.00
$F_{MSY\ upper}$	1604	1572	1390	183	32	8.12
F_{2021}	2345	2298	2031	267	47	11.87
$F_{2019–2021}$	2478	2428	2146	282	50	12.54
F35% Male	1604	1572	1390	183	32	8.12
F35% Female	3001	2941	2599	341	60	15.19
F35% Combined	2201	2157	1906	250	44	11.14
F0.1 Male	1405	1377	1217	160	28	7.11
F0.1 Female	2770	2714	2399	315	56	14.02
F0.1 Combined	1715	1681	1485	195	34	8.68
Fmax Male	2292	2246	1985	261	46	11.60
Fmax Female	4268	4182	3696	486	86	21.60
Fmax Combined	3023	2962	2618	344	61	15.30

*** Calculated for dead removals.**

***Nephrops* in FU 6. Catch options assuming zero discard rates. All weights are in tonnes.**

Basis	Total catch	Wanted catch	Unwanted catch**	% harvest rate *
MSY approach	1540	1334	206	8.12
FMSY lower	1328	1150	178	7.00
FMSY upper	1540	1334	206	8.12
F2021	2251	1949	301	11.87
F2019–2021	2378	2060	318	12.54
F35% Male	1540	1334	206	8.12
F35% Female	2881	2495	386	15.19
F35% Combined	2113	1830	283	11.14
F0.1 Male	1348	1168	180	7.11
F0.1 Female	2659	2303	356	14.02
F0.1 Combined	1646	1426	220	8.68
Fmax Male	2200	1906	294	11.60
Fmax Female	4097	3548	548	21.60
Fmax Combined	2902	2513	388	15.30

*** Calculated for dead removals.**

**** Represents the amount that otherwise would have been discarded but is now landed under the landing obligation.**

11.4.10 BRPs

Suggestions for proxies of biological reference points are shown in the catch option table and discussed in 11.4.8.

11.4.11 Quality of the assessment

Changes to the legislation regarding the reporting of catches in 2006 means that the levels of reported landings from this point forward are considered to better reflect the true landings and hence effort input into this fishery. This does mean that comparison of LPUE with previous years is inadvisable.

There was an issue with the UK official database in 2017 and 2018, and some fishing trips were missed. These trips were made by non-Scottish vessels that sold their catch to Scottish buyers. In order to associate the missing landings with a functional unit, it was assumed the vessels (all of them under 10 m length) fished near the landing port. Consequently, vessels landing *Nephrops* in North Shields, Amber, Hartlepool, Blyth, North Sunderland and Boulmer (England) were assumed to fish in Farn Deeps during those missing trips.

The addition of these missing landings for 2017 resulted in an increase of 151 tonnes compared with the value submitted in 2017. It also caused an increase of the estimated discard and harvest rate, and a decrease of the mean weight and size of the catch for that year. The fishing effort and LPUE for English vessels were also updated.

Normally, the length and sex compositions arising from the land-based catch sampling programme are considered to be representative of the fishery. Estimates of discarded and retained length frequencies arising from the vessel observer sampling programme are also normally considered robust. However, the unusual situation in 2020 resulted in missing sampling data in quarters two to four. These data gaps have been filled in according to the procedure described in Section 11.4.9. The impact on the assessment due to missing sampling data is unknown.

The UWTV survey in this area has a high density of survey stations compared to other surveys, and the abundance estimates are generally considered robust. There is greater uncertainty in the index for 2009 due to the absence of stations in the higher density areas which may result in an over-estimate of the magnitude of the decline for this year. The spatial distribution of the 2022 survey abundance continues the spatial pattern observed in previous years, with the spine of high density on the western edge of the ground, but with overall reduced density compared with the previous three years.

11.4.12 Status of stock

The 2022 UWTV survey indicates that the size of the stock has continued to decrease since 2019. The abundance remains above the MSY $B_{trigger}$. However, the lower bound of the confidence interval is now at the biomass trigger point.

The harvest rate by number, estimated as the proportion of the stock that has been fished (including dead discards), significantly increased from 2018 to 2019. Although in 2020 the harvest rate decreased again to between the values of 2017–2018, it remained above the $F_{MSYtrigger}$ and has increased again in 2021.

The turning point in abundance in 2019 coincided with the unusually high reported landings during that year. However, population biomass is also affected by reproductive success, in addition to fishing. Recruitment is affected by many environmental factors and has so far not been assessed for this stock.

11.4.13 Management considerations

The WG, ACFM and STECF have repeatedly advised that management should be at a smaller scale than the ICES Subarea 4 level, and management at the functional unit level could provide the controls to ensure that catch opportunities and effort were compatible and in line with the scale of the resource.

Catches generally have been well above ICES advice in Farn Deeps, highlighting the issue that current management arrangements are not sufficient to contain the fishery within the sustainable limits determined by ICES, and that management should be implemented at the functional unit level.

It is expected that, under the EU landing obligation, below minimum size individuals that would formerly have been discarded would now be reported as below minimum size (BMS) landings in logbooks. However, BMS landings reported to ICES may be lower than expected for several reasons: minimum size individuals could either not have been landed and not recorded in logbooks, or have been landed but not recorded as BMS. Furthermore, BMS landings recorded in logbooks may not have been reported to ICES. Only insignificant amounts of *Nephrops* (463 kg in 2020, on the order of one permille of the reported discards) were recorded as below MCRS (BMS category) in FU 6, despite catches having been observed below the MCRS.

11.5 Fladen Ground (FU 7)

11.5.1 Ecosystem aspects

The Fladen Ground (Functional Unit 7) is located towards the centre of the Northern North Sea off the east coast of Scotland (Figure 10.1.1). This region is characterised by an extensive area of mud and muddy sand, and hydrographic conditions include a large-scale seasonal gyre which develops in the late spring over a dome of colder water.

Owing to its burrowing behaviour, the distribution of *Nephrops* is restricted to areas of mud, sandy mud and muddy sand. Within the Fladen Ground FU these substrates are distributed more or less continuously over a very large area (approx. 30 000 km^2). Figure 11.5.5 shows the distribution of sediment in the area. Sandy mud and muddy sand are the dominant sediment types, with patches of mud in the south west area of the FU. Numerous fish species occur in the same area as *Nephrops* with demersal fish more prevalent in the northern area. In the softest areas of mud, *Pandalus borealis* is also found.

11.5.2 The Fishery in 2021

The *Nephrops* fishery at Fladen is the largest in the North Sea and is mainly prosecuted by UK (Scotland) vessels (total landings of 9559 tonnes in 2021), with Denmark taking 80 tonnes, and England 2 tonnes (Table 11.5.1). Around 90 vessels participated in the Fladen fishery at various times throughout the year. The majority are Scottish vessels fishing out of and landing to Fraserburgh and Peterhead. Catch consisted of *Nephrops*, haddock, whiting, cod, monkfish and megrim. A number of vessels have installed freezer capabilities to enable longer trips, but the average trip is around seven days. The fishery is seasonal and the fleet nomadic, moving between Fladen, Moray Firth, Firth of Forth, Devil's Hole, Farn Deeps and west coast of Scotland according with the time of the year and catch rates. Some vessels spent time fishing in the Farne Deeps (FU 6) and Devil's Hole (FU 34). The Covid-19 pandemic had a significant impact in the 2020 *Nephrops* fishing season with vessels having to deal with strict requirements from shellfish processors (buyers) in terms of amounts landed, grade sizes and demand abroad. These restrictions were not observed in 2021 and the fishery resumed its normal activity with a clear increase in landings. Most vessels fishing in FU 7 traditionally have used twin rigs with 80/90 mm mesh.

Recently, to reduce catches of whitefish (e.g. cod), mandatory measures implied that any vessel using gear with a mesh size of less than 100 mm (TR2) in Area 4.a in the North Sea must fish exclusively with any of the Highly Selective Gears (HSGs). Examples of these are the Gamrie Bay Trawl or Faithlie Cod Avoidance Panel. This made the majority of the fleet to switch to TR1 gears with mesh size combinations of 100–109 mm/120 mm, as they can target both *Nephrops* and fish. This confirms the information on the TR1/TR2 split which shows that in recent years, vessels fishing in Fladen have become more dual purpose in the sense that the large majority are now using larger mesh sizes and no longer solely dependent on *Nephrops*. This implies that these vessels have to buy both quota and days. Further general information on the fishery can be found in the Stock Annex.

11.5.3 Advice in 2021

The ICES advice in 2021 (for 2022) (Single-stock exploitation boundaries) was as follows:

MSY approach

"ICES advises that when the MSY approach is applied, and assuming that discard rates and fishery selection patterns do not change from the average of the years 2018–2020, catches in 2022 should be no more than 14 803 tonnes.

To ensure that the stock in Functional Unit (FU) 7 is exploited sustainably, management should be implemented at the functional unit level. The catch in FU 7 has been lower than advised in recent years, and if the difference is transferred to other FUs, this could result in non-precautionary exploitation of those FUs.

ICES notes the existence of a management plan, developed and adopted by one of the relevant management authorities for Subarea 4. ICES considers this plan to be precautionary when implemented at the functional unit level."

11.5.4 Management

Total Allowable Catch (TAC) management is at the ICES Subarea level. Historically most *Nephrops* vessels used to operate TR2 gears (≥ 70 and < 100 mm) which were subject to the effort regulations of the cod recovery plan. In recent year there has been a shift to using TR1 gears in Fladen allowing vessels to target *Nephrops* and fish simultaneously.

11.5.5 Assessment

Approach in 2022

The assessment of *Nephrops* in 2022 is based on examining trends in the UWTV survey data (1992–2021) and utilising an extensive series of commercial fishery data and follows the process defined by the benchmark WG 2009. The assessment approach is further described in the stock annex.

The provision of advice in 2022 followed the process of 2021, and attempts to incorporate decisions taken at WKFRAME (2010) for the provision of MSY advice. The approach was developed based on inter-sessional work carried out by participants of the benchmark and involved collaboration between WGNSSK and WGCSE. The UWTV based assessments have derived predicted landings by applying a harvest rate approach to populations described in terms of length compositions from the trawl component of the fishery. Considerations for setting Harvest Ratios (HR) associated with proxies for F_{MSY} for *Nephrops* are described in the WGNSSK 2010 report.

It was decided by ICES prior to the 2022 WG meeting that the advice for North Sea *Nephrops* stocks would be delayed until autumn after the summer surveys. The assessment presented in this report was concluded in September 2022 and incorporates the most recent *Nephrops* UWTV survey (2022).

11.5.6 Data available

Commercial catch and effort data

Landings from this fishery are predominantly reported from Scotland, with small contributions from Denmark and England, and are presented in Table 11.5.1 and Figure 11.5.1. Total international landings (as reported to the WG) in 2021 were 9559 tonnes (72% increase in comparison with the 2020 total), consisting mostly of Scottish landings with 82 tonnes landed by other countries (England and Denmark). *Nephrops* is one of the species in the North Sea under the landing obligation. No landings below the minimum conservation reference size (BMS) or logbook registered discards were reported for FU 7 in 2021.

In previous years, concerns were expressed over the reliability of the effort figures provided for Scottish *Nephrops* trawlers; effort figures were unrealistically low in some areas, particularly Fladen. Investigation of the issue revealed a problem in the MSS Marine Laboratory database, where only the effort expended in the first statistical rectangle visited by a vessel during a trip was being output. This did not affect landings. An extraction of effort data by the Marine Scotland data unit in Edinburgh covering the four main trawl gears landing *Nephrops* into Scotland produced higher Figures which capture all the effort. At the present time, these revised data cover the period 2000 to 2021 and only annual summaries are available.

Trends in Scottish effort of *Nephrops* trawlers and LPUE are shown in Figure 11.5.1 and Table 11.5.2. From 2015, effort data for this stock is expressed both in days fishing and kW days (there are no major differences in effort trends between those different units). Effort has been relatively stable from 2002 to 2010 but fell markedly in 2011–2012 because of poor fishing and part the fleet relocating to other areas. The spatial contraction of the fishery was further confirmed by the VMS distribution of otter trawlers fishing in Fladen (2010–2021) shown in Figure 11.5.8. In this period, a decreasing number of trips have been taking place in FU 7 and in 2015-2017, the south of the ground was the area where most fishing took place. From 2018, vessels seem to have returned to the northern areas of the Fladen grounds (Figure 11.5.8). In 2021 there was a slight increase in effort for Scottish trawlers. LPUE has gradually increased since 2000 to a peak of over 620 kg/day in 2009. It has fallen since then until 2015 to values similar to those observed in the early 2000s (~200 kg/day). In 2019, the Scottish LPUE increased markedly and is currently at a similar level to that observed in the late 2010s. Danish LPUE data (1991–2021) are presented in Table 11.5.3. Effort has generally decreased over the time whilst LPUE has gradually increased to its highest value in 2009 followed by a dramatic decrease as *Nephrops* became mostly a bycatch species for the Danish fleet in recent years. In 2021, the Danish LPUE showed a marked increase to 0.3 kg/kwd. This is in agreement with the trend observed in the Scottish LPUE which also seems to support a higher availability of *Nephrops* in the Fladen grounds.

Males consistently make the largest contribution to the landings (Figure 11.5.2). This is likely to be due to the varying seasonal pattern in the fishery and associated relative catchability (due to different burrow emergence behaviour) of male and female *Nephrops*. This is confirmed by the quarterly landings as shown in Figure 11.5.2. From 2012, landings were generally lower in the second quarter of the year, a period when females would be expected to be more available for capture. In recent years landings were larger in the third and fourth quarters although quarter 1 in 2021 was relatively higher than what has been observed in the last five years. Figure 11.5.7 shows the quarterly sex ratio by number from 2000. The seasonality of *Nephrops* emergency behaviour is apparent with males dominating catches, in particular during winter time (quarters 1 and 4). In quarters 2 and 3, females become more active and are more available to the fishery, although in FU 7 (unlike FU 8 and 9) the sex ratio is less seasonal and male percentages in catches (by number) have varied between 40–80%. In 2013–2016 the male proportion in quarter 2 was higher than previously observed. This may have been related with sampling noise associated with the recent decrease in landings (and sampling opportunities) in that quarter. Sex ratio data does not seem to show an overall increase of female proportion in catches in the time series, except for the period 2013–2015 where male percentage in catches decreased to less than 50%. Increased female catchability has been associated with stocks which are in a poor state (females may remain more active as they have been unable to mate due to lack of males in the population). It is unclear if this was the case in FU 7 but sex ratio monitoring in catches will continue to inform on potential shifts in the balance of the population.

Discarding of undersized and unwanted *Nephrops* has occurred in this fishery, and quarterly discard sampling has been conducted on the Scottish *Nephrops* trawler fleet since 2000. In 2021 due to the Covid-19 pandemic and the suspension of the on-board observer programme, discards were not sampled in quarter 1. The discarding rate average from 2000 is approximately 6% by number in this FU. From 2011 to 2016, discard rates dropped below the long-term average and were close to zero. This reduction in discard rate appears to be due to a change in the discard pattern with lower numbers of small individuals being caught and could also signal reduced recruitment and a tendency towards the use of larger mesh gears (see below on length compositions). From 2017 catches increased in FU 7 but discarding remained at a relatively low level. The discard rate in 2021 was estimated at 1.7% by number.

It is likely that some *Nephrops* survive the discarding process. An estimate of 25% survival has been assumed in order to calculate dead removals (landings + dead discards) from the population.

Intercatch

Scottish 2021 data (official landings and sampled data for landings and discards) were successfully uploaded into Intercatch. National data co-ordinators for other countries (England and Denmark) also uploaded landings data to Intercatch ahead of the 2022 WG. Output data for landings and discards were produced and extracted following the same raising procedure used in previous years to obtain length compositions in formats suitable for running the assessment. In 2021 there were no discard data imported for quarter 1. Discard rates and allocations for length frequencies in quarter 1 were based in the available data for quarter 4. No BMS or logbook registered discard data were reported for this FU in 2021. Since 2017, observer sampling from the Scottish-Science observer sampling scheme was extended to include *Nephrops* catches in FU 7. In 2021, all discard sampling data available for this FU were collected by industry observers.

Length compositions

Length compositions of landings and discards are obtained during monthly market sampling and quarterly on-board observer sampling respectively. Although assessments based on detailed catch data analysis are not presently possible for this species, examination of length compositions can provide a preliminary indication of exploitation effects.

Figure 11.5.3 shows a series of annual length frequency distributions for the period 2000 to 2021. Catch (removals) length compositions are shown for each sex with the mean catch and landings lengths shown in relation to MLS (25 mm) and 35 mm. In both sexes, the mean sizes have been generally stable over time until 2011 when a noticeable shift in the length distribution and an increase in the mean size has been observed for males and to a lesser extent, females. In 2017, length distributions in both sexes showed a marked decrease in the mean size in catches to similar values as those observed prior to 2011. In 2021, length distributions were generally similar to 2017–2020. In 2018 and 2020, a second peak (mode) was detected in the length distribution of females, implying possibly a large cohort moving through the population. Figure 11.5.1 and Table 11.5.4 show the series of mean sizes of larger *Nephrops* (>35 mm) in the landings. This parameter might be expected to reduce in size if overexploitation were taking place but there is no evidence of this. The mean size of smaller animals (<35 mm) in the catch is fairly stable through time until 2010 when an increase is noticeable which may be associated with lower recruitments combined with the increasing use of more selective gears. In 2017, the mean size in catches <35 mm decreased sharply followed by an increase in 2018–2021 and is now around 31 mm CL for females and 32 mm CL for males. The discard rate in 2021 was estimated to have decreased from the 2017 high value (4.4%) and is now 1.7% by number. Quantitative information on trends in gear changes is not currently available but a shift from TR2 to TR1 gears was observed from 2010. No major gear changes were noted in recent years suggesting the current reduced mean sizes in catches may be related with a strong recruitment in 2016–2017. A further difficulty in the interpretation of these size observations is that the ground extends over a wide area and the distributional pattern of fleet activity is known to vary over time. This may lead to exploitation of subareas within the ground, where size compositions may be slightly different.

Mean weights in the landings through time (1990–2021) are shown in Figure 11.5.4 and Table 11.5.5. The variability in mean size is greater in FU 7 (and FU 34) than in other areas. In 2021, the mean weight in landings remained stable at approximately 36 g and were similar to the values observed in the early 2010's.

Natural mortality, maturity at age and other biological parameters

Biological parameter values are included in the Stock Annex.

Research vessel data

Underwater TV (UWTV) surveys using a stratified random design are available for FU 7 since 1992 (missing survey in 1996). UWTV surveys of *Nephrops* burrow density and distribution reduces the problems associated with traditional trawl surveys that arise from variability in burrow emergence of *Nephrops*.

The numbers of valid stations used in the final analysis in each year are shown in Table 11.5.6. On average, approximately 66 stations have been considered valid each year. There were 70 stations completed in the 2022. Data are raised to a stock area of 28 153 km^2 based on the stratification (by sediment type). General analysis methods for UWTV survey data are similar for each of the Scottish surveys, and are described in more detail in the Stock Annex.

Previous review groups have noted that the UWTV survey did not cover the stock distribution. The survey stations are randomly distributed within strata and therefore the actual location of the survey stations varies from year to year and in some years, particular regions of the main part of the ground may not be surveyed. There is an additional small patch of mud to the north of the ground which it is not possible to survey (due to time constraints and distance to survey ground) and therefore the estimated absolute abundance is likely to be slightly underestimated by the UWTV survey.

11.5.7 Data analyses

Exploratory analyses of survey data

Table 11.5.7 shows the basic analysis (corrected to absolute values) for the three most recent UWTV surveys conducted in FU 7. The table includes estimates of abundance and variability in each of the strata adopted in the stratified random approach. The ground has a range of mud types from soft silty clays to coarser sandy muds (<40% silt and clay) and the latter predominates.

Most of the variance in the survey is associated with the coarse sediment which surrounds the main centres of abundance.

Figure 11.5.5 shows the distribution of stations in recent UWTV surveys (2011–2022) with the size of the symbol reflecting the *Nephrops* burrow density. The abundance in 2022 decreased 12% from 2021. Abundance is generally higher in the soft and intermediate sediments located to the centre and south east of the ground. Table 11.5.6 and Figure 11.5.6 show the time series estimated abundance for the UWTV surveys (U6028), with 95% confidence intervals on annual estimates. Following the low UWTV estimated densities in the period 2011–2015 and the apparent *Nephrops* fleet preference for the fishing grounds located to the south of Fladen (Figure 11.5.8), the WG looked closely at the spatial distribution of the UWTV survey in the last decade. It was suggested (as a hypothesis) that the north of the ground has been more affected by the recent decline (from 2009) in abundance than the areas in the south where most fishing took place in recent years. The TV surveys from 2009–2022 were re-worked by sediment type, splitting the ground in two areas, north and south of the 58.75 N latitude line. Results seem to support that the areas mostly affected by the fluctuations in the mean *Nephrops* burrow density from 2009 were in fact located in the south, especially those made of finer sediments located in the central south region (Figure 11.5.9). In the north of Fladen, where coarser sediments (<40% silt and clay) dominate, a decrease in density was observed in the period 2011–2015 but to a lesser extent when compared with those in the south. This analysis also shows that even during the period of lowest abundance in FU 7, the mean densities in the south remain on average higher than those in the north. The density increase recorded from 2016 occurred across the different strata but is more evident in the three finer sediments (F, MF and MC) in the south and in the medium fine (MF) and medium coarse (MC) sediments in the north (Figure 11.5.9).

The use of the UWTV surveys for *Nephrops* in the provision of advice was extensively reviewed by WKNEPH (ICES, 2009). A number of potential biases were highlighted including those due to edge effects, species burrow misidentification and burrow occupancy. The cumulative bias correction factor estimated for FU 7 was 1.35 meaning that the raw UWTV survey is likely to overestimate *Nephrops* abundance by 35%. In order to convert the raw UWTV survey abundance to an absolute abundance the raw data are divided by 1.35.

Final assessment

The UWTV survey is again presented as the best available information on the Fladen *Nephrops* stock. This survey provides a fishery independent estimate of *Nephrops* abundance. At present it is not possible to extract any length or age structure information from the survey and it therefore only provides information on abundance over the area of the survey.

The latest UWTV survey data shows that the abundance has decreased 12% in 2022. The stock is above the average abundance over the time series and is well above the biomass trigger. The harvest ratio in 2021 (4.7%, calculated as dead removals/TV abundance) is below F_{MSY}. The effort by *Nephrops* trawlers and respective LPUE declined from 2010 until 2015 and this appears to be consistent with the abundance trends from the UWTV survey. The LPUE increased markedly in 2019 and is currently approximately at the same high level as recorded in 2011–2012. The low LPUEs observed prior to 2006 may be due the under-reporting of landings before the introduction of 'Buyers and Sellers' legislation. The relatively high LPUEs calculated for the period 2009–2011, after the stock have declined could also be explained by the fishing fleet targeting areas where the density of *Nephrops* is higher. The mean size of individuals >35 mm in the catch remains relatively stable. The discard rate in catches has increased and the mean size of individuals below 35 mm decreased in 2017. This suggests a period of lower recruitment between 2010 and 2015 followed by a strong recruitment event in 2016–2017. In 2019–2021, the observed recruitment pulse seems to be moving up in the length distributions as suggested by a decrease in the discard rate and an increase in the mean sizes of catches below 35 mm CL from 2017.

Historical Stock trends

The UWTV survey estimates of abundance for *Nephrops* in FU 7 suggest that the population has fluctuated over the 30-year period of the surveys. From 1997 to 2008, the abundance has generally increased and reached a peak of 7360 million individuals in 2008. The abundance has fallen subsequently and was below the $B_{trigger}$ in 2012 and 2015. In 2016–2017, the abundance continued to increase sharply from the lowest point in the time series. In 2022, the abundance remains at a relatively high level estimated to be 5550 million (Table 11.5.8).

Table 11.5.8 also shows the estimated harvest ratios from 1992–2021. These range from 1.4–10% over this period and are all below F_{MSY}. It is unlikely that prior to 2006, the estimated harvest ratios are representative of actual harvest ratios due to under-reporting of landings. In 2021, landings and abundance increased by 72% and 38% respectively, as such, the harvest ratio has increased slightly and was estimated to be at 4.7% (3.7% in 2020), well below the F_{MSY} proxy (7.5%).

In addition to the discard rate, Table 11.5.8 shows the dead discard rate which is the quantity of dead discards as a proportion (by number) of the removals (landings + dead discards). Discards were estimated to be 1.7% by number in 2021.

11.5.8 Recruitment estimates

Recruitment estimates from surveys are not available for this FU. However, the increase in mean size of small animals <35 mm (i.e. a lower proportion of small animals in this component of the catch) observed in recent years may be indicative of lower recruitments in the period 2010–2015. The recent increase in abundance suggests a good recruitment in 2016–2017.

11.5.9 MSY considerations

F_{MSY} proxies for *Nephrops* are obtained from the per-recruit analysis as documented in the WGNSSK 2015 report. The most recent analysis used 2012–2014 catch-at-length data, to account for the apparent changes in the discard pattern in this fishery. Length frequency data in Fladen have shifted towards larger animals since 2010 (see Section 11.5.5 and Figure 11.5.3) suggesting a different selection pattern in the fishery. In addition, the discard rate has shown generally a declining trend over the last 10 years due to a combination of low recruitments, a shift to larger meshes (TR1) and the increase in the use of the use of Highly Selective Gears for reducing fish bycatch. The biological parameters used in the analysis can be found in the Stock Annex. The complete range of the per-recruit F_{MSY} proxies is given in the table below and the basis for choosing an appropriate F_{MSY} proxy remains the same and is described in WGNSSK 2010 report.

WGNSSK 2015		**F_{bar}(20–40 mm)**		**HR (%)**	**SpR (%)**		
		M	**F**		**M**	**F**	**T**
$F_{0.1}$	M	0.07	0.07	6.4	47.4	58.3	51.9
	F	0.14	0.15	10.6	33.3	40.8	36.4
	T	0.08	0.09	7.5	43.0	53.1	47.2
F_{max}	M	0.21	0.22	13.8	26.6	31.6	28.7
	F	0.44	0.46	21.2	17.5	18.7	18.0
	T	0.27	0.29	16.4	22.8	26.1	24.2
$F_{35\%SpR}$	M	0.13	0.13	10.0	34.8	42.9	38.1
	F	0.18	0.19	12.6	29.0	34.9	31.4
	T	0.15	0.16	11.2	31.9	39.0	34.8

*** M = males, F = females, T = combined**

For this FU, the absolute density observed on the UWTV survey remains low (average just below 0.2 m^{-2}) suggesting the stock may have low productivity. In addition, the expansion of the fishery in this area is a relatively recent phenomenon and as a result the population has not been well-studied and biological parameters are considered particularly uncertain. Furthermore, historical harvest ratios in this FU have been below that equivalent to fishing at $F_{0.1}$. For these reasons, it is suggested that a conservative proxy is chosen for F_{MSY} such as $F_{0.1(T)}$.

The F_{MSY} proxy harvest ratio is 7.5%.

The $B_{trigger}$ point for this FU (lowest observed absolute UWTV abundance, 1992–2010) is calculated as 2767 million individuals.

11.5.10 Short-term forecasts

A catch prediction for 2023 was made for the Fladen Ground (FU 7) using the approach agreed at the Benchmark Workshop in 2009 and outlined in the introductory section of the 2010 WGNSSK report. The table below shows catch predictions at various harvest ratios, including a selection of those equivalent to the per-recruit reference points discussed in Section 11.5.9 of this report and the harvest ratio in 2021 using the input parameters agreed at WKNEPH (ICES, 2009). The catch prediction is calculated following the procedure outlined in the stock annex (section: short term projections).

To account for the landing obligation coming into force for *Nephrops* in 2016, the projected amount of discards (now referred to as projected discards) have been added to the catch options table. The advice given in 2022 considers that *Nephrops* discarding is allowed to continue as in previous years. Under this scenario the harvest rate is assumed to include landings (projected landings) plus dead discards (Projected dead discards). The catch options table includes projected surviving discards (discards survival for *Nephrops* in FU 7 is assumed to be 25%). Projected discards (by number) are calculated using data from the on-board observer sampling programme. This value is multiplied by the mean weight in discards to obtain the projected discard weight. There is a *de minimis* exemption in place for *Nephrops* in the UK waters of the North Sea (ICES division 2.a and Subarea 4) with certain gears. The forecast includes an extra catch options table assuming a discard ban for 2023. The main difference in this scenario is that there is no survival assumed for the projected discards.

The advice for Category 1 stocks (where assessment includes landings and discards data) is based on catches. The prediction for 2023 is that catches should be no more than 13679 tonnes, assuming recent discard rates. This represents a 7.6% decrease from the advice given for 2022. It should be noted that the F_{MSY} proxy harvest ratio for Fladen is based on a combined Length Cohort Analysis (data 2012–2014) using dead removals (landings + dead discards). A discussion of F_{MSY} reference points for *Nephrops* is provided in Section 11.5.9.

The inputs to the landings forecast were as follows:

FU 7 basis for the catch options

Variable	Value	Notes
Stock abundance (2023)	5550	Underwater TV (UWTV) survey 2022; individuals in millions
Mean weight in projected landings	33.08	Average 2019-2021; grammes
Mean weight in projected discards	12.75	Average 2019-2021; grammes
Projected total discard rate	1.80	Average 2019-2021; percentage by number of the total catch
Discard survival rate	25	Percentage by number of the discards

Catch scenarios assuming recent discard rates

Basis	Total catch	Dead removals	Projected landings	Projected dead discards	Projected surviving discards	Harvest rate * for PL+PDD	% advice change **
	PL + PDD + PSD	PL + PDD	PL	PDD	PSD		
ICES advice basis							
MSY approach	13679	13655	13583	72	24	7.5	-7.6
Other scenarios							
$F_{2019–2021}$	8390	8375	8331	44	15	4.6	-43
F_{2021}	8530	8515	8470	45	15	4.7	-42
F_{MSY} lower	12037	12016	11953	63	21	6.6	-18.7
F_{MSY} upper***	13679	13655	13583	72	24	7.5	-7.6
$F_{35\%SpR}$	20427	20391	20284	107	36	11.2	38
F_{max}	29910	29858	29701	157	52	16.4	102

Catch scenarios assuming zero discards

Basis	Total catch	Projected landings	Projected discards ^	Harvest rate * for PL + PD	% advice change **
	PL + PD	PL	PD		
ICES advice basis					
MSY approach	13618	13522	96	7.5	-8.0%
Other scenarios					
$F_{2019–2021}$	8352	8293	59	4.6	-44%
F_{2021}	8492	8432	60	4.7	-43%
F_{MSY} lower	11983	11899	84	6.6	-19.1%
F_{MSY} upper***	13618	13522	96	7.5	-8.0%
$F_{35\%SpR}$	20335	20192	143	11.2	37%
F_{max}	29776	29567	209	16.4	101%

^ Represents the amount that otherwise would have been discarded but is now landed under the landing obligation.
*** Calculated for dead removals.**
**** Advice basis values for 2023 relative to the 2022 advice values (14803 tonnes).**
***** $F_{MSY\ upper}$ = F_{MSY} for this stock.**

Biological Reference points

Biological reference points have not been defined for this stock.

11.5.11 Quality of assessment

The length and sex composition of the landings data is considered to be well sampled. Discard sampling has been conducted on a quarterly basis for Scottish *Nephrops* trawlers in this fishery since 2000, and is considered to represent the fishery adequately. Discard sampling in 2020-2021 was impacted by the Covid-19 pandemic and there were some missing samples (quarters 2 and 3 in 2020 and quarter 1 in 2021). The proportion of landings with discards associated (same strata) is 71% in 2021 (71% of the discards were imported and 29% were raised discards).

The quality of landings (and catch) data is likely to have improved in recent years following the implementation of 'the registration of buyers and sellers' legislation in the UK in 2006, but because of concerns over the accuracy of earlier years, the final assessment adopted is independent of official statistics.

Underwater TV surveys have been conducted for this stock since 1992, with a continuous annual series available since 1997. The number of valid stations in the survey has remained relatively stable throughout the time period. Confidence intervals are relatively small.

The UWTV survey is conducted over the main part of the ground, representing an area of around 28 200 km^2 of suitable mud substrate (the largest ground in Europe). The Fladen Functional Unit contains several patches of mud to the north of the ground which are fished, bringing the overall area of substrate to 30 633 km^2. This area is not surveyed but would add to the abundance estimate. The absolute abundance estimate for this ground is therefore likely to be underestimated by the current methodology.

The Fishers' North Sea stock survey suggests that moderate or high amounts of recruits were apparent in Area 1 (which Fladen FU lies largely within) in 2011 compared to 2009. The time series of perceived abundance in Area 1 increases up to 2011. Opinion on discards appears to be split fairly evenly between lower, higher and no change. There are no Fishers' North Sea survey data available for 2013–2021.

11.5.12 Status of the stock

The stock has declined in the period 2008–2015 to the lowest point in the time series, and increased in the following years with the current abundance being close to the highest value recorded in 2008. The stock abundance is well above the MSY $B_{trigger}$ level. Landings taken from this FU in 2021 (9559 tonnes) were lower than the 2020 total catch advice (for 2021) of 9579 tonnes. The harvest rate increased in 2021 (in relation to the previous year) to 4.7% but remains below F_{MSY}. Length frequencies in the caches have evolved towards larger animals, suggesting a selectivity change and/or lower recruitment in the period 2010–2015. In 2017, length distributions in catches showed a decrease in the mean size and discard rates (previously estimated to be zero) increased. In the last two years, there is again some evidence of larger animals in the length distributions with increases recorded in the mean size and mean weight of catches.

11.5.13 Management considerations

The WG, ACOM and STECF have repeatedly advised that management should be at a smaller scale than the ICES division level. Management implemented at the Functional Unit level could provide controls to ensure that catch opportunities and effort were in line with the scale of the resource and that other FUs do not suffer from displacement from unused catch options from this FU.

Nephrops fisheries have a bycatch of cod. The Scottish industry is implementing improved selectivity measures in gears which target *Nephrops* with a view to reducing unwanted by-catch of cod and other species.

The increase in abundance registered in recent years points to a high recruitment event. Most of these small individuals only became available to the fishery in 2017 given the increase in selectivity recently observed for this FU. The selectivity of the survey is >17 mm carapace length (CL), the current MCRS is 25 mm CL. This stock is considered to be lightly exploited, and the difference between advice and catches may be transferred to other FUs in the North Sea which could result in non-precautionary exploitation of those FUs.

This stock is under the landings obligation although there is a *de minimis* exemption in place for *Nephrops* in the UK waters of the North Sea (ICES division 2.a and Subarea 4) with certain gears, according to the Marine Management Organization (MMO, 2021). The exemption applies to catches of Norway lobster below the minimum conservation reference size, which shall not exceed 2% of the total annual catches of that species. In 2021, no *Nephrops* were recorded as below the minimum size (BMS) in FU 7. This is consistent with the discard rates estimated for this FU which have been low.

References:

MMO, 2021. Fishing gear requirements and Landing Obligation exemptions 2022. Applicable to the Nephrops Fishery in UK waters of the North Sea. Document No.: V1. Date of Issue: December 2021.

11.6 Firth of Forth (FU 8)

11.6.1 Ecosystem aspects

The Firth of Forth Functional Unit 8 is located in the south-west of the Northern North Sea and is an inshore ground just off the east coast of Scotland (Figure 10.1.1.). In common with other firths around the Scottish coast, the area is characterised by a wide entrance to seaward, narrowing towards the coast with river basins draining into the area. Sandy mud and muddy sand deposits are widespread throughout the area covering an area of 915 km^2, the coarsest muds being found offshore beyond the Isle of May.

Owing to its burrowing behaviour, the distribution of *Nephrops* is restricted to areas of mud, sandy mud and muddy sand. Figure 11.6.4 shows the distribution of sediment in the area. There is some evidence of *Nephrops* larval drift from grounds to the south of the area but most larvae appear to be produced locally and the population is characterised by high density and generally small size. Although this area was historically important for fish catches, this area has now declined and *Nephrops* is the main commercial species. The recruits of numerous demersal fish species occasionally aggregate in the area and small pelagics (sprat and juvenile herring) are seasonally abundant. Important seabird colonies occur in the area and the ‘Wee Bankie’ gravel area, important for sandeel is located further offshore to the north and east of the Firth.

11.6.2 The fishery in 2021

The *Nephrops* fishery in the Firth of Forth is dominated by UK (Scotland) vessels with low landings reported by other UK nations (Table 11.6.1). In recent years, around 40 vessels worked regularly in the Firth of Forth. Most vessels are under 12 m in length with about 10 in 12–15 m category and a few above 15 m. Engine power ranges from just under 100 kw to around the 300 kw. The trip length for most of the fleet is one day. In the winter, most vessels fish from around dawn till 16:00–19:00. In spring/summer, vessels switch to nights, working from around 19:00 to 07:00–10:00. The few larger vessels (over 15 m) fishing in FU 8, undertake trips of around 2–3 days. The overall number of boats operating varies seasonally as vessels move around the UK in response to varying catch rates. In recent years some large Fraserburgh boats, which usually operate in FU 7, moved into the area, fishing mostly to the east grounds of the Firth. Visitor boats come generally from the Northeast of Scotland (FU 7 and FU 9) in periods of poor fishing in those grounds but tend to land to harbours in the northeast of Scotland. A few English vessels also visited FU 8 with landings from the rest of UK estimated at 9 tonnes in 2021. The low market price for *Nephrops* was an issue faced by the fishery in 2020 when prices have, to an extent, crashed compared to previous years. In 2021 prices improved compared with 2020 and remained stable throughout the year. Fuel prices have been reported as similar to previous years. The predominant trawl gear mesh sizes are 80 mm and 95 mm with several vessels working with twin rigs. The fishery continues to be characterised by catches of small *Nephrops* which often leads to higher discard rates than in other east coast Functional Units. There were only 2 tonnes of *Nephrops* landings by creel vessels in FU 8 in 2021 – typically, the main target species of these vessels are crabs and lobsters.

Further general information on the fishery can be found in the Stock Annex.

11.6.3 Advice in 2021

The ICES advice in 2021 (for 2022) (Single-stock exploitation boundaries) was as follows:

MSY approach

"ICES advises that when the MSY approach is applied, and assuming that discard rates and fishery selection patterns do not change from the average of the years 2018–2020, catches in 2022 should be no more than 3216 tonnes.

To ensure that the stock in Functional Unit (FU) 8 is exploited sustainably, management should be implemented at the functional unit level.

ICES notes the existence of a management plan, developed and adopted by one of the relevant management authorities for Subarea 4. ICES considers this plan to be precautionary when implemented at the functional unit level."

11.6.4 Management

Management is at the ICES Subarea level as described in Section 10.1.

11.6.5 Assessment

Approach in 2022

The assessment in 2022 is based on a combination of examining trends in fishery indicators and underwater TV using an extensive data series for the Firth of Forth Ground FU 8. The assessment of *Nephrops* through the use of the UWTV survey data and other commercial fishery data follows the process defined by the benchmark WG 2009 and described in the stock annex.

The provision of advice in 2022 followed the process of 2021, and attempts to incorporate decisions taken at WKFRAME (2010) for the provision of MSY advice. The approach was developed based on inter-sessional work carried out by participants of the benchmark and involving collaboration between WGNSSK and WGCSE. The UWTV based assessments have derived predicted landings by applying a harvest rate approach to populations described in terms of length compositions from the trawl component of the fishery. Considerations for setting Harvest Ratios (HR) associated with proxies for F_{MSY} for *Nephrops* are described in the WGNSSK 2010 report.

It was decided by ICES prior to the 2022 WG meeting that the advice for North Sea *Nephrops* stocks would be delayed until autumn after the summer surveys. The assessment presented in this report was concluded in September 2022 and incorporates the most recent *Nephrops* UWTV survey (2022). The assessment presented in this report was re-run in September 2022 but it only incorporates survey data up to 2021 given the fact that a FU 8 Nephrops UWTV survey was not carried out in 2022. The 2021 survey was used in the catch forecasts for 2023.

Data available

Commercial catch and effort data

Landings from this fishery are predominantly reported from Scotland, with very small contributions from England, and are presented in Table 11.6.1 and Figure 11.6.1. Most of the landings are made by trawlers with creels generally accounting for less than 1% of the total (only 2 tonnes of creel landings were recorded in 2021). Reported landings rose from 1100 to over 2650 tonnes between 2003 and 2009 and have fluctuated since then around 2000 tonnes. The value for 2021 of 1835 tonnes represents a 3% increase from 2020 and is below the ten-year average (2130 tonnes). *Nephrops* is one of the species in the North Sea under the landing obligation. In 2021 there were 15 tonnes landed below the minimum conservation reference size (BMS) and no logbook registered discards were reported in FU 8.

In previous years, concerns were expressed over the reliability of the effort figures provided for Scottish *Nephrops* trawlers; effort Figures were unrealistically low in some areas. Investigation of the issue revealed a problem in the MSS Marine Laboratory database, where only the effort expended in the first statistical rectangle visited by a vessel during a trip was being output. This did not affect landings. An extraction of effort data by the Marine Scotland data unit in Edinburgh covering the 4 main trawl gears landing *Nephrops* into Scotland produced higher figures which capture all the effort. At the present time, these revised data cover the period 2000 to the present and only annual summaries are available.

Trends in Scottish effort and LPUE are shown in Figure 11.6.1 and Table 11.6.2. Effort data is expressed both in days fishing and kW days (only small differences in recent years are noticeable between these different units). Effort has shown a gradual decline over the time period. Some of this is recently attributable to the EU effort management regime although, as part of the Scottish conservation credits scheme, *Nephrops* vessels have been eligible for effort 'buy-backs'. LPUE rose in the early 2000s, stabilised at a relatively high level from 2006 to 2016 and increased again in recent years reaching the highest level of the time series in 2018.

Males consistently make the largest contribution to the landings by weight (Figure 11.6.2), although the sex ratio does vary. In 2011–2013, more females recorded in the catches moved the ratio closer to 1:1. This may be due to the changes in seasonal effort distribution in the late 2000s with greatest effort in the 3rd quarter when females are likely to be more available to the fishery (compared with a more evenly distributed seasonal effort pattern in previous years, Figure 11.6.2). Figure 11.6.6 shows the quarterly sex ratio by number from 2000. The seasonality of *Nephrops* emergency behaviour is evident with males dominating catches during winter time. In quarters 2 and 3, females become more active and are more available to the fishery. These data suggest a gradual increase of female proportion in catches up to 2015, in particular during quarters 2 and 3. Increased female catchability has also been associated with stocks which are in a poor state (females may remain more active as they have been unable to mate due to lack of males in the population). This problem usually manifests itself at times of the year when females would normally be reduced in the catches. This does not appear to be the case here.

Discarding of undersized and unwanted *Nephrops* occurs in this fishery, and quarterly discard sampling has been conducted on the Scottish *Nephrops* trawler fleet since 1990. In 2021 due to the Covid-19 pandemic and the suspension of the on-board observer programme, discards were only sampled in quarter 4. Historically, discard rates have been higher in this stock than the more northerly North Sea FUs for which Scottish discard estimates are also available. This could arise from the fact that the use of larger meshed nets is not so prevalent in this fishery (80–95 mm is more common) and in addition, the population appears to consist of smaller individuals due to slower growth. Discarding rates in this FU have varied between 7% and 55% of the catch by number (2012–2021 average is 20%). In 2021, the discard rate was recorded at 13%. It is likely that some *Nephrops* survive the discarding process, an estimate of 25% survival is assumed in order to calculate dead removals (landings + dead discards) from the population.

InterCatch

Scottish 2021 data (official landings and sampled data for landings and discards) were successfully uploaded into InterCatch. National data co-ordinators for other countries (England) also uploaded landings data to InterCatch ahead of the 2022 WG. Output data for landings were produced and extracted following the same raising procedure used in previous years to obtain length compositions in formats suitable for running the assessment. In 2021 there were only discard data imported for quarter 4. Analyses were carried out to visualize the relationship between discard rates and season – this showed that discard rates in FU8 are highly variable with no clear seasonality patterns. As such, discard rates and allocations for length frequencies in quarters 1-3 were estimated as follows: calculations were performed to obtain the mean discard rate (and mean length frequency distributions for males and females separately) in the last 3 years (2017-2019) for quarters 1-3 (avQ1-3) and quarter 4 (avQ4); then, the 2021 discard rates for Q1-3 were estimated according with the formula: avQ1-3*(Q4_2021/avQ4). This results in a mean discard length distribution for each of quarters 1, 2 and 3 which is scaled to the 2021 Q4 estimate (the only available for 2021). Borrowing discard rates from previous years is not a feature allowed in Intercatch, as such the method described above was performed outside Intercatch. This procedure follows that which was implemented in the previous year with the difference being that in 2020 discards were only available for quarter 1. In 2021 there were 15 tonnes of BMS recorded but no logbook registered discard data reported for this FU.

Length compositions

Length compositions of landings and discards are obtained during monthly market sampling and quarterly on-board observer sampling respectively. Although assessments based on detailed annual catch data analysis are not presently possible, examination of length compositions may provide an indication of exploitation effects.

Figure 11.6.3 shows a series of annual length frequency distributions for the period 2000 to 2021. Size information on catches (removals) are shown for each sex with the mean catch and landings lengths shown in relation to MLS and 35 mm. There is little evidence of change in the mean size of either sex over time and examination of the tails of the distributions above 35 mm shows no evidence of reductions in relative numbers of larger animals.

The observation of relatively stable length compositions is further confirmed in the series of mean sizes of larger *Nephrops* (>35 mm) in the landings shown in Figure 11.6.1 and Table 11.6.3. This parameter might be expected to reduce in size if overexploitation were taking place but over the last 30 years has in fact been quite stable. The mean size in the catch in the <35 mm category (Figure 11.6.1) also shows no particular trend. There was a slight shift to the right in the length distributions in 2020, implying a higher relative number of large animals present in the catches (Figure 11.6.3). In 2021, the length distribution was very similar to that observed in 2019 and the previous 5 years. The observation of a larger mean size in landings in 2020 coincides with an increase in the mean size of animals below 35 mm (Figure 11.6.1) and a decrease in the discard rate. However, given the limited discard sampling in 2020 (only quarter 1 coverage) caution should be taken in the interpretation of these results and this does not necessarily imply clear recruitment changes in FU 8, particularly given that discard rates are known to be variable throughout the year. In 2021 the mean size below 35 mm decreased and is close to that observed in 2019.

Mean weight in the landings is shown in Figure 11.5.4 and Table 11.5.5 and this shows no systematic changes over the time series. The mean weight recorded for 2021 decreased from 2020 (28.8 g) and is currently estimated at 24.8 g.

Natural mortality, maturity at age and other biological parameters

Biological parameter values are included in the Stock Annex.

Research vessel data

Due to operational limitations the 2022 FU 8 UWTV survey was not carried out. TV surveys using a stratified random design are available for FU 8 since 1993 (missing surveys in 1995, 1997 and in the current year, 2022). Underwater television surveys of *Nephrops* burrow number and distribution, reduce the problems associated with traditional trawl surveys that arise from variability in burrow emergence of *Nephrops*.

The numbers of valid stations used in the final analysis in each year are shown in Table 11.6.4. On average, about 44 stations have been considered valid each year. In recent years the aim of the survey is to sample 50 stations. The last survey in FU 8 was completed in 2021, however, due to limitations related with the Covid-19 pandemic and the research vessel's availability, the 2021 survey was carried out in June (it is normally conducted in August) together with other Functional Units to the west of Scotland (FU 11, FU 12 and FU 13) and in the North Sea (FU 7, FU 9 and FU 34). Abundance data are raised to a stock area of 915 km^2. General analysis methods for underwater TV survey data are similar for each of the Scottish surveys, and are described in the Stock Annex.

A further non-surveyed area of sediment (Lunan Bay) exists just north of the Firth of Forth FU. There is a small *Nephrops* fishery in this area (off Arbroath), but the area is only surveyed on an irregular basis and therefore is not included in any estimates of abundance. The WG wishes to emphasise that this area is out-with the Firth of Forth functional unit, is considered as part of the 'other' North Sea *Nephrops* area and hence not further considered in this section.

Data analyses

Exploratory analyses of survey data

Table 11.6.5 shows the basic analysis for the three most recent TV surveys conducted in FU 8. The table includes estimates of abundance and variability in each of the strata adopted in the stratified random approach. The ground is predominantly of coarser muddy sand. Depending on the year, high variance in the survey is associated with different strata and there is no clear distributional or sedimentary pattern in this area. Densities observed in this FU are typically higher than those of the more northerly FUs in the North Sea.

Figure 11.6.4 shows the distribution of stations in TV surveys, with the size of the symbol reflecting the *Nephrops* burrow density. Abundance is currently higher towards the western parts of the ground and around the Isle of May. Table 11.6.4 and Figure 11.6.5 show the time series of estimated abundance for the TV surveys (U6028), with 95% confidence intervals on annual estimates. The use of the UWTV surveys for *Nephrops* in the provision of advice was extensively reviewed by WKNEPH (ICES, 2009). A number of potential issues were highlighted including those arising from edge effects, species burrow mis-identification and burrow occupancy. To take account of these effects, a cumulative correction factor of 1.18 was estimated for FU 8 and this is applied to raw counts in order to derive the absolute abundance.

Final assessment

The underwater TV survey is again presented as the best available information on the Firth of Forth *Nephrops* stock. This survey provides a fishery independent estimate of *Nephrops* abundance. At present it is not possible to extract any length or age structure information from the survey, and it therefore only provides information on abundance over the area of the survey.

The UWTV abundance was relatively high in the period 2003 to 2008 but has shown a decreasing trend in 2008–2014. The stock has increased again in recent years and in 2020 reached the highest point of the time series. The 2022 UWTV survey was not carried out, as such, the most recent abundance estimate available for this stock is from 2021(837 million). The stock is currently above the average abundance over the time series and remains well above the biomass trigger. The calculated harvest ratio in 2021 (dead removals/TV abundance) increased but continues to be below F_{MSY}. This is the result of a 25% decrease in stock abundance (in 2021) and landings in 2021 remaining at approximately the same level in relation to 2020. The mean size of individuals >35 mm in the catch shows no strong trend in recent years. The mean size of individuals below 35 mm has shown an increasing trend since 2009. Larger square mesh panels and new, more selective TR2 gears implemented from 2010 as part of the Scottish Conservation Credits scheme may have improved the exploitation pattern. The effect of these changes are not however, as evident as those observed in FU 7 and generally with the exception of 2020, length frequencies in recent years remain relatively stable in the Firth of Forth.

11.6.6 Historical stock trends

The TV survey estimate of abundance for *Nephrops* in the Firth of Forth suggests that the population decreased between 1993 and 1998 and then began a steady increase up to 2008 followed by a further decrease until 2014. Abundance is estimated to have increased in the years since then. The abundance estimates from 1993–2021 are shown in Table 11.6.6. The stock is currently estimated to consist of 837 million individuals.

Table 11.6.6 also shows the estimated harvest ratios over this period. From 2003 (the period over which the survey estimates have been revised) these range from 6–29% with the upper range being the value for 2014 (estimated harvest ratios prior to 2006 may not be representative of actual harvest ratios due to under-reporting of landings before the introduction of ‘Buyers and Sellers’ legislation). The estimated harvest rate in 2021 is 10.8% which has increased from the 2020 value (6.1%, the lowest harvest rate in the time series) but is still below the estimated value at F_{MSY} (16.3%).

In addition to the discard rate, Table 11.6.6 also shows the dead discard rate which is calculated as the quantity of dead discards as a proportion (by number) of the removals (landings + dead discards).

11.6.7 Recruitment estimates

Survey recruitment estimates are not available for this stock.

11.6.8 MSY considerations

A number of potential F_{MSY} proxies were obtained from the per-recruit analysis for *Nephrops* as documented in the WGNSSK 2010 report. The most recent analysis (in 2011) used 2008–2010 catch-at-length data, to account for the apparent changes in the discard pattern in this fishery. The biological parameters used in the analysis can be found in the Stock Annex. The complete range of the per-recruit F_{MSY} proxies is given in the table below and the process for choosing an appropriate F_{MSY} proxy is described in WGNSSK 2010 report.

WGNSSK 2011		F_{bar}(20–40 mm)		HR (%)	SpR (%)		
		M	F		M	F	T
F0.1	M	0.14	0.06	7.7	40.8	62.3	49.9
	F	0.31	0.13	15.2	20.5	40.7	29
	T	0.17	0.07	9.4	34.6	56.6	43.9
Fmax	M	0.25	0.11	12.7	25.3	46.8	34.4
	F	0.64	0.28	26.7	9.1	22.9	14.9
	T	0.34	0.14	16.3	18.8	38.5	27.1
F35%SpR	M	0.17	0.07	9.4	34.6	56.6	43.9
	F	0.39	0.17	18.3	16	34.5	23.9
	T	0.25	0.11	12.7	25.3	46.8	34.4

For this FU, the absolute density observed in the UWTV survey is relatively high (average of ~ 0.7 m^{-2}). Harvest ratios (which are likely to have been underestimated prior to 2006) have mostly been well above F_{max} and in addition there is a long time series of relatively stable landings (average reported landings ~ 2000 tonnes, well above those predicted by currently fishing at F_{max}) suggesting a productive stock. For these reasons, it is suggested that the sexes combined $F_{max(T)}$ is chosen as the F_{MSY} proxy.

The F_{MSY} proxy harvest ratio is 16.3%.

The $B_{trigger}$ point for this FU (lowest observed absolute UWTV abundance) is calculated as 292 million individuals.

11.6.9 Short-term forecasts

A catch prediction for 2023 was made for the Firth of Forth (FU 8) using the approach agreed at the Benchmark Workshop in 2009 and outlined in the introductory section of the 2010 WGNSSK report. The table below shows catch predictions at various harvest ratios, including a selection of those equivalent to the per-recruit reference points discussed in Section 11.7.8 of this report and the harvest ratio in 2020 using the input parameters agreed at WKNEPH (ICES, 2009). The catch prediction is calculated following the procedure outlined in the stock annex (section: short term projections).

Recently, to account for the landings obligation coming into force for *Nephrops* in 2016, the projected amount of discards (now referred to as projected discards) have been added to the catch options table. The advice given in 2022 considers that *Nephrops* discarding is allowed to continue as in previous years. Under this scenario the harvest rate is assumed to include landings (projected landings) plus dead discards (Projected dead discards). The catch options table includes projected surviving discards (discards survival for *Nephrops* in FU 8 is assumed to be 25%). Projected discards (by number) are calculated using data from the on-board observer sampling programme. This value is multiplied by the mean weight in discards to obtain the projected discard weight. There is a *de minimis* exemption in place for *Nephrops* in the UK waters of the North Sea (ICES division 2.a and Subarea 4) with certain gears. The forecast includes an extra catch options table assuming a discard ban for 2023. The main difference in this scenario is that there is no survival assumed for the projected discards.

The advice for Category 1 stocks (where assessment includes landings and discards data) is based on catches. There was no survey carried out for the Firth of Forth in 2022, as such, the 2021 value was used as the most recent abundance estimate in FU 8. The prediction for 2023 is that catches should be no more than 3201 tonnes, assuming recent discard rates. This represents a

0.5% decrease from the advice given for 2022. It should be noted that the F_{MSY} proxy harvest ratio in the Firth of Forth is still based on a combined Length Cohort Analysis (data 2008–2010) using dead removals (landings + dead discards). A discussion of F_{MSY} reference points for *Nephrops* is provided in Section 11.7.8.

The inputs to the landings forecast were as follows:

FU 8 basis for the catch options

Variable	Value	Notes
Stock abundance (2023)	837	Underwater TV (UWTV) survey 2021 (no survey available in 2022); millions
Mean weight in projected landings	24.78	Average 2019-2021; grammes
Mean weight in projected discards	10.09	Average 2019-2021; grammes
Projected total discard rate	14.9	Average 2019-2021; percentage by number of the total catch
Discard survival rate	25	Percentage by number of the discards

Catch scenarios assuming recent discard rates

Basis	Total catch PL + PDD + PSD	Dead removals PL + PDD	Projected landings PL	Projected dead discards PDD	Projected surviving discards PSD	Harvest rate * for PL+PDD	% advice change **
ICES advice basis							
MSY approach	3201	3148	2988	160	53	16.3	-0.47
Other scenarios							
$F_{0.1}$	1846	1815	1723	92	31	9.4	-43
F_{MSY} lower	2082	2047	1943	104	35	10.6	-35
F_{2021}	2123	2088	1982	106	35	10.8	-34
$F_{2019–2021}$	2298	2260	2145	115	38	11.7	-29
$F_{35\%SpR}$	2493	2452	2328	124	41	12.7	-22
F_{MSY} upper***	3201	3148	2988	160	53	16.3	-0.47

Catch scenarios assuming zero discards

Basis	Total catch PL + PD	Projected landings PL	Projected discards ^ PD	Harvest rate * for PL + PD	% advice change **
ICES advice basis					
MSY approach	3082	2877	205	16.3	-4.2
Other scenarios					
$F_{0.1}$	1777	1659	118	9.4	-45
F_{MSY} lower	2004	1871	133	10.6	-38
F_{2021}	2044	1908	136	10.8	-36
$F_{2019–2021}$	2212	2065	147	11.7	-31
$F_{35\%SpR}$	2402	2242	160	12.7	-25
F_{MSY} upper***	3082	2877	205	16.3	-4.2

^ Represents the amount that otherwise would have been discarded but is now landed under the landing obligation.

*** Calculated for dead removals.**

**** Advice basis values for 2023 relative to the 2022 advice values (3216 tonnes).**

***** $F_{MSY\ upper}$ = F_{MSY} for this stock.**

Biological Reference points

Biological reference points have not been defined for this stock.

11.6.10 Quality of assessment

There were no UWTV survey data available for FU 8 in 2022, therefore the stock size indicator is unknown for 2022. The assessment and advice were based on the 2021 UWTV survey along with 2019-2021 catch mean weights and discard rates. UWTV surveys have been conducted for this stock since 1993, with a continual annual series available between 1998 and 2021. The number of valid stations in the survey has remained relatively stable throughout the time period.

The length and sex composition of the landings data is considered to be well sampled. Discard sampling has been conducted on a quarterly basis for Scottish *Nephrops* trawlers in this fishery since 1990, and is considered to represent the fishery adequately. Discard sampling in 2020-2021 was impacted by the Covid-19 pandemic and only samples for quarter 1 (2020) and quarter 4 (2021) were available with discard rates and length distribution for the missing quarters being borrowed from years 2017–2019. The proportion of landings with discards associated (same strata) is 27% in 2021 (27% of the discards were imported and 73% were raised discards).

There are concerns over the accuracy of historical landings (pre-2006) due to misreporting and because of this the final assessment adopted is independent of officially reported data.

The Fishers' North Sea Stock survey does not include specific information for the Firth of Forth. Area 3 shows a perception of decreased abundance over the period 2007–2012, but this covers the Firth of Forth and parts of the Devil's Hole in addition to the Moray Firth. There are no Fishers' North Sea survey data available for 2013–2021.

11.6.11 Status of the stock

The stock has shown an increasing trend since 2014 and is above the average abundance and well above the MSY $B_{trigger}$ level. The abundance value calculated for 2021 is 837 million. Landings taken from this FU in 2021 (1835 tonnes) were lower than the 2020 total catch advice (for 2021) of 3931 tonnes. The harvest rate increased in 2021 to 10.8% (a combination of a decrease in stock abundance and stable landings in 2021) but remains below F_{MSY}. Length frequencies in the catches have been relatively stable.

11.6.12 Management considerations

Catches in 2018 increased to levels above ICES advice for 2018, highlighting the issue that current management arrangements are not sufficient to contain the fishery within the sustainable limits determined by ICES. The WG, ACOM and STECF have repeatedly advised that management should be at a smaller scale than the ICES Division level. Management at the Functional Unit level could provide the controls to ensure that catch opportunities and effort were compatible and in line with the scale of the resource.

Nephrops discard rates in this Functional Unit are relatively high in comparison to other Functional Units and there is a need to reduce these and to improve the exploitation pattern. An additional reason for suggesting improved selectivity in this area relates to bycatch. It is important that efforts are made to ensure that other fish are not taken as unwanted bycatch in this fishery which mainly uses 80 mm mesh. Larger square mesh panels and new, more selective TR2 gears should help to improve the exploitation pattern for some species such as haddock and whiting and small cod.

Although the persistently high estimated harvest rates in the past do not appear to have adversely affected the stock, in recent years they have occasionally been equivalent to fishing at a rate greater than F_{MSY} and therefore it would be unwise to allow effort to increase in this FU.

This stock is under the landings obligation although there is a *de minimis* exemption in place for *Nephrops* in the UK waters of the North Sea (ICES Division 2.a and Subarea 4) with certain gears, according to the Marine Management Organization (MMO, 2021). The exemption applies to catches of Norway lobster below the minimum conservation reference size, which shall not exceed 2% of the total annual catches of that species. In 2021, only 15 tonnes of *Nephrops* were recorded as below the minimum size (BMS) in FU 8 despite relatively high amounts of catches have been observed below the MCRS and this being a Functional unit that historically have shown high discard rates.

References:

MMO, 2021. Fishing gear requirements and Landing Obligation exemptions 2022. Applicable to the Nephrops Fishery in UK waters of the North Sea. Document No.: V1. Date of Issue: December 2021.

11.7 Moray Firth (FU 9)

11.7.1 Ecosystem aspects

The Moray Firth Functional Unit is located in the east of the Northern North Sea and is an inshore ground just off the east coast of Scotland (Figure 10.1.1). In common with other firths around the Scottish coast, the area is characterised by a wide entrance to seaward, narrowing towards the coast with river basins draining into the area. Muddy sand deposits are the most widespread sediment, particularly towards the outer areas of the Firth, with smaller areas of sandy mud. Overall the ground covers an area of 2195 km^2. In the inner parts of the Firth the sediment is patchier and there are several areas of sand and of gravel.

Owing to its burrowing behaviour, the distribution of *Nephrops* is restricted to areas of mud, sandy mud and muddy sand. Figure 11.7.4 shows the distribution of sediment in the area. It is thought that most larvae are produced locally although some drift from the Fladen may occur. The population is characterised by medium densities of *Nephrops*. Although the Moray Firth was historically important for whitefish fisheries, catches declined and *Nephrops* is the main commercial species with squid catches important in some years. The recruits of numerous demersal fish species occasionally aggregate in the area and small pelagics (sprat and juvenile herring) are seasonally abundant. The area is important for marine mammals (seals and cetaceans).

11.7.2 The fishery in 2021

The Moray Firth *Nephrops* fishery is essentially a Scottish fishery with only occasional landings made by vessels from elsewhere in the UK (Table 11.7.1). Vessels targeting this fishery typically conduct day trips from the nearby ports along the Moray Firth coast. Around 20–25 local vessels (all single riggers) regularly fish in Moray Firth area, mostly out of Burghead and Buckie. The majority of the Moray Firth fleet is under 10 m. Most vessels over 10 m are using 250 mm square mesh panels and reporting better catches than when they used HSGs. Square mesh panels of 160 mm and 200 mm were introduced for under 10 m vessels in the end of 2017. The fleet have been consistent in their grounds throughout the years, with smaller vessels fishing locally from Burghead and larger and more powerful vessels venturing further out. Occasionally larger vessels fish the outer Moray Firth grounds on their way to/from the Fladen or in times of poor weather. These larger twin riggers (typically over 15 m) fished in the outer areas of the Firth during the winter months and unlike the smaller local vessels, they can continue to operate in periods of poor weather. In 2012, a voluntary code of conduct for *Nephrops* trawlers (Moray Firth Prawn Agreement) has been agreed amongst fishermen for the Inner Moray Firth so as to protect the viability of smaller vessels based in the area. The agreement proposes that an area in the most westerly part of the Moray Firth be reserved for vessels under 300 HP with a further small area reserved for vessels under 400 HP. In 2020, *Nephrops* fleet had to deal with the effects of the Covid-19 pandemic. The majority of shellfish processors did not purchase *Nephrops* between April and May 2020, leaving the fleet tied up in this period. Markets returned to a more normal status in 2021 with no restrictions on landings imposed by buyers and a slight increase in *Nephrops* prices, although not to pre-Covid/Brexit levels. Anecdotal evidence suggests some bycatch of monkfish and haddock occurred but vessels under 10 m, which make most of the fleet, are generally limited by quota restrictions. *Nephrops* creeling in the Moray Firth is not common (only 4 tonnes landed in 2021) as grounds are in open water and gear conflicts with trawl vessels are likely to happen. A squid fishery took place as usual in the Moray Firth in the late summer, starting in the Southern Trench when squid moves inshore. The majority of the local fleet participated in the squid fishery between September and October, returning to *Nephrops* fishing in November. A number of vessels from other districts joined the Moray Firth *Nephrops* fishery towards the end of the year after the squid fishery season was over. Further general information on the fishery can be found in the Stock Annex.

11.7.3 Advice in 2021

The ICES advice in 2021 (for 2022) (Single-stock exploitation boundaries) was as follows:

MSY approach

"ICES advises that when the MSY approach is applied, and assuming that discard rates and fishery selection patterns do not change from the average of the years 2018–2020, catches in 2022 should be no more than 2062 tonnes.

To ensure that the stock in Functional Unit (FU) 9 is exploited sustainably, management should be implemented at the functional unit level.

ICES notes the existence of a management plan, developed and adopted by one of the relevant management authorities for Subarea 4. ICES considers this plan to be precautionary when implemented at the functional unit level."

11.7.4 Management

Management is at the ICES Subarea level as described in Section 10.1.

11.7.5 Assessment

Approach in 2021

The assessment in 2022 is based on a combination of examining trends in fishery indicators and UWTV using an extensive data series for the Moray Firth FU 9. The assessment of *Nephrops* through the use of the UWTV survey data and other commercial fishery data follows the process defined by the benchmark WG 2009 and described in the stock annex.

The provision of advice in 2022 followed the process of 2021, and attempts to incorporate decisions taken at WKFRAME (2010) for the provision of MSY advice. The approach was developed based on inter-sessional work carried out by participants of the benchmark and involved collaboration between WGNSSK and WGCSE. The UWTV based assessments have derived predicted landings by applying a harvest rate approach to populations described in terms of length compositions from the trawl component of the fishery. Considerations for setting Harvest Ratios (HR) associated with proxies for F_{MSY} for *Nephrops* are described in the WGNSSK 2010 report.

It was decided by ICES prior to the 2022 WG meeting that the advice for North Sea *Nephrops* stocks would be delayed until autumn after the summer surveys. The assessment presented in this report was concluded in September 2022 and incorporates the most recent *Nephrops* UWTV survey (2022).

Data available

Commercial catch and effort data

Landings from this fishery are predominantly reported from Scotland, with very small contributions from England, and are presented in Table 11.7.1. Total landings (as reported to the WG) in 2021 for Scotland were 1221 tonnes (an increase of 21% in relation to 2020). Landings in recent years (post 2006) are more reliable due to the introduction of 'buyers and sellers' legislation. The long-term landings trends are shown in Figure 11.7.1. *Nephrops* is one of the species in the North Sea under the landing obligation. No landings below the minimum conservation reference size (BMS) or logbook registered discards were reported for FU 9 in 2021.

In previous years, concerns were expressed over the reliability of the effort Figures provided for Scottish *Nephrops* trawlers; effort Figures were unrealistically low in some areas. Investigation of the issue revealed a problem in the MSS Marine Laboratory database, where only the effort expended in the first statistical rectangle visited by a vessel during a trip was being output. This did not affect landings. An extraction of effort data by the Marine Scotland data unit in Edinburgh covering the four main trawl gears landing *Nephrops* into Scotland produced higher figures which capture all the effort. At the present time, these revised data cover the period 2000 to the present and only annual summaries are available.

Trends in Scottish effort and LPUE are shown in Figure 11.7.1 and Table 11.7.2. From 2015, effort data for this stock is expressed both in days fishing and kW days (there are no major differences in effort trends between those different units). Effort has shown a gradual decline over the time period although an increase was recorded in 2017 to the same level as that estimated for the mid-2000s. Some of this is attributable to the EU effort management regime although *Nephrops* vessels have generally been allocated exemptions. LPUE rose in the early 2000s and since 2006 it has fluctuated. In 2021 there was a sharp increase in LPUE to the second highest value observed in the time series as a result of increasing landings and reduced effort.

Males generally make the largest contribution to the landings by weight (Figure 11.7.2), although in 2011 and 2015 the proportion of females was higher than in the recent past. In 2016–2021, males dominate again. The high contribution of females previously recorded appears to be due to a much higher proportion of the fishery taking place in the second and third quarter when females are more available. This observation has been made a number of times before in the Moray Firth (particularly for example in 1994 when female catches exceeded those of males). Figure 11.7.6 shows the quarterly sex ratio by number from 2000. The seasonality of *Nephrops* emergency behaviour is evident with males dominating catches during winter time. In quarters 2 and 3, females become more active and are more available to the fishery. These data suggest a fairly stable sex ratio in quarterly catches throughout the time series. Increased female catchability has also been associated with stocks which are in a poor state (females may remain more active as they have been unable to mate due to lack of males in the population). This problem usually manifests itself at times of the year when females would normally be reduced in the catches. This is not the case here.

Discarding of undersize and unwanted *Nephrops* occurs in this fishery, and quarterly discard sampling has been conducted on the Scottish *Nephrops* trawler fleet since 1990. In 2020 due to the Covid-19 pandemic and the suspension of the on-board observer programme, discards were only sampled in quarter 1 and in 2021 there were no discard data collected in FU 9. As such, discard rates calculated for 2021 were based on averages from 2017 to 2019 when sampling levels in the fishery were higher. Discarding rates in this FU appear to be highly variable with rates over the time series of 1% to 54% of the catch by number. In 2020 the observed rate by number (based on quarter 1 only) was at a low level, approximately 5.5% by number, suggesting that recruitment to the fishery is likely to be at a low level. Discards rates were generally higher in the past and in recent years appear to be lower but with occasional high annual levels which may be associated with sporadic high recruitments (e.g. 2002, 2004, 2010 and 2014–2016). It is likely that some *Nephrops* survive the discarding process, an estimate of 25% survival is assumed in order to calculate dead removals (landings + dead discards) from the population.

InterCatch

Scottish 2021 data (official landings and sampled data for landings) were successfully uploaded into InterCatch. There were no landings uploaded from other countries in 2021. In 2021 there were no discard data imported for this FU. Discard rates and allocations for length frequencies in 2021 were based on averages from years 2017-2019. Borrowing discard rates from previous years is not a feature allowed in Intercatch, as such the method described above was performed outside Intercatch. Output data for landings and discards were produced and extracted following the same raising procedure used in previous years to obtain length compositions in formats suitable for running the assessment. No BMS or logbook registered discard data were reported for this FU in 2021.

Length compositions

Length compositions of landings and discards are obtained during monthly market sampling and quarterly on-board observer sampling respectively. Although assessments based on detailed catch analysis are not presently possible, examination of length compositions may provide an indication of exploitation effects.

Figure 11.7.3 shows a series of annual length frequency distributions for the period 2000 to 2021. Catch (removals) are shown for each sex with the mean catch and landings lengths shown in relation to MLS and 35 mm. There is little evidence of change in the mean size of either sex over time and examination of the tails of the distributions above 35 mm shows no evidence of reductions in relative numbers of larger animals. Occasional large year classes can be observed in these length frequency data (2002, 2004 and more recently, 2016). This is consistent with the occasional high discard rates observed for this FU.

The observation of relatively stable length compositions is further confirmed in the series of mean sizes of larger *Nephrops* (>35 mm) in the landings shown in Figure 11.7.1 and Table 11.7.3. This parameter might be expected to reduce in size if overexploitation were taking place, but it appears to be stable throughout the time series. In 2013–2015, length frequencies seem to suggest a slight increase in the retention of larger males, which given the larger male contribution to the catches, caused an increase in the mean weight in the landings (Figure 11.5.4 and Table 11.5.5).

The mean size in the catch in the <35 mm category (Figure 11.7.1) shows no particular trend over the time series. This parameter is however slightly above average over the last five years, which is consistent with the recent decrease in the discard rate and that is likely related with the trend found in the length frequency distributions (Figure 11.7.3) suggesting a series of poor recruitment in recent years.

Natural mortality, maturity at age and other biological parameters

Biological parameter values are included in the Stock Annex.

Research vessel data

Underwater TV (UWTV) surveys of *Nephrops* burrow number and distribution reduce the problems associated with traditional trawl surveys that arise from variability in burrow emergence of *Nephrops*.

The numbers of valid stations used in the final analysis in each year are shown in Table 11.7.4. The UWTV survey did not cover FU 9 in 2020 due to a decreased sampling schedule caused by limited time at sea available related with the Covid-19 pandemic. In 2021 a TV survey was carried out but the timing of the survey was changed from August into June, due to limitations related with the research vessel's availability. In 2022 the FU 9 survey was carried out as normally in August/September. On average, 43 stations have been considered valid each year and 45 stations were sampled in 2022. Abundance data are raised to a stock area of 2195 km^2. General analysis methods for UWTV survey data are similar for each of the Scottish surveys, and are described in the Stock Annex.

Data analyses

Exploratory analyses of survey data

Table 11.7.5 shows the basic analysis for the three most recent UWTV surveys conducted in FU 9. The table includes estimates of abundance and variability in each of the strata adopted in the stratified random approach. The ground is predominantly of coarser muddy sand and typically, the variance in the survey is higher in the west and east muddy sand strata and lower in central muddy sand and sandy mud strata. The densities typically observed in this FU are lower than those observed in FU 8.

Figure 11.7.4 shows the distribution of stations in UWTV surveys (U6028), with the size of the symbol reflecting the *Nephrops* burrow density. In recent years the abundance appears to be highest at the southwestern inshore and to the east of the FU, with lower densities in the central areas. Table 11.7.4 and Figure 11.7.5 show the time series of estimated abundance for the UWTV surveys, with 95% confidence intervals on annual estimates. With the exception of 2003, the confidence intervals have been fairly stable in this survey.

The use of the UWTV surveys for *Nephrops* in the provision of advice was extensively reviewed by WKNEPH (ICES, 2009). A number of potential biases were highlighted including those due to edge effects, species burrow mis-identification and burrow occupancy. The cumulative bias correction factor estimated for FU 9 was 1.21 meaning that the TV survey is likely to overestimate

Nephrops abundance by 21%. In order to convert the raw UWTV survey abundance to an absolute abundance the raw data are divided by 1.21.

Final assessment

The UWTV survey is again presented as the best available information on the Moray Firth *Nephrops* stock. This survey provides a fishery independent estimate of *Nephrops* abundance. At present it is not possible to extract any length or age structure information from the survey and it therefore only provides information on abundance over the area of the survey.

The abundance in the Moray Firth has declined markedly in 2005 having remained stable around 400 million until 2019. In 2021 the abundance increased sharply but decreased again in 2022 and is now estimated at 396 million, a 40% reduction compared with the 2021 value. The stock is currently below the average abundance over the time series but remains above the biomass trigger. The calculated harvest ratio in 2021 (dead removals/TV abundance) is 6.4% which is now below F_{MSY} (previously above F_{MSY}). The mean size of individuals >35 mm in the catch shows no strong trend in recent years. The mean size of individuals below 35 mm has shown an increase in 2017–2018 which, together with the low discard rate observed in the last 5 years suggests a recent low recruitment period in relation to 2014–2016. Larger square mesh panels and new, more selective TR2 gears implemented from 2010 as part of the Scottish Conservation Credits scheme may have improved the exploitation pattern as shown by a small increase in the proportion of large males in caches in 2013–2015. The effect of these changes are not however, as evident as those observed in FU 7 and length frequencies in recent years remain relatively stable in the Moray Firth.

11.7.6 Historical stock trends

The UWTV survey estimate of abundance for *Nephrops* in the Moray Firth suggests that the population increased in 1997–2005 and has gradually fallen until 2012. In recent years abundance has remained at a relatively low level with the exception of 2021 when a sharp increase (75%) in abundance was observed (there was no survey in 2020). The abundance estimates from 1993–2022 are shown in Table 11.7.6 and Table 11.7.6 shows the estimated harvest ratios. These range from 6–33% over this period. Estimated harvest ratios prior to 2006 may not be representative of actual harvest ratios due to under-reporting of landings before the introduction of 'Buyers and Sellers' legislation.

In addition to the discard rate, Table 11.7.6 also shows the dead discard rate which is calculated as the quantity of dead discards as a proportion (by number) of the removals (landings + dead discards).

11.7.7 Recruitment estimates

Survey recruitment estimates are not available for this stock, although the length frequency distributions and highly variable discard rates suggest that this FU may be characterised by occasional large year classes.

11.7.8 MSY considerations

A number of potential F_{MSY} proxies were obtained from the per-recruit analysis for *Nephrops* as documented in the WGNSSK 2010 report. The analysis was updated in 2011 using 2008–2010 catch-at-length data, to account for the apparent changes in the discard pattern in this fishery and since previous estimates were derived several years before. An update was not performed this year. The complete range of the per-recruit F_{MSY} proxies is given in the table below and the process for choosing an appropriate F_{MSY} proxy is described in WGNSSK 2010 report.

		F_{bar}(20–40 mm)		HR (%)	SpR (%)		
		M	F		M	F	T
F0.1	M	0.13	0.07	7.16	42.35	61.48	49.89
	F	0.24	0.12	11.61	27.45	47.01	35.16
	T	0.14	0.07	7.84	39.46	58.93	47.13
Fmax	M	0.26	0.13	12.31	25.80	45.16	33.42
	F	0.68	0.36	23.82	11.42	25.16	16.83
	T	0.34	0.18	14.92	20.79	39.10	28.01
F35%SpR	M	0.17	0.09	9.11	34.69	54.48	42.48
	F	0.41	0.22	17.12	17.62	34.83	24.40
	T	0.24	0.13	11.79	27.02	46.53	34.71

The changes in the selection and discard patterns, and relative availability of females as estimated by the LCA result in slight decreases in the estimated MSY harvest ratio proxies compared to those calculated previously. (See stock annex for previously calculated values used at WGNSSK 2010).

Moderate absolute densities are generally observed on the UWTV survey of this FU (average of ~ 0.2 m^{-2}). Harvest ratios (which are likely to have been underestimated prior to 2006) appear to have been above $F_{35\%SpR}$ and in addition there is a long time series of relatively stable landings (average reported landings ~ 1300 tonnes, above those predicted by currently fishing at $F_{35\%SpR}$). For these reasons, it is suggested that $F_{35\%SpR(T)}$ is used as the F_{MSY} proxy.

The F_{MSY} proxy harvest ratio is 11.8%.

The $B_{trigger}$ point for this FU (lowest observed UWTV abundance) is calculated as 262 million individuals.

11.7.9 Short-term forecasts

A catch prediction for 2023 was made for the Moray Firth (FU 9) using the approach agreed at the Benchmark Workshop in 2009 and outlined in the introductory section of the 2010 WGNSSK report. The table below shows catch predictions at various harvest ratios, including a selection of those equivalent to the per-recruit reference points discussed in Section 11.7.8 of this report and the harvest ratio in 2020 using the input parameters agreed at WKNEPH (ICES, 2009). The catch prediction is calculated following the procedure outlined in the stock annex (section: short term projections).

Recently, to account for the landing obligation coming into force for *Nephrops* in 2016, the projected amount of discards (now referred to as projected discards) have been added to the catch options table. The advice given in 2022 considers that *Nephrops* discarding is allowed to continue as in previous years. Under this scenario the harvest rate is assumed to include landings (projected landings) plus dead discards (Projected dead discards). The catch options table includes projected surviving discards (discards survival for *Nephrops* in FU 9 is assumed to be 25%). Projected discards (by number) are calculated using data from the on-board observer sampling programme. This value is multiplied by the mean weight in discards to obtain the projected discard weight. There is a *de minimis* exemption in place for *Nephrops* in the UK waters of the North Sea (ICES division 2.a and Subarea 4) with certain gears. The forecast includes an extra catch options table assuming a discard ban for 2023. The main difference in this scenario is that there is no survival assumed for the projected discards.

The advice for Category 1 stocks (where assessment includes landings and discards data) is based on catches. The prediction for 2023 is that catches should be no more than 1249 tonnes, assuming recent discard rates. This represents a 39% decrease from the advice given for 2022. It should be noted that the F_{MSY} proxy harvest ratio in the Moray Firth is still based on a combined Length Cohort Analysis (data 2008–2010) using dead removals (landings + dead discards). A discussion of F_{MSY} reference points for *Nephrops* is provided in Section 11.7.8.

The inputs to the landings forecast were as follows:

FU 9 basis for the catch options

Variable	Value	Notes
Stock abundance (2023)	396	Underwater TV (UWTV) survey 2022; individuals in millions
Mean weight in projected landings	27.06	Average 2019-2021; grammes
Mean weight in projected discards	9.29	Average 2019-2021; grammes
Projected total discard rate	3.0	Average 2019-2021; percentage by number of the total catch
Discard survival rate	25	Percentage by number of the discards

Catch scenarios assuming recent discard rates

Basis	Total catch PL + PDD + PSD	Dead removals PL + PDD	Projected landings PL	Projected dead discards PDD	Projected surviving discards PSD	Harvest rate * for PL+PDD	% advice change **
ICES advice basis							
MSY approach	1249	1246	1236	10	3	11.8	-39
Other scenarios							
F_{2021}	675	673	668	5	2	6.4	-67
$F_{0.1}$	826	824	817	7	2	7.8	-60
F_{MSY} lower	964	961	953	8	3	9.1	-53
$F_{2019–2021}$	1006	1003	995	8	3	9.5	-51
F_{MSY} upper***	1249	1246	1236	10	3	11.8	-39
F_{max}	1576	1572	1560	12	4	14.9	-24

Catch scenarios assuming zero discards

Basis	Total catch PL + PD	Projected landings PL	Projected discards ^ PD	Harvest rate * for PL + PD	% advice change **
ICES advice basis					
MSY approach	1240	1227	13	11.8	-40
Other scenarios					
F_{2021}	670	663	7	6.4	-68
$F_{0.1}$	820	811	9	7.8	-60
F_{MSY} lower	956	946	10	9.1	-54
$F_{2019-2021}$	997	987	10	9.5	-52
F_{MSY} upper***	1240	1227	13	11.8	-40
F_{max}	1565	1549	16	14.9	-24

^ Represents the amount that otherwise would have been discarded but is now landed under the landing obligation.
*** Calculated for dead removals.**
**** Advice basis values for 2023 relative to the 2022 advice values (2062 tonnes).**
***** $F_{MSY\ upper}$ = F_{MSY} for this stock.**

Biological Reference points

Biological reference points have not been defined for this stock.

11.7.10 Quality of assessment

The length and sex composition of the landings data is considered to be relatively well sampled. Discard sampling has been conducted on a quarterly basis for Scottish *Nephrops* trawlers in this fishery since 1990, and is considered to represent the fishery adequately. Discard sampling in 2020-2021 was impacted by the Covid-19 pandemic and only samples for quarter 1 are available in 2020 and no samples were collected for 2021. The proportion of landings with discards associated (same strata) is 0% in 2021. As there were no discards imported, averages from years 2017-2019 were used to estimate discard rates and length frequencies in 2021.

There are concerns over the accuracy of landings (pre 2006) and effort data and because of this the final assessment adopted is independent of official statistics.

UWTV surveys have been conducted for this stock from 1993 to 2019 (no surveys in 1995 and 2020). The number of valid stations in the survey has remained relatively stable throughout the time period.

The Fishers' North Sea stock survey does not include specific information for the Moray Firth. Area 3 covers the Moray Firth, Firth of Forth and areas of the Devil's Hole and there appears to be some inconsistencies between the report in 2011 and 2012. In 2011, the report documented a perceived increase in the *Nephrops* abundance in this area since 2008; however, the 2012 report appears to show a perceived decrease since 2008. There are no Fishers' North Sea survey data available for 2013–2021.

11.7.11 Status of the stock

The evidence from the UWTV survey suggests that following a continuous decrease from 2007 to 2012 the abundance has fluctuated around 400 million until 2020. The abundance has increased 75% in 2021 and decreased again in 2022 (to 396 million) and is approximately at the same level as in the late 2000s. The stock size is above the MSY $B_{trigger}$ level. Landings taken from this FU in 2021 (1221 tonnes) were higher than the 2020 total catch advice (for 2021) of

1180 tonnes. The harvest rate decreased in 2021 to 6.4% and is now below F_{MSY} (11.8%). Length frequencies in the catches have been relatively stable.

11.7.12 Management considerations

Catches in 2021 were above ICES advice in 2020 (for 2021), highlighting the issue that current management arrangements are not sufficient to contain the fishery within the sustainable limits determined by ICES. The WG, ACOM and STECF have repeatedly advised that management should be at a smaller scale than the ICES Division level. Management at the Functional Unit level could provide the controls to ensure that catch opportunities and effort were compatible and in line with the scale of the resource.

There is a by-catch of other species in the Moray Firth area. It is important that efforts are made to ensure that unwanted bycatch is kept to a minimum in this fishery. Current efforts to reduce discards and unwanted bycatches include the implementation of larger meshed square mesh panels.

The estimated harvest rates have been fluctuating around F_{MSY} but the abundance (as estimated by the UWTV survey) in recent years is just above the MSY $B_{trigger}$, therefore it would be unwise to allow effort to increase in this FU.

This stock is under the landings obligation although there is a *de minimis* exemption in place for *Nephrops* in the UK waters of the North Sea (ICES division 2.a and Subarea 4) with certain gears, according to the Marine Management Organization (MMO, 2021). The exemption applies to catches of Norway lobster below the minimum conservation reference size, which shall not exceed 2% of the total annual catches of that species. In 2021, no *Nephrops* were recorded as below the minimum size (BMS) in FU 9 despite catches having been observed below the MCRS and this being a Functional unit that historically have shown occasional high discard rates.

References:

MMO, 2021. Fishing gear requirements and Landing Obligation exemptions 2022. Applicable to the Nephrops Fishery in UK waters of the North Sea. Document No.: V1. Date of Issue: December 2021.

11.8 Noup (FU 10)

11.8.1 Ecosystem aspects

The Noup is a small area of muddy sand located to the west of Orkney. The area is exposed to the open Atlantic to the west and strong tidal currents occur in the area. The surrounding coarser grounds are important brown crab fishing areas and fish populations (mixed demersal species) are important in the locality.

11.8.2 The fishery in 2020 and 2021

The Noup currently supports a relatively small fishery. Few vessels target *Nephrops* regularly in this area. In Orkney there are currently only one part-time vessel fishing seasonally for *Nephrops* (mostly around summer) as most of the local fleet targets crabs and lobsters. *Nephrops* boats from Orkney spend most of the year fishing in the Moray Firth (FU 9). In recent years, vessels from Scrabster landing *Nephrops* use 120 mm mesh twin rigs (targeting whitefish). Landings from Noup have decreased steadily since 2002 and in 2021, only 14 tonnes of *Nephrops* were landed (Table 11.8.1). Further general information on the fishery can be found in the Stock Annex.

11.8.3 Advice in 2020

The advice provided in 2020 was biennial and valid for 2021 and 2022.

"ICES advises that when the precautionary approach is applied, catches in each of the years 2021 and 2022 should not exceed 46 tonnes, assuming recent discard rates.

To ensure the stock in Functional Unit (FU) 10 is exploited sustainably, management should be implemented at the functional unit level."

Data available

Commercial catch and effort data

Landings from this fishery are reported only from Scotland and are presented in Table 11.8.1 and Figure 11.8.1. Total landings (as reported to the WG) in 2021 were 14 tonnes, an increase of 4 tonnes from 2020. *Nephrops* are almost exclusively landed by 'non-*Nephrops*' vessels. This supports the anecdotal information received from the fishing industry that this area is rarely fished by *Nephrops* vessels due to the high catch rates of whitefish in the area.

In previous years, concerns were expressed over the reliability of the effort figures provided for Scottish *Nephrops* trawlers; effort figures were unrealistically low in some areas. Investigation of the issue revealed a problem in the MSS Marine Laboratory database, where only the effort expended in the first statistical rectangle visited by a vessel during a trip was being output. This did not affect landings. An extraction of effort data by the Marine Scotland data unit in Edinburgh covering the four main trawl gears landing *Nephrops* into Scotland produced higher figures which capture all the effort. At the present time, these revised data cover the period 2000 to the present and only annual summaries are available.

Trends in Scottish effort and LPUE are shown in Figure 11.8.1 and Table 11.8.2. Effort has declined over the time period and this is more marked than on other *Nephrops* grounds owing to the presence of demersal fish in the area. In the last years the LPUE have been stable.

Length compositions

Levels of market sampling are low and discard sampling is not available. Mean sizes in the landings in previous years are shown in Figure 11.8.1 and Table 11.8.3. There were no sampling data available for 2015, 2018 and 2020, two sampling trips in 2016, and one trip in each of 2017, 2019 and 2021. The low levels of sampling for this fishery mean it is not realistic to draw conclusions from changes in size composition or sex ratio.

InterCatch

Scottish data for 2021 were successfully uploaded into InterCatch prior to the 2022 WG meeting according with the deadline proposed. The 2021 data provided by Scotland was raised based on length frequencies collected in quarter 3. Careful must be taken when interpreting this information due to the low levels of sampling.

Natural mortality, maturity at age and other biological parameters

No data available.

Research vessel data

An underwater TV (UWTV) survey of this FU has been conducted sporadically (1994, 1999, 2006, 2007 and 2014). In 2019, Noup was re-visited by the summer Scotia UWTV survey after five years past the previous survey. Figure 11.8.3 shows the distribution of stations in the UWTV surveys, with the size of the symbol reflecting the *Nephrops* burrow density. In 2019, 11 stations were successfully surveyed. The most recent survey gives an estimate of population size of 90 million

(0.22 burrows/m^2) similar to that found in 1999 which is significantly higher than the previous survey (51 million, 0.13 burrows/m^2). All of these are lower than the very high value observed in 1994. The results of the UWTV surveys are shown in Figure 11.8.4 and Table 11.8.4. There were no surveys carried out in FU 10 in 2020-2022.

11.8.4 Historical stock trends

The TV survey estimate of abundance for *Nephrops* in the Noup suggests that the population declined from the first survey in 1994 and remained at a lower level on the following surveyed years until 2019 when the abundance increased again. Landings fluctuated between 200 and 400 tonnes between 1995 and 2002, and declined markedly from then. Recent landings for this FU have been low, 11 tonnes in 2020 and 14 tonnes in 2021.

11.8.5 Recruitment estimates

There are no recruitment estimates for this FU.

11.8.6 Short-term Forecasts

The advice guidance and category classification for data-limited stocks (DLS) was addressed at WKLIFE2 (ICES 2012). The methodology for DLS *Nephrops* stocks is further described in the 2013 Benchmark report (ICES 2013). Following the procedure outlined (Section 10.1), the spatial extent of the *Nephrops* grounds were estimated (based on BGS sediment maps) to provide a likely envelope for the total abundance of *Nephrops* in FU 10 (see table below). UWTV survey information on the mean density of *Nephrops* (0.22 *Nephrops*/m^2), from the 2019 survey, was used together with discard percentages, and mean weights taken from FU 9 (Moray Firth). The same advice as provided in 2020 of 46 tonnes (catch) results in a harvest ratio of 1.93%. The stock appears to be very lightly exploited. Providing the harvest rate is less than 7.5%, the default basis for advice is the average landings of the last ten years (2012–2021), subject to the application of the uncertainty cap to restrict annual advice change to less than 20%. The ten-year average corresponds to 14 tonnes of advised catch which implies a 70% reduction from the 2020 advice. Therefore, the chosen advice option was the 2020 advice – 20% corresponding to catches of 37 tonnes, assuming recent discard rates, obtained from the neighbouring FU 9. The current advice option results in a harvest rate of 1.55%. This is well below the range of maximum sustainable yield (MSY) harvest rates in the North Sea (between 7.5% and 16%), which is considered conservative. The precautionary buffer was applied in 2020 and its application has, therefore, not been considered again. Stock size in relation to reference points is unknown and the stock has not increased significantly. Additional options including a medium term (10 year) average and a recent (3 year) average projected landings were also included in the table. Assuming the 2019 survey density, all the options (with the exception of the time series maximum landing value) result in a harvest ratio lower or equal to 7.5%, reflecting the low exploitation level in recent years in FU 10. In line with the advice for other stocks, total catches, projected landings and projected discards expected under the landing obligation policy were added to the table. For data limited stocks the discard survival is assumed to be zero.

Basis for the catch scenarios.

Variable	Value	Notes
Stock density (2023)	0.22	Underwater TV (UWTV) survey 2019 (UWTV was not completed in 2022); density in numbers m-2
Mean weight in projected landings (2023)	27.06	Average 2019-2021 (from FU 9); grammes
Mean weight in projected discards (2023)	9.29	Average 2019–2021 (from FU 9); grammes
Projected total discard rate (2023)	3.0	Average 2019–2021 (from FU 9); percentage by number of the total catch
Discard survival rate (2023)	0	Discard survival is assumed to be zero
Surface area estimate	409	Benchmark estimate WKNEPHTV (ICES, 2007); km2

***Nephrops* FU 10. Catch options assuming discarding continues at recent average. All weights are in tonnes. Harvest rates in percent are calculated for a range of densities, with values above the MSY proxy of 7.5% highlighted in grey.**

Basis	Total Catch	Projected landings	Projected discards	Range of potential densities (*Nephrops* m^{-2})									% advice change**
				0.05	0.1	0.15	0.2	0.22 *	0.3	0.4	0.6	0.8	
Advice for 2021 and 2022 −20% cap (Precautionary approach)^	**37**	**37**	**0**	6.8	3.4	2.3	1.71	**1.55**	1.14	0.85	0.57	0.43	**-20**
Average landings (2012–2021)	14	14	0	2.6	1.31	0.88	0.66	0.60	0.44	0.33	0.22	0.164	-70
Recent average landings (2019–2021)	15	15	0	2.9	1.43	0.95	0.71	0.65	0.48	0.36	0.24	0.179	-67
Advice for 2021 and 2022 −20% cap	37	37	0	6.8	3.4	2.3	1.71	1.55	1.14	0.85	0.57	0.43	-20
Advice for 2021 and 2022	46	46	0	8.5	4.2	2.8	2.1	1.93	1.41	1.06	0.71	0.53	0
Advice for 2021 and 2022 +20% cap (Precautionary approach)	55	54	1	10.1	5.1	3.4	2.5	2.3	1.69	1.27	0.84	0.63	20
MSY proxy harvest rate (HR)	179	177	2	33	16.5	11.0	8.2	7.5	5.5	4.1	2.8	2.1	289
Maximum landings	499	494	5	92	46	31	23	21	15.3	11.5	7.7	5.8	984

***Most recent abundance estimate (2019 UWTV survey). Harvest rates are calculated for dead removals and applied to total catch.**

**** Advice basis values for 2023 and 2024 relative to the advice value for 2021 and 2022 (catch advice of 46 tonnes).**

^ The average landings (2012–2021) option results in a -70% advice change, therefore, a -20% cap was applied.

11.8.7 Quality of the assessment

The time-series of UWTV survey data is incomplete, and the last survey was conducted in 2019. Given the low number of vessels involved in the fishery and the fact that some vessels were not targeting *Nephrops*, caution should be exercised when interpreting the effort data for this FU and the resulting landings per unit of effort (LPUE).

There is no recent discard information for this fishery. Discard percentages and mean weights have been taken from the closest inshore functional unit (FU 9). The catch options presented in recent years were based on a calculation of potential landing options and harvest rates, given the known surface area of Norway lobster habitat and observed densities of the functional unit.

11.8.8 Status of the stock

The current state of the stock is unknown.

11.8.9 Management considerations

The WG, ACOM and STECF have repeatedly advised that management should be at a smaller scale than the ICES Division level. Management at the Functional Unit level could provide the controls to ensure that catch opportunities and effort were compatible and in line with the scale of the resource.

The Noup area supports a mixed fishery in which *Nephrops* are taken mainly by demersal trawlers targeting fish. It is important that efforts are made to ensure that unwanted bycatch is kept to a minimum in this fishery.

This stock is under the landings obligation although there is a survivability exemption in place for *Nephrops* in the UK waters of the North Sea (ICES division 2.a and Subarea 4) with certain gears, according to the Marine Management Organization (MMO, 2021).

References:

ICES. 2012. Report of The Workshop to Finalize the ICES Data-limited Stock (DLS) Methodologies Documentation in an Operational Form for the 2013 Advice Season and to make Recommendations on Target Categories for Data-limited Stocks (WKLIFE II), 20–22 November 2012, Copenhagen, Denmark. ICES CM 2012/ACOM:79. 46 pp.

ICES. 2013. Report of the Benchmark Workshop on *Nephrops* Stocks (WKNEPH), 25 February–1 March 2013, Lysekil, Sweden. ICES CM 2013/ACOM:45. 230 pp.

MMO, 2021. Fishing gear requirements and Landing Obligation exemptions 2022. Applicable to the Nephrops Fishery in UK waters of the North Sea. Document No.: V1. Date of Issue: December 2021.

11.9 Norwegian Deep (FU 32)

11.9.1 Ecosystem aspects.

See stock annex (Section A.3).

11.9.2 The fishery in 2020 and 2021

The annual spatial distribution of the Danish and Norwegian fisheries in FU 32 are shown in figures 11.9.1, 11.9.2 and 11.9.3. The Danish fishery is still largely confined to the southernmost part of the functional unit. The Norwegian large vessel trawl fisheries (large mesh bottom trawl and small mesh shrimp trawl) with *Nephrops* as bycatch declined from 2012 to 2013. In 2013–2015, these trawl fisheries were confined to the southernmost part of the functional unit as well as an area just west of the city Stavanger, while from 2016 onwards trawling has again taken place along the western rim of the Norwegian Trench. The Norwegian creel fishery is concentrated in outer coastal areas from Stavanger to Bergen.

The total landings from FU 32 in 2021 were 216 tonnes, an increase of 20% from 2020. Denmark landed 129 tonnes, which was an increase from 2020 (81 tonnes), while Norway landed 80 tonnes, a decrease from 2020 (94 tonnes).

See also stock annex (Section A.2) and Section 11.9.5.

11.9.3 Advice in 2020

Advice for *Nephrops* in FU 32 is biennial and was last updated in 2020. This advice applied for 2021 and 2022 (single-stock exploitation boundaries). The stock is not subject to the reopening procedure.

"ICES advises that when the precautionary approach is applied, catches in each of the years 2021 and 2022 should be no more than 381 tonnes. If this stock is not under the Norwegian discard ban in 2021 and 2022, and discard rates do not change from the recent average, this implies landings of no more than 379 tonnes."

ICES did not remark on the state of the stock in 2020, as an abbreviated advice was issued due to the COVID-19 disruption.

11.9.4 Management

An overview of the management of *Nephrops* in FU 32 is given in the stock annex (Section A.2). There is a minimum mesh size of 120 mm for large mesh bottom trawls in Norwegian waters in the North Sea (area 04-N). MLS is 40 mm CL in Norwegian waters. The EU fisheries are managed by a separate TAC for the Norwegian EEZ, decided by the annual Norway–EU negotiations. The TAC for EU vessels has decreased from 1300 tonnes in 2008 to 200 tonnes in 2021-2022 (Table 11.9.1). The EU quota of *Nephrops* in Norwegian waters is mainly allocated to Denmark (app. 95%) with a small fraction of app. 5% to UK. There is no quota restriction currently for the Norwegian fishery. Since 1st January 2022, discarding of *Nephrops* in the Norwegian waters in the North Sea has been prohibited.

11.9.5 Assessment

Data available

Landings data for all fleets in 2021 have been uploaded using InterCatch. Estimated discards exist only for the Danish landings (Figure 11.9.4). Previously, length data were only presented for the Danish catches, but in 2022 all Norwegian length data back in time have been compiled. Only the Danish length data have been uploaded to Intercatch (Figure 11.9.5). A fishery independent biomass index exists from a Norwegian bottom trawl survey.

Catch

International landings from the Norwegian Deep increased from less than 20 tonnes in the mid–1980s to 1190 tonnes in 2001 (Table 11.9.1, Figure 11.9.6). Since then, landings declined due to a reduction of Danish landings, to only 137 tonnes in 2018, the lowest figure since 1990. Since 2019 total landings have increased again. The decreased Danish landings can be explained by increasing fuel costs, fewer vessels, and *Nephrops* catches now occurring mainly as bycatch in mixed fisheries. Danish vessels used to take 80–90% of the total landings, while in 2018, Denmark landed only 25% of the total landings. In 2021, due to Danish landings being almost four times higher than in 2018, Denmark landed 60% of the total landings. Norwegian landings decreased from 2008 to 2014 (62 tonnes), but increased thereafter. In 2017–2018, 90% of Norwegian landings were from creels. Norwegian trawl landings increased in 2019-2021, while creel landings decreased, resulting in 68% creel landings in 2021.

Since 2003, the Danish at-sea-sampling programme has provided discard estimates (Table 11.9.1) and length measurements. In 2017, only a small number of *Nephrops* was length measured (stock annex, Section B.1). The 2017 observer data were considered not representative and were therefore not used as part of the information going into the harvest rate table used in the 2020 advice (see below). Danish sampling was also low in both 2020 and 2021, and there was no discard sampling in 2020 and no landings sampling in 2021.

Danish discards are low due to the legislated 120 mm mesh size. The Danish discard rate (discard as percentage of catch) varied between 10% and 35% in the years 2003–2013, while in 2014–2021 estimated Danish discards were between 0.2 and 6 tonnes, resulting in very low Danish discard rates of between 1% and 5%. The low discards the last eight years may indicate low recruitment to the stock. There are no Norwegian discard data, and Norwegian discards are assumed to be zero (stock annex, Section A.3). At least for the creel fishery, with high survival of discarded *Nephrops*, this is a valid assumption.

Length composition

The average size of *Nephrops* in Danish landings (≥ 40 mm = MLS) showed a general increasing trend for both males and females in the period 2005–2012 (Figure 11.9.6). This increase coincided with a sharp decrease in landings and may imply a lower exploitation pressure. However, the mean size of both males and females in the Danish landings decreased sharply from 2012 to 2013. In 2014, the mean size of landed males jumped back to the high 2012–level, increased further until 2018, and then dropped to the 2012-level in 2019 and 2020. The average size of landed females, on the other hand, remained at the low 2013-level until 2019, but showed a very high value in 2020. The mean size of discards (< 40 mm) has fluctuated without trend since 2002. There was no sampling of discards in 2020, and no sampling of landings in 2021. The Danish fishery has shown a gradual contraction into the southern part of the functional unit, an area with possibly smaller *Nephrops*, however, sampling has in most years taken place in the whole functional unit (Figure 11.9.1). It should be noted that Danish sampling has been low in 2017 and 2019-2021, and these data should be interpreted with care.

Mean size of the Danish catches from the years 2007, 2010, 2012, 2014, 2016, 2017, and especially 2018, 2019 and 2020, were larger compared with former years (Figure 11.9.7). The high 2018 mean size was due to the high mean size of the males, while the high 2020 mean size was due to the high mean size of the females as well as the lack of length sampling of discards. In general, there are few individuals below the MLS of 40 mm due to the legislated 120 mm minimum mesh size. The figure was not updated in 2022 due to lack of sampling of landings in 2021.

In 2022, length samples from Danish and Norwegian trawl catches obtained from Norwegian Coast Guard inspections were analysed. Data are available back to 2002, except 2005. Most length measurements are in total length (TL) which were converted to CL and pooled with the CL-samples in order to use all available data for estimating annual mean size and length frequency distribution (stock annex, Section B.1). Mean size of both landings (catch fraction ≥ 40 mm) and discards (catch fraction < 40 mm) fluctuated without trend from 2002 to 2021 (Figure 11.9.6). Mean sizes of discards were in general lower than the corresponding values from the Danish data. The length frequency distributions show low catches of *Nephrops* below MLS, similar to the Danish data (Figures 11.9.7, 11.9.8).

Natural mortality, maturity at age and other biological parameters

Very little data are available.

Data on sex ratio exist from a citizen science survey (recreational creel fishers) in 2012-2014 in the coastal part of FU 32 (Zimmermann et al. 2022). The proportion of females in all catches was 27%, with the highest proportions (37%) in the third quarter. The proportion of berried females was 9% (of all females) across all fishing trips and showed a seasonal pattern towards an increased proportion in the fourth quarter (20% of all females).

Effort, LPUE and scientific survey data

Effort figures for the period 1989–2021 are available from Danish logbooks (Table 11.9.2, Figure 11.9.6). In 2013, the Danish effort index was changed to kW days (formerly fishing days) (stock annex, Section B.4), as kW days account for temporal differences in vessel size. Days at sea and fishing days are presented in addition to kW days (Table 11.9.2). The Danish effort increased from 2004 to 2006, but showed a strong decline in 2007 and continued decreasing, to 313 kW days in 2018, the lowest observed effort in the time series. The effort more than doubled from 2018 to 2019, but increased some in both 2020 and 2021 (462 kW days) (Table 11.9.2). It has not been possible to incorporate 'technological creep' in the evaluation of the effort data. However, the use of twin trawls has been widespread for many years.

The Danish LPUE index based on kW days shows a stepwise decreasing trend (Figure 11.9.6). However, due to changes in the management regime, changes in the LPUE index do not necessarily imply stock size changes. In the beginning of the 1990s, vessel size increased in the Danish fleet fishing in FU 32. This increase, and more directed fisheries for *Nephrops* in areas with previously low exploitation levels are probably partly responsible for the observed increase in the Danish LPUE in those years (Table 11.9.2, Figure 11.9.6). The Norwegian mesh size legislation was changed in 2004 (stock annex, Section A.2) with the introduction of a larger minimum mesh size of 120 mm. This change in legislation occurred some years too late to explain the decrease in LPUE (catch rate) from 1999 to 2001 with a subsequent stabilizing at a lower level relative to the late 1990s. The lower LPUE may, on the other hand, reflect a stock decrease as Danish landings in 1999 increased to > 1000 tonnes and remained at this level until 2006. In 2007, individual vessel quotas were introduced in the Danish fishery. This resulted in vessels buying up a lot of fish quotas and shifting their effort to finfish rather than *Nephrops*. To get good catches of *Nephrops* vessels need to target this species by fishing at dusk/dawn when the animals are out of their burrows, as opposed to finfish fisheries where good catches can be obtained around the clock. This change in management coincided with the onset of steadily decreasing Danish *Nephrops* landings as well as a decreasing LPUE. From 2020 to 2021, the Danish LPUE increased by 116%, as landings increased and effort decreased. It is not clear why the effort did not increase as landings increased.

Spatial analyses of Danish logbooks and VMS data in the 2016 benchmark (ICES, 2016) showed that the LPUE decreased over the whole Norwegian Deep from 2005 to 2015, with the largest decline in the north. Only the southernmost part of the functional unit had reasonably good catch rates in 2013–2015. Environmental changes resulting in lower *Nephrops* densities in the whole functional unit cannot be ruled out. The likely low recruitment to the stock in 2014–2021 may imply continuing low catch rates.

The 2013 benchmark (ICES, 2013) analysed Norwegian logbooks from bottom and shrimp trawls. Data prior to 2011 are considered unsuitable for LPUE analyses (stock annex, Section B.4). The 2016 benchmark (ICES, 2016) analysed data from Norwegian electronic logbooks (Electronic Reporting System (ERS)), compulsory since 2011 for all vessels ≥ 15 m. The data situation did not improve, however, basically because of few large Norwegian vessels landing *Nephrops* from this area. The creel fishery is carried out by small vessels, not obliged to fill out logbooks. A Norwegian reference fleet of creel fishers established in 2019 and compulsory ERS reporting for vessels 11-15 m from July 1st 2022, and for vessels 10-10.99 m from March 1st 2023, will enable the establishment of new CPUE time series for both the trawl and the creel fisheries.

Zimmermann et al. (2022) estimated stock indices by gear for *Nephrops* in FU 32 from 2005 to 2020 from Norwegian landings data per fishing trip (sales notes of all boats in each year with more than one trip and annual landings of > 100 kg). The trawl index declined from 2005 to 2018, but showed a marked increase in 2019 and 2020, while the creel index increased from 2005 to 2012, but has since shown a decreasing trend.

The annual Norwegian shrimp bottom trawl survey covers all of Skagerrak and the Norwegian Deep (stock annex, Section B.3). *Nephrops* is distributed in areas deeper than 100 m in FU 32 (Figure 11.9.9). (Areas shallower than 100 m are not covered by the survey). Catches of *Nephrops* in the bottom trawl are small and variable within and between years. The 2016 benchmark (ICES, 2016) analysed the *Nephrops* data from the shrimp survey with the aim of establishing a fishery independent stock size index (stock annex, Section B.3).

Data analysis

The advice given in 2022 is based on the previous advice from 2020 plus a 20% uncertainty cap for a gradual increase in catches, which follows the precautionary approach for the stock and is well founded given the results of the assessment. As the state of the stock in relation to reference points is unknown, the precautionary buffer of 20% was applied to the advice for the first time in 2020. The 2022-advice translates to an estimated harvest rate of 1.69%, which is below the most conservative lower bound for MSY in other FUs (7.5%).

Exploratory analysis of catch data

The Danish LPUE has shown a decreasing trend since 2007, but increased markedly from 2020 to 2021 (Figure 11.9.6). The Norwegian landings-per-boat-trip indices show opposite trends for the coastal (creel) and offshore (trawl) fisheries. The increase in 2019-2020 in the trawl index is in accordance with the increase in the Danish LPUE index in 2021.

There was no length-based analysis carried out.

Exploratory analysis of survey data

The biomass index from the Norwegian shrimp bottom trawl survey showed high values in 2006 and 2007, but declined to a lower level in 2008. Thereafter it fluctuated without trend around this lower level until 2019. The last three years have seen a further downward trend, with the index reaching its minimum value in 2022 (Table 11.9.3, Figure 11.9.10). The survey index is based on few observations (Figure 11.9.9). However, in lack of an UWTV survey, the 2016 benchmark concluded that the index should be presented and updated as part of the assessment of the FU 32 stock.

Final assessment

No assessment model exists for *Nephrops* in FU 32. The state of the stock was judged on the basis of basic fishery data and the biomass index from the Norwegian shrimp survey. The indices show similar decreasing trends since 2007, but disagree regarding stock status in recent years. It should be noted that the survey index covers the whole Norwegian Deep for depths > 100 m, while the Danish LPUE covers the western and southern part of the Norwegian Deep.

11.9.6 Historic stock trends

The increase in mean size in landings from 2006 to 2012 in females and from 2005 to 2018 in males could reflect the lower exploitation pressure since 2007. The introduction of a new Danish effort index (kW days) in 2013 resulted in a stepwise declining trend in the LPUE index, from the mid–1990s until present. The survey biomass index has declined since 2015.

11.9.7 Recruitment estimates

There are no recruitment estimates for this stock. Fluctuations in catches of small *Nephrops* are used as a proxy for recruitment. Danish discards of small *Nephrops* were very low in 2014–2021, indicating low recruitment these years.

11.9.8 Forecasts

The ICES framework for category 4 *Nephrops* stocks was applied (ICES, 2012). In the absence of a full analytical assessment, ICES base its advice for *Nephrops* on the most recent advice. Maximum sustainable yield (MSY) harvest rates estimated for other functional units vary between 7.5% and 16%. ICES use the lower boundary as an upper limit for advice for data-limited *Nephrops* stocks. Providing the harvest rate is less than 7.5%, the default basis for advice is the average landings of the last ten years (2012–2021), subject to the application of the uncertainty cap to restrict annual advice change to less than 20%. The ten-year average corresponds to 196 tonnes of advised catch which implies a 49% reduction from the 2020 advice. Therefore, the chosen advice option was the 2020 advice – 20% corresponding to catches of 304 tonnes, assuming recent discard rates. The current advice option results in a harvest rate of 1.13%. This is well below the range of maximum sustainable yield (MSY) harvest rates in the North Sea (between 7.5% and 16%), which is considered conservative. The precautionary buffer was applied in 2020 and its application has, therefore, not been considered again.

Following the precautionary approach, catches in each of the years 2023 and 2024 should be no more than 304 tonnes. Assuming discard rates do not change from the recent average, this implies landings of no more than 303 tonnes.

Basis for the catch scenarios.

Variable	Value	Notes
Density in TV assessment	0.1 *Nephrops*	Minimum value from FU 7; density in numbers per m^{-2}
Mean weight in projected landings	75.17	Average of 2016, 2018 and 2019; poor sampling in 2017, 2020 and 2021: grammes
Mean weight in projected discards	42.79	Average of 2016, 2018 and 2019; poor sampling in 2017, 2020 and 2021; grammes
Projected discard rate (total)	0.8	Average of 2016, 2018 and 2019 (percentage by numbers); poor sampling in 2017, 2020 and 2021; percentage by number of the total catch
Discard survival rate	25	Percentage by numbers of the discard
Surface area estimate	3613	Benchmark estimate WKNEP (2016); km^2

Sensitivity analysis of harvest rates for a range of potential densities. All weights in tonnes.

Discarding not allowed, but based on recent sampling assumed to take place

Basis	Total catch	Projected surviving discards	Projected dead discards	Projected landings	Dead removals	Range of potential densities (*Nephrops* m^{-2})								
						0.05	0.1*	0.2	0.3	0.4	0.5	0.6	0.7	0.8
						Harvest rate in %								
Average landings (2012–2021)	196	0	1	195	196	1.45	0.73	0.36	0.24	0.182	0.145	0.121	0.104	0.091
Recent average landings (2019-2021)	196	0	1	195	196	1.45	0.73	0.36	0.24	0.182	0.145	0.121	0.104	0.091
0.5 × Average landings (2012–2021)	97	0	0	97	97	0.72	0.36	0.181	0.120	0.090	0.072	0.060	0.052	0.045
2020 advice -20% cap	304	0	1	303	304	2.3	1.13	0.57	0.38	0.28	0.23	0.188	0.161	0.141
2020 advice	381	1	1	379	380	2.8	1.41	0.71	0.47	0.35	0.28	0.24	0.20	0.176
2020 advice +20% cap	457	1	1	455	456	3.4	1.69	0.85	0.57	0.42	0.34	0.28	0.24	0.21
Maximum landings	1195	1	4	1190	1194	8.9	4.4	2.2	1.48	1.11	0.89	0.74	0.63	0.55
FMSY	2029	2	7	2020	2027	15.1	7.5	3.8	2.5	1.88	1.51	1.25	1.08	0.94

*** A density of 0.1 *Nephrops* m^{-2} is among the lowest observed densities in the North Sea in FU 7 (Fladen Ground).**

11.9.9 Biological reference points

No reference points are defined for this stock.

11.9.10 Quality of assessment

The data available for this stock remain limited.

A large part of the Norwegian *Nephrops* landings come from the coastal creel fishery. A reference fleet of creel fishers was established in 2019 and will provide information on this fishery, as well as biological information about the coastal part of the stock.

The advice is based on calculation of potential catch options and harvest rates, given the estimated surface area of *Nephrops* habitat and assumed densities of the functional unit. The area of the *Nephrops* grounds in FU 32 is based on the distribution of the current Danish trawl fishery; this estimate does not include the *Nephrops* habitat along the Norwegian coast where the creel fishery takes place nor *Nephrops* ground in northern parts of the functional unit.

11.9.11 Status of stock

The perceptions of this stock (FU 32) are based on Danish landings and effort data, mean sizes (CL) in landings and discards, and a biomass index from the Norwegian shrimp bottom trawl survey. This year, a recently published study on the Norwegian *Nephrops* fishery presenting landings-per-boat-trip indices for both the trawl and the creel fisheries (Zimmermann et al. 2022) was also considered. The Danish LPUE index shows a stepwise declining trend from the mid–1990s until present, however with a substantial increase in 2021. It is difficult to determine whether the decrease in LPUE is due to changes in management and the fishery, or whether the decrease to some extent also reflects stock changes. Recent Danish landings are small, but fished in a restricted area. The low LPUE in 2013–2020 might imply stock size changes in the southern part of FU 32, but could also be caused by vessels now targeting finfish rather than *Nephrops*. The increased index in 2021 is difficult to explain, but is in accordance with trends in the trawl-based landings index in Zimmermann et al. (2022). The survey index is presently at a low level compared with the years 2006–2007, indicating a lower stock size. Trends in mean size in landings and discards and overall size distribution in catches have for many years indicated that the *Nephrops* stock in FU 32 is not over-exploited. The low catches of small *Nephrops* during the last eight years indicate low recruitment to the stock.

The WG concludes that the available data give a non-conclusive perception of stock status. The average annual landings over the last ten years are 195 tonnes (2012–2021), and the short-term average landings are also 195 tonnes (2019–2021).

11.9.12 Issues for future benchmarks

Data

Sampling of trawl catches by the Norwegian Coast Guard should be improved by sampling discards and landings components separately to enable discards estimations. The sampled *Nephrops* should also be sexed.

An UWTV survey should be carried out in FU 32 to explore and map distribution and density.

More biological knowledge on the coastal part of the stock, and the creel fishery is needed. Catch data from reference fishers since 2020 will help to fill the knowledge gap. Electronic logbooks made mandatory for larger segments of the Norwegian fleet since mid-2022 will provide data for a new Norwegian CPUE time series from the trawl fishery.

Assessment

Assessment methods for data poor species should be explored for this *Nephrops* stock.

11.9.13 Ecosystem and fisheries productivity

Stock indices indicate that the density of *Nephrops* may be lower in recent years, but there is no information on actual density in the functional unit, neither present nor past. The 2016 benchmark (ICES, 2016) concluded that catch rates (LPUE) declined especially in northern parts of the functional unit from 2005 to 2015. Catch advice has always been based on a density of 0.1 m^{-2} (the lowest observed density in the neighbouring FU 7 (Fladen Ground)). It is unknown why density seems to be lower in recent years. Discards have been low the last eight years, indicating low recruitment to the stock, which may be part of the explanation. The area of *Nephrops* grounds in the harvest rates table was changed in the 2016 benchmark, from an estimate of the area of the whole functional unit to an estimate of the area of the distribution of the present Danish trawl fishery.

11.9.14 Management considerations

ICES provide catch advice for *Nephrops* in FU 32. Discarding of *Nephrops* is illegal in FU 32 as of January 1st 2022. As discarding is assumed to continue, advice in 2022 was given for a scenario assuming continued discards. Following the procedure outlined in the stock annex (Section H) a table of harvest rates (see table in Section 11.9.8) was calculated. The biomass estimates imply low harvest rates in FU 32, even in former years with high landings (1000–1200 tonnes).

References

ICES. 2013. Report of the Benchmark Workshop on *Nephrops* Stocks (WKNEPH). 25 February-1 March 2013 Lysekil, Sweden. ICES CM 2013/ACOM: 45. 183 pp.

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Zimmermann, F., Kleiven, A. R., Ottesen, M. V. and Søvik, G. 2022. Inclusion of recreational fishing in data-limited stocks: a case study on Norway lobster (*Nephrops norvegicus*) in Norway. Canadian Journal of Fisheries and Aquatic Sciences. https://cdnsciencepub.com/doi/full/10.1139/cjfas-2021-0152.

11.10 Off Horns Reef (FU 33)

11.10.1 Ecosystem aspects.

See stock annex (Section A).

11.10.2 Management

Total Allowable Catch (TAC) management is at the ICES Subarea level.

11.10.3 Advice in 2020

Advice for *Nephrops* in FU 33 is biennial and was last updated in 2020. This advice applied for 2021 and 2022 (single-stock exploitation boundaries). The stock is not subject to the reopening procedure.

"ICES advises that when the precautionary approach (PA) is applied, landings in each of the years 2021 and 2022 should not exceed 956 tonnes. ICES cannot quantify the corresponding total catches.

To ensure that the stock in Functional Unit (FU) 33 is exploited sustainably, management should be implemented at the functional unit level."

ICES did not remark on the state of the stock in 2020, as an abbreviated advice was issued due to the COVID-19 disruption.

11.10.4 Assessment

Data available

Catch

The landings from FU 33 were marginal for many years. However, from 1997 to 2004, Danish landings increased considerably, from 274 to 1097 tonnes. Denmark dominated the fishery during this period. Between 2004 and 2015, Danish landings gradually decreased, and in 2015 were 371 tonnes. In 2016 and 2017, the Danish landings increased considerably from previous years, however, in 2018 they were at the lowest level since the beginning of the 1990s. From 2019 to 2021, landings have shown an increasing trend, with Danish landings in 2021 being 349 tonnes. The other countries reporting landings from this FU are Belgium, Netherlands, Germany and the UK. Dutch landings show an increasing trend from the start of the time series until 2007 when landings were almost 500 tonnes. Since 2007, Dutch landings show a decreasing trend and in 2015 were the lowest landings recorded over the last decade (187 tonnes). However, since 2016 Dutch landings increased considerably with record high landings of 599 tonnes in 2019. In 2021, Dutch landings were still high with 541 tonnes landed from FU 33. Belgium and German landings having increased throughout the period and in 2019 were the highest landings recorded for this FU, 462 and 329 tonnes, respectively. However, in more recent years landings from both countries have decreased considerably, with landings of 287 and 193 tonnes in 2021 for Belgium and Germany, respectively. UK landings were highest in 2009 (170 tonnes) and have since decreased dramatically, reporting 0.5 tonnes from this FU in 2021. Regarding total landings from this FU, in 2016 total landings were the highest on record (1636 tonnes). However, in 2018 total landings decreased substantially, primarily due to the large reduction in Danish landings. Total landings in 2019 have returned to levels of the previous years with the second highest total landings on record, 1612 tonnes. In 2021, total landings from Off Horns Reef were 1371 tonnes (Table 11.10.1 and Figure 11.10.1).

Discards from FU 33 are poorly documented and scarce. Discard information from Denmark were recorded in InterCatch since 2015. These data typically consist of few trips per year and are considered too scarce to be used for providing catch advice. No length data were available from Denmark from 2017–2021. In 2015, Dutch discards were recorded in InterCatch, however, length information was missing. Between 2016 and 2021, Dutch discards included length information. Due to a National minimum landing size, a large majority of the Dutch discards are above the MCS of 25 mm set for the North Sea and, thus, not considered representative for the other countries.

Length compositions

Length (CL) distributions of the Danish catches 2001–2005 and 2009–2016 are shown in Figure 11.10.2. Notice, that except for 2005 and 2011 they are rather similar. No discards were observed in the Danish at-sea observer data in 2016, hence the large increase in mean length. Figure 11.10.1 shows the development of the mean size of *Nephrops* in catches. The drop in the mean CL in the catches in 2005 and 2011 reflects an increase in numbers at around 30 mm CL and could indicate a large recruitment in these years, see also Figure 11.10.1.

In the period 2001–2005, and in 2009–2015 the Danish at-sea-sampling programme has provided data for discard estimates. However, the samples do not cover all quarters. In 2021, length distributions were only available from Dutch catches.

Natural mortality, maturity at age and other biological parameters

No data available

Catch and effort data

Figure 11.10.1 shows the development in Danish effort and LPUE. Notice that the 10-fold increase in fishing effort from 1996 to 2004 seems to correspond to the increase in landings during the same period and the LPUE was relatively stable. After 2004, the Danish effort decreased markedly, and since 2009 has remained stable at around 300 000 kW days. In 2021, Danish effort was around 555 000 kW days, although lower than the effort in 2017 (~615 000 kW days). Dutch effort data are available for 2005–2021 and shows an increasing trend over the time period. However, Dutch effort decreased from around 1 300 000 kW days in 2013 to 1 000 000 kW days in 2014 and 2015. Between 2016 and 2019, Dutch effort returned to the same levels as observed in 2013. In 2020 and 2021, Dutch effort was approximately 1 550 000 kW days, the highest recorded since the beginning of the time series, and maybe attributed to the redefinition of métiers in the Netherlands.

From the beginning of the time-series until 2016, the Danish LPUE showed an increasing trend, and in 2016, was the highest in the time series at around 1.7 kg/kW day. This increase in LPUE observed from 2011–2016 could reflect an increase in gear efficiency (technological creep) or in fishers' ability to exploit the stock. However, in 2017 and 2018 the Danish LPUE decreased considerably, to 0.8 kg/kW day and 0.2 kg/kW day, respectively. Between 2019 and 2021, the Danish LPUE increased and stabilised around 0.6 kg/kW day. These low Danish LPUE values observed in recent years may be explained by the low number of Danish vessels exploiting this FU. This may also explain some of the variability in LPUE observed. LPUE from the Netherlands increased from 0.3 kg/kW day in 2005 to around 0.7 kg/kW day in 2007, and has since fluctuated between 0.2 and 0.5 kg/kW day, being 0.3 kg/kW day in 2021.

Research vessel data

An underwater TV (UWTV) survey for this FU has been conducted since 2017, with no survey occurring in 2020 or 2022. Figure 11.10.3 shows the distribution of stations in the UWTV surveys, with the size of the symbol reflecting the *Nephrops* burrow density. The number of stations sampled per year has been relatively high, with 59, 85 and 60 stations in 2017, 2018 and 2019, respectively. In 2021 the number of stations was only 28, due to reduction of planned stations and logistic issues during the survey. The most recent survey gives an estimated density of 0.22 burrows per m^2 that is three times higher than the two previous surveys estimates (2018 and 2019). The range of 95% confidence interval around the density estimate for 2021 reflects the lower sample size, but its lower bound is still around 0.2 burrows per m^2, thus supporting the conclusion that the increase in abundance for FU 33 is most likely true. The results of the UWTV surveys are shown in Figure 11.10.4 and Table 11.10.2.

11.10.5 Historic stock trends

The available data do not provide any clear signals on stock development:

The TV survey estimate of abundance for *Nephrops* in Off Horn's Reef suggests that the population declined from the first survey in 2017 to 2018 and remained at a lower level on the following surveyed year. However, in 2021 the TV survey estimates of abundance for *Nephrops* in Off Horn's Reef suggests an increase in stock abundance, with the estimate of lower bound of the 95% confidence interval being two times larger than the abundance estimates from 2019.

In general, over the entire time-series landings have shown an increasing trend. Since 2001, landings have fluctuated without trend from around 800 to 1600 tonnes. Landings in 2019, were the second highest on record, although in more recent years seem to have stabilized around 1400 tonnes being 1371 tonnes in 2021.

In 2016, the size distribution in the catches is similar to those in 2001–2004, 2009–2010 and 2012–2013. The smaller individuals in the 2005 and 2011 catches could reflect a high recruitment in these years. Data for 2020 showed the lowest mean size in catch recorded, which could be an explanation for the higher density values observed in the UWTV survey in the area for 2021. Data for 2021, showed the third highest mean size of catches, potentially indicating lower recruitment for this functional unit. The decrease in mean size could indicate either high recruitment or a decline in the stock, reflected by fewer large individuals. However, there are no recruitment estimates for this FU.

Biological reference points

There are no reference points defined for this stock.

Perceptions of the stock are based on Danish and Dutch LPUE data and trends in size composition in Danish catches. As stated above, comparing the size distribution in the 2005 and 2011 catches with those in other years could indicate high recruitment in 2005 and 2011. Likewise, 2020 showed the lowest mean size in catch in the current time series, indicating again that a strong recruitment event could have occurred in the area.

11.10.6 Forecasts

The ICES framework for category 4 Norway lobster stocks was applied (ICES, 2012). In the absence of a full analytical assessment, ICES base its advice for Norway lobster on the most recent advice. Maximum sustainable yield (MSY) harvest rates estimated for other FUs vary between 7.5% and 16%. ICES use the lower boundary as an upper limit for advice for data-limited Norway lobster stocks.

Providing the harvest rate is less than 7.5%, the default basis for advice is the average landings of the last ten years (2012–2021), subject to the application of the uncertainty cap to restrict annual advice change to less than 20%. The ten year average corresponds to 1223 tonnes of advised catch which implies a 28% increase from the 2020 advice. Therefore, the chosen advice option was the 2020 advice + 20% corresponding to landings of 918 tonnes, assuming a 25% discard rate. This advice option results in a harvest rate of 3.0%. This is well below the range of maximum sustainable yield (MSY) harvest rates in the North Sea (between 7.5% and 16%), which is considered conservative. The precautionary buffer was last applied in 2019 and its application has, therefore, been considered again. The stock status relative to candidate reference points is unknown; therefore, the precautionary buffer was applied in the advice.

Following the precautionary approach, catches in each of the years 2023 and 2024 should be no more than 918 tonnes.

Basis for the catch scenarios.

Variable	Value	Notes
Mean observed density	0.22 *Nephrops* m^{-2}	Density in UWTV 2021. The UWTV survey was not conducted in 2022.
Mean weight in projected landings	40.57 g	Estimated in 2015.
Mean weight in projected discards	17.2 g	Assumed mean discard weight for the calculation of the harvest rate only. Mean weight in Danish discards in 2015.
Projected discard rate (total)	25%	Assumed maximum discard rate for the calculation of the harvest rate only.
Discard survival rate	0%	ICES (2019).
Surface area estimate	5737 km^2	Estimate from the underwater TV (UWTV) survey. WGNEPS (ICES, 2017).

Sensitivity analysis of harvest rates for a range of potential densities (assuming discard rate of 25%). Shaded cells indicate harvest ratios above the MSY proxy harvest rate for this stock of 7.5%. All weights are in tonnes.

Basis	Total catch	Projected landings	Projected discards	Range of potential densities (*Nephrops* m^{-2})									
				0.05	0.1	0.2	0.22*	0.3	0.4	0.5	0.6	0.7	0.8
				Harvest rate in %									
0.5 x Average landings (2012–2021)	698	612	86	7	3.5	1.75	1.59	1.17	0.88	0.7	0.58	0.5	0.44
Advice for 2020 & 2021 −20% cap	873	765	108	8.8	4.4	2.2	1.99	1.46	1.1	0.88	0.73	0.63	0.55
(Average landings (2012–2021) +20% cap) - 20% PA buffer	**1047**	**918**	**130**	**10.5**	**5.3**	**2.6**	**2.4**	**1.75**	**1.31**	**1.05**	**0.88**	**0.75**	**0.66**
Advice for 2020 & 2021	1091	956	135	11	5.5	2.7	2.5	1.83	1.37	1.1	0.91	0.78	0.68
Advice for 2020 & 2021 +20%	1309	1147	162	13.1	6.6	3.3	3	2.2	1.64	1.31	1.1	0.94	0.82
Average landings (2012–2021)	1396	1223	173	14	7	3.5		3.2	2.3	1.75	1.4	1.17	1
Maximum	1867	1636	231	18.7	9.4	4.7	4.3	3.1	2.3	1.87	1.56	1.34	1.17
MSY proxy harvest rate	3287	2880	407	33	16.5	8.3	7.5	5.5	4.1	3.3	2.7	2.4	2.1

11.10.7 Quality of the assessment

Catch sampling needs to be improved. Discard data exist but are not considered representative and are not used to formulate advice. It is currently not possible to update mean weight estimates for landings because current sampling levels are too low. Samples are needed from the main fleets fishing in this FU.

The advice is based on a calculation of potential landing options and harvest rates, given the known surface area of Norway lobster habitat and observed densities of the functional unit.

11.10.8 Management considerations for FU 33

The North Sea TAC is not thought to be restrictive for the fleets exploiting this stock. Considering the recent trend in LPUE and the technological creep of the gear, the exploitation of this stock should be monitored closely.

11.10.9 Status of the stock

Previously, the state of this stock has been unknown, where an assumed low density (based on the lowest observed density in FU 7 (Fladen Ground) has been used to estimate harvest rates. In 2017, Denmark began conducting an UWTV survey of this functional unit. The observed density in 2017 (0.13 *Nephrops* m^{-2}) conformed well to those previous adopted from FU 7 (0.1 *Nephrops* m^{-2}). In 2018 and 2019, the observed densities were lower than what was observed in 2017 at 0.073 *Nephrops* m^{-2}. Harvest rates are considered low for this stock.

The mean individual weight in landings and discards in 2015 are 40.57 and 17.19 g respectively and the survival rate of discards is 0%. Discards are known to take place for the entire fishery, however only length measured discard data exist for the Dutch fishery. These data are not believed to be representative for the entire fishery as considerable high-grading is known to take place. Therefore, these data have not been used to calculate the values in the catch options table. Based on the available landings and discards it was not possible to update these estimates and therefore the 2015 values have been used.

References

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ICES. 2019. Working Group on the Assessment of Demersal Stocks in the North Sea and Skagerrak (WGNSSK). ICES Scientific Reports, 1:7. 1271 pp. http://doi.org/10.17895/ices.pub.5402.

11.11 Devil's Hole (FU 34)

The Devil's Hole was designated as a functional unit in 2010, after recommendation from SGNEPS because of increasing landings in the area. The latest advice for this functional unit was provided in 2020 using the ICES data limited approach for *Nephrops*.

11.11.1 Ecosystem aspects

The area consists of a number of narrow trenches (up to 2 km wide) running in a north-south direction, with an average length of 20–30 km. These trenches fall across six ICES statistical rectangles: 41–43F0 and 41–43F1, which are used to define this functional unit. The British Geological Survey (BGS) sediment map (showing sediments suitable for *Nephrops*) of the area is shown in Figure 11.11.5 and suggests that there is one large, and several smaller areas of muddy sand (10–50% silt and clay).

11.11.2 The Fishery in 2020 and 2021

The fishery in this area is prosecuted largely by Scottish vessels operating out of ports in the northeast of Scotland, but occasionally making landings into northeast England. The fleet consists of large *Nephrops* trawlers which have the capability of operating in such offshore areas. Around five vessels operate out of Peterhead with another 12 from Fraserburgh regularly visiting the areas. These vessels also fish the Fladen on a regular basis and visit the other more inshore functional units in times of poor weather or poor *Nephrops* catch rates in the offshore areas.

Advice in 2020

Advice provided in 2020 was biennial for 2021 and 2022.

"ICES advises that when the precautionary approach is applied, catches in each of the years 2021 and 2022 should not exceed 566 tonnes, assuming recent discard rates.

In order to ensure the stock in this functional unit (FU) is exploited sustainably, management should be implemented at the functional unit level."

11.11.3 Management

Total Allowable Catch (TAC) management is at the ICES Subarea level.

11.11.4 Assessment

Data are presented which in future may form the basis for an assessment. A benchmark was carried out for this functional unit in 2013 (WKNEPH, 2013) which advised to continue with the data limited approach at present with the aim of moving to a full underwater TV (UWTV) assessment (Category 1) in the near future.

Data available

Commercial catch and effort data

Overall landings from this fishery for 1986–2021 are presented in Table 11.11.1 and Figure 11.11.1. Landings gradually increased from 378 tonnes in 2005 to approximately 1300 tonnes in 2009 followed by a decline in the following years to 121 tonnes in 2013. In recent years landings increased again and in 2021, 875 tonnes were recorded (a 10% decrease in relation to 2021).

In previous years, concerns were expressed over the reliability of the effort figures provided for Scottish *Nephrops* trawlers; effort figures were unrealistically low in some areas. Investigation of the issue revealed a problem in the MSS Marine Laboratory database, where only the effort expended in the first statistical rectangle visited by a vessel during a trip was being output. This did not affect landings. An extraction of effort data by the Marine Scotland data unit in Edinburgh covering the four main trawl gears landing *Nephrops* into Scotland produced higher figures which capture all the effort.

Trends in Scottish effort and LPUE are shown in Figure 11.11.2 and Table 11.11.2. Combined effort for trawlers has declined over the time period showing generally a downwards trend and reaching its lowest point in 2013. The decrease may partly be explained as a result of reductions in available effort imposed by the effort management regime and partly because this ground is more remote than a number of other *Nephrops* grounds and costs of steaming to and from the ground are likely to be high. Effort decreased from the start of the time series until 2011 after which it has shown a fluctuating trend. LPUE increased until 2009, decreasing in the early 2010s to around 400 kg/day and in 2019 a marked increase was recorded in line with the landings rise, and it remains at a relatively high value (~800 kg/day) in 2021.

Length compositions

Levels of both market and discard sampling are low and data are only available from the Scottish fleet. Most observer sampling in FU 34 took place in the period 2008–2011. In the last ten years, occasional sampling events in observer trips targeting FU 7 reveal low levels of discarding in the fishery. No market samples were taken in 2012–2013 and in the following years only a few fishing trips were sampled. Mean sizes in the catch and landings from 2006 are shown in Table 11.11.3. Sampling has not been conducted in all quarters, so there is potential bias in these results.

InterCatch

Scottish data for 2021 were successfully uploaded into InterCatch prior the 2022 WG meeting according with the deadline proposed. Both landings and discard sampling have been very limited in recent years and Intercatch has been used mainly to record landings data from countries who submitted data into FU 34 (Scotland and England).

Length Base Indicators (LBI)

The terms of Reference for the 2018 WGNSSK meeting requested the WG to propose appropriate MSY proxies for a number of Category 3 and 4 stocks including (*Nephrops* FU 34) by using methods provided in the ICES Technical Guidelines (ICES, 2017) along with available data and expert judgement. For FU 34, only limited length frequency information is available with few landings and discard samples collected per year. An attempt was made to run the Length Base Indicators (LBI) screening method using data from 2014 to 2017 (Figure 11.11.7). In recent years, the low number of discard trips conducted within FU 34 showed discard rates to be approximately zero, therefore only landings data were used when applying the method.

Life history parameters such as L_{inf} and L_{mat} are required to run the LBI method. These parameters were taken from the stock annex for this FU although they were estimated and borrowed from other *Nephrops* stocks. The parameters used were L_{inf} = 66 mm CL and L_{mat} = 25 mm CL (for both males and females).

The results of the application of the LBI method for females and males are presented in the tables below. These show that indicators related to the conservation of immature individuals (L_c/L_{mat} and $L_{25\%}/L_{mat}$) were generally below reference points while other indicators were mostly above reference points. The LBI method applied to FU 34 was not considered to be conclusive due to the limited data available.

Nephrops in FU 34: Length-based indicators (LBI) for females (above) and males (below). Green indicates that the observed value for the indicator is above the respective reference point, red indicates that the indicator is below the reference point.

Females

	Conservation				Optimising yield	MSY
	Lc/Lmat	L25%/Lmat	Lmax5%/Linf	Pmega	Lmean/Lopt	Lmean/L(F=M)
Ref	>1	>1	>0.8	>0.3	~1(>0.9)	≥1
2014	1.32	1.48	0.69	0	0.89	0.95
2015	0.68	1.32	0.72	0.02	0.82	1.23
2016	1.08	1.16	0.67	0	0.77	0.92
2017	1.16	1.32	0.75	0.04	0.87	1

Males

	Conservation				Optimising yield	MSY
	Lc/Lmat	L25%/Lmat	Lmax5%/Linf	Pmega	Lmean/Lopt	Lmean/L(F=M)
Ref	>1	>1	>0.8	>0.3	~1(>0.9)	≥1
2014	1.56	1.56	0.74	0.03	0.95	0.91
2015	0.76	1.4	0.77	0.04	0.89	1.27
2016	1.24	1.32	0.74	0.03	0.87	0.97
2017	1.24	1.32	0.8	0.06	0.89	0.98

Natural mortality, maturity at age and other biological parameters

No specific data are available for this functional unit, but there may be potential to adapt parameters from other functional units which have apparently similar biological characteristics.

Research vessel data

Marine Scotland Science (MSS) have carried out UWTV surveys of the Devil's Hole area opportunistically over the past 15 years. Since 2009, VMS data (Figure 11.11.6) have been used to define the location of the survey stations. It is not known how station locations were selected on the earlier surveys in this area. It was not possible to survey FU 34 in 2013, 2016 and 2020 but the survey has continued in 2014, 2015, 2017–2019 and 2021. The most recent survey, conducted in the summer of 2021 (10 TV stations completed) gives an estimate of density of 0.28 burrows/m^2, a slight 3% decrease in relation to the previous 2019 estimate. A density distribution map of these surveys is shown in Figure 11.11.3 with the size of the symbol reflecting the *Nephrops* burrow density. Table 11.11.4 and Figure 11.11.4 show the time series of mean burrow densities and 95% confidence intervals. There was no survey carried out in FU 34 in 2022

11.11.5 Historical stock trends

Scottish landings from this area have risen substantially from 2005 to 2009 followed by a general decreasing trend until 2013 and increased again in recent years with 2021 being the fifth highest figure recorded in the time series. Estimates of mean density in the stock show an increasing trend since 2016.

11.11.6 Recruitment estimates

There are no recruitment estimates for this FU.

11.11.7 MSY considerations

There is currently insufficient catch-at-length data to conduct a combined length cohort analysis, and therefore F_{MSY} proxy harvest rates have not been calculated for this functional unit.

11.11.8 Short-term forecasts

The advice guidance and category classification for data-limited stocks (DLS) was addressed at WKLIFE2 (ICES 2012). The methodology for DLS *Nephrops* stocks is further described in the 2013 Benchmark report (ICES 2013). Following the procedure outlined (section 10.1), an estimate of the total *Nephrops* grounds was used to give a likely envelope for the total abundance of *Nephrops* in the FU 34 (see text table below). UWTV survey information on the mean density of *Nephrops* (0.28 *Nephrops*/m^2) from the 2021 UWTV survey, was used together with the mean weight in projected landings (average 2007–2010) and projected discard rate (average 2008–2011). The mean weight in projected discards used the information from FU 7 (average 2019–2021). The same advice as provided in 2020 of 566 tonnes (catch) results in a harvest ratio of 3.9%. Providing the harvest rate is less than 7.5%, the default basis for advice is the average landings of the last ten years (2012–2021), subject to the application of the uncertainty cap to restrict annual advice change to less than 20%. The 10-year average (2012-2021) results in a HR of 4.5% which is below the range of maximum sustainable yield (MSY) harvest rates in the North Sea (between 7.5% and 16%). Stock size in relation to reference points is unknown. The precautionary buffer was applied to this stock in the 2020 advice but not in the current advice (for 2023 and 2024). The proposed advice (given in 2022) for 2023 and 2024 is that catches should be no more than 652 tonnes (10-year average), which results in a 15.2% decrease from the previous advice. In line with the advice for other stocks, total catches, projected landings and projected discards expected under the landing obligation policy were added to the table. For data limited stocks the discard survival is assumed to be zero.

Basis for the catch scenarios.

Variable	Value	Notes
Stock density (2023)	0.28	Underwater TV (UWTV) survey in 2021 (UWTV was not completed in 2022); density in numbers m^{-2}
Mean weight in projected landings (2023)	31.76	Average 2007–2010 (benchmark estimate; ICES, 2013); grammes
Mean weight in projected discards (2023)	12.75	Average 2019–2021 (from FU 7); grammes
Projected total discard rate (2023)	12.9	Average 2008–2011 (benchmark estimate; ICES, 2013); percentage by number of the total catch.
Discard survival rate (2023)	0	Discard survival is assumed to be zero
Surface area estimate	1753	Benchmark estimate (ICES, 2013); km2

Sensitivity analysis of harvest rates for a range of potential densities for projected landings only (assuming discard rate of 12.9%). Shaded cells indicate harvest ratios above the MSY proxy harvest rate for this stock of 7.5%. All weights are in tonnes.

Basis	Total Catch	Projected landings	Projected discards	Range of potential densities (*Nephrops* m^{-2})								% advice change**
				0.05	0.1	0.15	0.2	0.28 *	0.4	0.6	0.8	
				Harvest rate in %								
Average landings (2012–2021) (Precautionary approach)	**652**	**615**	**37**	25	12.7	8.4	6.3	**4.5**	3.2	2.1	1.58	**-15.2**
Advice for 2021 and 2022 −20% cap	453	428	25	17.6	8.8	5.9	4.4	3.1	2.2	1.47	1.10	-20
Advice for 2021 and 2022	566	534	32	22	11.0	7.3	5.5	3.9	2.8	1.84	1.38	-0
Average landings (2012–2021)	652	615	37	25	12.7	8.4	6.3	4.5	3.2	2.1	1.58	-15.2
Advice for 2020 and 2022 +20% cap	679	641	38	26	13.2	8.8	6.6	4.7	3.3	2.2	1.65	20
Recent average landings (2019–2021)	1067	1007	60	42	20.8	13.8	10.4	7.4	5.2	3.5	2.6	88
MSY proxy harvest rate (HR)	1079	1018	61	42	21	14	10.5	7.5	5.2	3.5	2.6	91
Maximum landings	1383	1305	78	54	27	18	13.5	9.6	6.7	4.5	3.4	144

*Most recent abundance estimate (2021 UWTV survey). Harvest rates are calculated for dead removals and applied to total catch.

** Advice basis values for 2023 and 2024 relative to the advice value for 2021 and 2022 (catch advice of 566 tonnes).

11.11.9 Quality of the assessment

The time-series of underwater TV (UWTV) survey data is incomplete. Surveys were conducted in 2003 and 2005 and during the periods 2009–2012, 2014–2015, 2017–2019 and 2021.

Catch options (when provided) are based on a calculation of potential landing options and harvest rates, given the known surface area of Norway lobster habitat and observed densities of the functional unit. The surface area is based on an estimate of area derived from Scottish vessel monitoring system (VMS) data from Scottish Norway lobster vessels from 2006 to 2009. The area of ground shown in geological charts is significantly larger than this and landings have been made from these areas. Therefore, the area should be regarded as a minimum estimate and the harvest rate could well be lower than implied by the analysis.

In recent years, only limited sampling data of catches have been available for this stock. Therefore, mean weights in discards are borrowed from the adjacent FU 7 and are used in addition to historical data.

11.11.10 Status of the stock

The current state of the stock is unknown.

11.11.11 Management considerations

The WG, ACOM and STECF have repeatedly advised that management should be at a smaller scale than the ICES Division level. Management at the Functional Unit level could provide the controls to ensure that catch opportunities and effort were compatible and in line with the scale of the resource. In 2016–2017, catches increased substantially to levels well above ICES advice in 2016 and 2017, highlighting the issue that current management arrangements are not sufficient to contain the fishery within the sustainable limits determined by ICES.

There is a by-catch of other species in the Devil's Hole area. It is important that efforts are made to ensure that unwanted by-catch is kept to a minimum in this fishery.

This stock is under the landings obligation although there is a survivability exemption in place for *Nephrops* in the UK waters of the North Sea (ICES division 2.a and Subarea 4) with certain gears, according to the Marine Management Organization (MMO, 2021).

References:

ICES. 2012. Report of The Workshop to Finalize the ICES Data-limited Stock (DLS) Methodologies Documentation in an Operational Form for the 2013 Advice Season and to make Recommendations on Target Categories for Data-limited Stocks (WKLIFE II), 20–22 November 2012, Copenhagen, Den-mark. ICES CM 2012/ACOM:79. 46 pp.

ICES. 2013. Report of the Benchmark Workshop on Nephrops Stocks (WKNEPH), 25 February–1 March 2013, Lysekil, Sweden. ICES CM 2013/ACOM:45. 230 pp.

MMO, 2021. Fishing gear requirements and Landing Obligation exemptions 2022. Applicable to the *Nephrops* Fishery in UK waters of the North Sea. Document No.: V1. Date of Issue: December 2021. *Nephrops* in Subarea 4, outside the functional units (27.4outFU)

11.12 *Nephrops* in Subarea 4, outside the functional units (27.4outFU)

The fishery

The *Nephrops* fishery in Subarea 4 outside of the functional units is dominated by the Netherlands, Germany, Scotland, and Belgium, followed by England, Denmark and Sweden (Figure 11.12.1, Table 11.12.1). *Nephrops* are landed throughout the year although the main fishing season is the summer (mainly Q3), and the predominant gears are bottom otter trawl (OTB) and beam trawls (TBB) with 70–99 mm of mesh size. Landings by creel vessels are typically lower than 1.5%.

The *Nephrops* fishery outside of the functional units has fluctuated over time. Landings were 1166 tonnes in 2011, the first year with data. They then declined, reaching a minimum of 393 tonnes in 2014. This was followed by an increase to 1195 tonnes 2017. Except Scotland and Sweden, all countries decreased their landings in 2018 by 50–60% in comparison to 2017, while Scottish landings increased from 158 to 181 tonnes. Since then, landings have fluctuated within the 2012 – 2016 range.

Discards have been reported by Denmark since 2012 (but only negligible amounts since the first year), and by Netherlands since 2016. Scotland also reported discards in 2016, 2017, and 2019. The highest Dutch discards of 605 tonnes were reported in 2019, followed in magnitude by 551 tonnes in 2016 (Table 11.12.2). In 2020, Dutch reported discards dropped to 115 tonnes, decreasing further to 42 tonnes in 2021.

At WGNSSK 2022, the suggestion was made to analyse the spatial distribution of landings from the outside-FU area in more detailed. All nations participating in the *Nephrops* fishery in Subarea 4 provided annual landings by rectangle for the 2017 – 2021 period. On the basis of these data, the average annual landings by rectangle are shown in Figure 11.12.2. Over the past five years, the landings from the two southernmost rectangles within FU 5 have been low. The landings within the northeast corner of FU 5 seem to be connected to two neighbouring rectangles outside the functional unit, which are routinely fished by Belgium, the Netherlands, and Germany. An argument could therefore be made to reduce the current size of FU 5 by removing the two southernmost and the two easternmost rectangles, and by introducing a new functional unit that incorporates the three routinely fished rectangles in the northeast corner of FU 5 and links up with FU 33 from the south.

Advice in 2020

Subarea 4 outside the functional units is assessed every two years. The last assessment was conducted in 2020, and the outcome was that *"the state of Nephrops outside the functional units is unknown".*

No new information has emerged that would warrant a change to the previous advice:

"ICES advises that when the precautionary approach is applied, landings should be no more than 301 tonnes in each of the years 2021 and 2022. ICES cannot quantify the corresponding total catches."

Management

Management is at the ICES Subarea level as described in Section 10.1.

Assessment

The previous assessments of the Subarea 4 outside of the functional units has been based on the examination of the trends in landings, since they are the only information available in a consistent manner.

Catch scenarios

The ICES framework for Category 5 stocks was applied (ICES, 2012). For stocks without information on abundance or exploitation, ICES considers that a precautionary reduction of catches should be implemented, unless ancillary information clearly indicates that the current level of exploitation is appropriate for the stock. The precautionary buffer was applied for the previous advice in 2020.

Basis for the catch scenarios.

Advised landings for 2021–2022		301 tonnes
Discard rate		Unknown
Precautionary buffer	Not applied	
Landings advice		301 tonnes
% advice change *		0%

*** Advice value for 2023–2024 relative to the advice value for 2021–2022.**

Table 11.2.1. Nominal landings (tonnes, including BMS landings) of *Nephrops* in Subarea 4, 1984–2021, as officially reported to ICES.

	1984	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
Belgium	638	679	344	437	500	574	610	427	384	418	304	410	185	311	238
Denmark	7	50	323	479	409	508	743	880	581	691	1128	1182	1315	1309	1440
Faeroe Islands	-	-	-	0	0	0	0	0	0	1	3	12	0	1	1
France	-	-	-	7	0	0	0	0	0	0	0	0	0	0	0
Germany	.	.	.	0	0	0	0	2	2	16	24	16	69	64	58
Germany (Fed. Rep.)	5	4	5	1	2	1	2	0	0	0	0	0	0	627	
Netherlands	-	-	-	0	0	0	9	3	134	131	159	254	423	64	6945
Norway	1	1	1	2	17	17	46	117	125	107	171	74	83	1	93
Sweden	-	1	-	0	0	0	0	4	0	1	1	1	0		3
UK (Eng + Wales + NI)	.	.	.	0	0	2938	2332	1955	1451	2983	3613	2530	2462	2206	2094
UK (Eng + Wales)	1477	2052	2002	2173	2397	0	0	0	0	0	0	0	-	-	8980
UK (Scotland)	4158	5369	6190	5304	6527	7065	6871	7501	6898	8250	8850	10018	8981	10466	13602
Total	6286	8156	8865	8403	9852	11103	10613	10889	9575	12598	14253	14497	13518	15049	13602

Table 11.2.1 (continued). Nominal landings (tonnes, including BMS landings) of *Nephrops* in Subarea 4, 1984–2021, as officially reported to ICES.

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Belgium	350	252	283	284	229	213	180	214	205	200	265	115	295	374
Denmark	1963	1747	1935	2154	2128	2244	2339	2024	1408	1078	875	603	828	728
Faeroe Islands	1	0	-	-	-	-	-	-	-	-	-	-		
France	0	0	-	-	-	-	-	-	-	-	-	+		+
Germany	104	79	140	125	50	50	109	288	602	266	410	373	552	385
Netherlands	662	572	851	966	940	918	1019	982	1147	737	882	701	1012	1024
Norway	144	147	115	130	100	93	132	96	99	143	139	123	70	75
Sweden	4	37	26	14	1	1	3	1	5	26	2	1	1	1
UK (Eng + Wales + NI)	2431	2210	2691	1964	2295	2241	3236	4937	3295	1679	3437	-		
UK (Scotland)	10715	9834	9681	11045	10094	12912	10565	16165	17930	17960	18587	-		
UK	-	-	-	-	-	-		-	-	-	-	18941	14066	11108
Total	16374	14878	15722	16682	15838	18674	17583	24707	24691	22089	24597	20857	16824	13695

Table 11.2.1 (continued). Nominal landings (tonnes, including BMS landings) of *Nephrops* in Subarea 4, 1984–2021, as officially reported to ICES.

	2013	2014	2015	2016	2017	2018	2019	2020	2021
Belgium	303	494	349	880	1109	635	752	675	732
Denmark	387	624	515	755	594	100	343	307	687
Faeroe Islands	0	0	0	0	0	0	0	0	0
France	0	0	0	0	0	0	70	17	0
Germany	425	418	435	862	923	557	804	258	395
Ireland	0	1	0	0	0	0	1	0	0
Netherlands	910	1154	1113	1464	1418	803	1390	931	1275
Norway	63	63	81	98	94	103	103	97	81
Sweden	0		0	1	0	0	0	3	7
Isle of Man	-	-	-	-	-	-	-	-	5
UK	10685	13905	9457	13511	16317	13243	22176	11397	15540
Total	10713	13965	9318	13397	16049	13164	21808	13687	18723

* **Landings data for 2020 and 2021 are preliminary.**

Table 11.2.2. Summary of *Nephrops* landings from the ICES area, by Functional Unit, 1981–2021.

Year	FU 5	FU 6	FU 7	FU 8	FU 9	FU 10	FU 32	FU 33	FU 34	Other *	Total
1981		1073	372	1007	1416	35				76	3980
1982		2524	421	1195	1119	19				157	5437
1983		2078	693	1724	941	16				101	5551
1984		1479	646	2134	1169	111				88	5628
1985		2027	1147	1968	2081	22				139	7386
1986		2015	1543	2263	2143	67			23	204	8236
1987		2191	1695	1675	1992	45			5	195	7791
1988		2495	1575	2529	1959	76			2	364	8995
1989		3098	2299	1888	2576	84			28	233	10176
1990		2498	2540	1931	2037	218			26	222	9442
1991	862	2063	4223	1405	1520	197			85	560	10827
1992	612	1473	3363	1756	1591	188			106	401	9385
1993	721	3030	3492	2368	1809	376	339	160	44	434	12730
1994	503	3683	4568	1850	1537	494	755	137	129	703	14233
1995	869	2569	6419	1762	1279	279	489	164	132	844	14715
1996	679	2483	5210	1687	1451	345	952	77	129	808	13699
1997	1149	2189	6170	2193	1447	317	760	276	100	662	15163
1998	1111	2177	5136	2144	1032	256	836	350	88	694	13735
1999	1244	2391	6518	2207	1009	278	1119	724	202	988	16479
2000	1121	2178	5570	1785	1539	274	1084	597	184	900	15050
2001	1443	2574	5542	1527	1401	177	1190	791	271	1268	15915
2002	1231	1954	7245	1340	1132	403	1170	861	343	1383	16705
2003	1144	2245	6294	1127	1080	336	1089	929	675	1390	15633
2004	1070	2153	8730	1657	1333	228	922	1268	488	1224	18587
2005	1099	3094	10684	1989	1605	165	1089	1050	378	1120	21897
2006	974	4903	10791	2458	1805	133	11033	1288	448	1249	24627
2007	1294	2966	11911	2651	1843	153	755	1467	717	1637	24678
2008	963	1220	12239	2450	1515	172	675	1444	937	1673	22352
2009	728	2713	13327	2663	1067	87	477	1163	1305	2367	24593
2010	958	1443	12968	1950	1063	39	407	806	865	709**	20846
2011	1053	2072	7559	1889	1391	68	395	1191	432	1167^	17217
2012	1240	2460	4415	2129	866	13	310	1084	597	590	13704
2013	1050	2982	2951	1503	623	16	191	946	120	409	10791
2014	1416	2503	4147	2384	1253	15	205	1146	320	392	13765
2015	1517	1371	1784	1897	816	15	192	1003	440	610	9657

Year	FU 5	FU 6	FU 7	FU 8	FU 9	FU 10	FU 32	FU 33	FU 34	Other *	Total
2016	2535	1854	2399	1937	1146	23	178	1636	780	966	13454
2017	2109	1993	5155	2554	1143	9	147	1472	548	1195	16325
2018	1004	1881	4420	2698	1397	4	137	776	318	625	13260
2019	1172	4364	8931	2585	1356	21	191	1612	1167	724	22381
2020	540	1912	5543	1787	963	11	179	1186	980	531	13632
2021	1067	2022	9559	1835	1221	14	216	1371	875	636	18816

*** Includes Division 3.a.**

**** 695 t in Subarea 4 and 14 t in Division 3.a**

^ Subarea 4 only

Table 11.3.1. *Nephrops* in FU 5: Nominal Landings (tonnes) of *Nephrops*, 1991–2021, as reported to the WG.

	Belgium	Denmark	Netherlands	Germany	UK	Total*	Discards**
1991	682	176			4	862	
1992	571	22			19	612	
1993	694	20			7	721	
1994	494	0			9	503	
1995	641	77	148		3	869	
1996	266	41	317		55	679	
1997	486	67	540		56	1149	
1998	372	88	584	39	28	1111	
1999	436	53	538	59	158	1244	
2000	366	83	402	52	218	1121	
2001	353	145	553	114	278	1443	
2002	281	94	617	88	151	1231	
2003	265	36	661	24	158	1144	
2004	171	39	646	16	198	1070	
2005	109	87	654	51	198	1099	
2006	77	24	444	99	330	974	
2007	75	3	464	201	551	1294	
2008	49	29	268	108	509	963	
2009	52	3	288	98	287	728	
2010	48	5	354	140	411	958	
2011	60	18	480	145	350	1053	
2012	129	0	497	121	493	1240	
2013	142	1	447	168	292	1050	
2014	131	41	645	139	460	1416	
2015	146	0	681	184	506	1517	1352
2016	233	0	801	442	1059	2535	708
2017	416	0	745	374	574	2109	786
2018	234	1	429	204	136	1004	537
2019	194	0	551	284	143	1172	155

	Belgium	Denmark	Netherlands	Germany	UK	Total*	Discards**
2020	191	0	284	52	13	540	230
2021	314	37	603	101	12	1067	242

*** Totals for 1991–94 exclusive of landings by the Netherlands**
**** Reported Dutch discards, not raised**

Table 11.4.1. *Nephrops* in FU 6: Nominal Landings (tonnes) of *Nephrops*, 1981–2021, as reported to the WG.

Year	UK England & N. Ireland	UK Scotland	UK total	Other countries*	Total
1981	1006	67	1073	0	1073
1982	2443	81	2524	0	2524
1983	2073	5	2078	0	2078
1984	1471	8	1479	0	1479
1985	2009	18	2027	0	2027
1986	1987	28	2015	0	2015
1987	2158	33	2191	0	2191
1988	2390	105	2495	0	2495
1989	2930	168	3098	0	3098
1990	2306	192	2498	0	2498
1991	1884	179	2063	0	2063
1992	1403	60	1463	10	1473
1993	2941	89	3030	0	3030
1994	3530	153	3683	0	3683
1995	2478	90	2568	1	2569
1996	2386	96	2482	1	2483
1997	2109	80	2189	0	2189
1998	2029	147	2176	1	2177
1999	2197	194	2391	0	2391
2000	1947	231	2178	0	2178
2001	2319	255	2574	0	2574
2002	1739	215	1954	0	1954
2003	2031	214	2245	0	2245
2004	1952	201	2153	0	2153
2005	2936	158	3094	0	3094
2006	4430	434	4864	39	4903
2007	2525	437	2962	4	2966
2008	976	244	1220	0	1220
2009	2299	414	2713	0	2713
2010	1258	185	1443	0	1443
2011	1806	251	2057	15	2072
2012	2177	257	2434	26	2460
2013	2666	305	2971	11	2982

Year	UK England & N. Ireland	UK Scotland	UK total	Other countries*	Total
2014	2104	345	2449	54	2503
2015	1187	174	1361	10	1371
2016	1726	125	1851	3	1854
2017	1685	290	1975	18	1993
2018	1557	304	1861	20	1881
2019	3456	853	4309	55	4364
2020	1644	234	1878	34	1912
2021	1800	218	2018	4	2022

*** Other countries includes NL, BE, DK, and SE**

Table 11.4.2. *Nephrops* in FU 6: Mean carapace lengths (mm) in catches and landings by sex.

Year	Catches		Landings	
	Males	Females	Males	Females
1985	30.1	28.5	35.4	33.8
1986	31.7	30.2	35.3	33.7
1987	28.6	27	35.3	33.3
1988	28.7	27.3	35	33.9
1989	29	28.2	32.4	31.9
1990	27.1	27.4	31.8	31.3
1991	28.9	27.1	33.5	33.1
1992	30.8	29	33	31.9
1993	32.1	28.7	33.4	30.1
1994	30.5	27.7	33.8	30.5
1995	28.4	27.4	33.8	31.6
1996	29.8	28.2	34.5	32.1
1997	29.9	29.6	33.5	32.1
1998	30	28.9	34.9	33.7
1999	29.6	27.5	35.1	33.6
2000	27.2	26.8	31.1	31.3
2001	26.2	26.3	30.6	31.3
2002	28.0	26.9	30.9	30.0
2003	29.0	27.1	31.7	30.6
2004	29.2	27.0	32.3	30.6
2005	29.7	29.4	32.1	32.2
2006	29.0	30.3	31.4	32.4
2007	31.3	30.7	33.3	32.6
2008	31.5	31.1	33.5	33.3
2009	30.0	31.0	32.1	33.3
2010	31.2	31.4	32.8	33.2
2011	32.0	31.6	33.7	33.6

Year	Catches		Landings	
	Males	Females	Males	Females
2012	30.8	32.0	33.2	34.5
2013	29.6	32.4	32.0	35.4
2014	31.8	35.4	32.9	36.6
2015	31.5	31.7	33.9	34.9
2016	31.2	31.3	33.3	34.3
2017	32.4	32.1	34.1	34.7
2018	32.2	32.4	33.6	34.6
2019	32.1	32.8	33.4	34.6
2020	30.3	30.1	31.9	32.5
2021	30.8	28.3	33.0	31.2

Table 11.4.3. *Nephrops* in FU 6: Landings and effort by UK vessels targeting *Nephrops*

Year	Landings (tonnes)	Effort (kWd)	LPUE (kg/kWd)	Number of trips	Landings per trip (kg)	Days at sea	Landings per day at sea (kg)
2006	3046	3232136	0.942	7647	398	12577	242
2007	2208	2933270	0.753	6082	363	10893	203
2008	1207	1772977	0.681	4636	260	7313	165
2009	2267	2827506	0.802	6596	344	9685	234
2010	1438	1948707	0.738	4821	298	7017	205
2011	1816	1941503	0.935	5756	316	7776	234
2012	1997	2136594	0.935	6038	331	8410	237
2013	2315	2432936	0.952	6259	370	8787	263
2014	2032	2324575	0.874	5702	356	8022	253
2015	1139	1691667	0.673	4347	262	5925	192
2016	1519	1754167	0.866	5622	270	7555	201
2017	1178	1393107	0.845	4744	248	6032	195
2018	911	1398222	0.652	4258	214	5302	172
2019	1834	2410208	0.761	5860	313	7542	243
2020	873	1359463	0.642	3930	222	4957	176
2021	1157	1629491	0.710	4548	254	6640	174

Table 11.4.4. ***Nephrops*** **in FU 6: Results of the UWTV survey.**

Year	Stations	Season	Mean density (burrows/m²)	Absolute abundance (millions)	95% confidence interval (millions)	Method
1997	87	Autumn	0.46	1500	125	Box
1998	91	Autumn	0.33	1090	89	Box
1999	-	Autumn		No survey		Box
2000	-	Autumn		No survey		Box
2001	180	Autumn	0.56	1685	67	Box
2002	37	Autumn	0.33	1048	112	Box
2003	73	Autumn	0.33	1085	90	Box
2004	76	Autumn	0.43	1377	101	Box
2005	105	Autumn	0.49	1657	148	Box
2006	105	Autumn*	0.37	1244	114	Box
2007	105	Autumn*	0.28	858	23	Geostatistics
2008	95	Autumn*	0.31	987	39	Geostatistics
2009	76	Autumn*	0.22	682	38	Geostatistics
2010	95	Autumn*	0.25	785	21	Geostatistics
2011	97	Autumn*	0.28	878	17	Geostatistics
2012	97	Autumn*	0.24	758	13	Geostatistics
2013	110	Summer	0.23	706	18	Geostatistics
2014	110	Summer	0.24	755	18	Geostatistics
2015	110	Summer	0.18	565	13	Geostatistics
2016	110	Summer	0.22	697	19	Geostatistics
2017	110	Summer	0.29	902	21	Geostatistics
2018	109	Summer	0.31	950	23	Geostatistics
2019	86	Summer	0.37	1163	26	Geostatistics
2020	110	Summer	0.35	1102	24	Geostatistics
2021	110	Summer	0.31	982	22	Geostatistics
2022	109	Summer	0.28	878	20	Geostatistics

Table 11.4.5. *Nephrops* in FU 6: Individual mean weights in landings and discards, and observed harvest rate.

Year	UWTV abundance	Landings	Discards	Dead discards	Mean weight in landings (g)	Mean weight in discards (g)	Individuals landed	Individuals discarded	Individuals removed	Discard rate	Dead discard rate	Observed harvest rate
	millions	tonnes	tonnes	tonnes			millions	millions	millions	% by number	% by number	% by number
2001	1685	2574	2393	2034	20.60	9.62	125	249	336	66.6	56.6	20.0
2002	1048	1954	795	676	20.01	9.50	98	84	169	46.1	39.2	16.1
2003	1085	2245	716	608	21.89	9.56	103	75	166	42.2	35.9	15.3
2004	1377	2153	615	523	23.14	9.22	93	67	150	41.8	35.5	10.9
2005	1657	3094	715	608	23.58	10.32	131	69	190	34.6	29.4	11.5
2006	1244	4903	1051	893	22.53	10.58	218	99	302	31.3	26.6	24.3
2007	858	2966	432	367	24.95	10.89	119	40	153	25.0	21.3	17.8
2008	987	1220	166	141	26.63	10.97	46	15	59	24.9	21.1	5.9
2009	682	2713	461	392	24.45	10.54	111	44	148	28.3	24.1	21.7
2010	785	1443	201	171	25.18	11.74	57	17	72	23.0	19.5	9.2
2011	878	2072	246	209	27.05	11.02	77	22	96	22.6	19.2	10.9
2012	758	2460	345	293	27.34	10.16	90	34	119	27.4	23.3	15.7
2013	706	2982	450	383	27.60	9.79	108	46	147	29.9	25.4	20.8
2014	755	2503	199	169	29.93	13.59	84	15	96	14.9	12.7	12.7
2015	565	1371	190	162	29.28	10.01	47	19	63	28.8	24.5	11.1
2016	697	1854	272	231	28.03	10.24	66	27	89	28.7	24.4	12.7
2017	902	1993	200	170	29.38	10.29	68	19	84	22.3	18.9	9.4
2018	950	1881	195	166	28.14	11.22	67	17	82	20.6	17.5	8.6
2019	1163	4364	453	385	28.21	11.74	155	39	187	20.0	17.0	16.1
2020*	1102	1912	310	264	23.50	10.63	81	29	106	26.4	22.4	9.6
2021	982	2022	419	356	24.88	10.10	81	41	117	33.8	28.7	11.9
2022	878											

*** Discard rates and mean weights in landings and discards are adjusted according to the procedure described in Section 11.4.9.**

Table 11.5.1. ***Nephrops*****, Fladen (FU 7), Nominal Landings (tonnes) of** ***Nephrops*****, 1981–2021, as reported to the WG**

Year	UK Scotland				Denmark	Other countries **	Total
	Nephrops trawl	Other trawl	Creel	Sub-total			
1981	304	68	0	372	0	0	372
1982	381	40	0	421	0	0	421
1983	588	105	0	693	0	0	693
1984	552	94	0	646	0	0	646
1985	1020	120	0	1140	7	0	1147
1986	1401	92	0	1493	50	0	1543
1987	1023	349	0	1372	323	0	1695
1988	1309	185	0	1494	81	0	1575
1989	1724	410	0	2134	165	0	2299
1990	1703	598	0	2301	236	3	2540
1991	3021	772	0	3793	424	6	4223
1992	1809	1164	0	2973	359	31	3363
1993	2031	1234	0	3265	224	3	3492
1994	1816	2356	0	4172	390	6	4568
1995	3568	2389	19	5976	439	4	6419
1996	2338	2578	7	4923	286	1	5210
1997	2712	3221	0	5933	235	2	6170
1998	2290	2673	0	4963	173	0	5136
1999	2860	3546	0	6406	96	16	6518
2000	2916	2546	0	5462	103	5	5570
2001	3540	1936	0	5476	64	2	5542
2002	4511	2546	0	7057	173	15	7245
2003	4175	2033	0	6208	82	4	6294
2004	7274	1319	1	8594	136	0	8730
2005	8849	1508	5	10362	321	1	10684
2006	9470	1026	1	10497	283	11	10791
2007	11055	734	0	11789	119	3	11911
2008	11432	666	0	12098	133	8	12239
2009	12688	499	0	13187	130	10	13327
2010	12544	288	0	12832	124	12	12968
2011	7367	128	0	7495	64	<0.5	7559
2012	4257	81	0	4338	75	2	4415
2013	2275	663	0	2938	5	8	2951
2014	3928	206	0	4134	10	3	4147
2015	1465	307	0	1772	8	4	1784
2016	2021	374	0	2395	2	2	2399
2017	2862	2290	0	5152	1	2	5155
2018	2282	2133	0	4415	1	4	4420
2019	6702	2203	0	8905	7	19	8931
2020	3532	1991	0	5523	18	2	5543
2021*	7191	2286	0	9477	80	2	9559

* provisional

**Other countries includes Belgium, Norway, Netherlands, Sweden and UK England

Table 11.5.2. *Nephrops*, Fladen (FU 7): Landings, effort (days fishing) and LPUE (kg/day) for UK bottom trawlers landing in Scotland and fishing *Nephrops* with codend mesh sizes of 70 mm or above, 2000–2021.

Year	Landings (tonnes)	Effort (days)	LPUE (kg/day)
2000	5462	35367	154.4
2001	5476	28558	191.8
2002	7057	28586	246.9
2003	6208	21960	282.7
2004	8593	21562	398.5
2005	10357	23555	439.7
2006	10496	22836	459.6
2007	11789	21603	545.7
2008	12098	22856	529.3
2009	13187	21153	623.4
2010	12832	20968	612.0
2011	7495	15273	490.7
2012	4338	11994	361.7
2013	2938	11933	246.2
2014	4134	12629	327.3
2015	1772	10562	167.8
2016	2395	12297	194.8
2017	5152	15205	338.8
2018	4415	14431	305.9
2019	8905	15244	584.2
2020	5523	13543	407.8
2021*	9477	16351	579.6

*** Provisional**

Table 11.5.3. *Nephrops*, Fladen (FU 7): Logbook recorded effort (kW days) and LPUE (kg/kW day) for bottom trawlers catching *Nephrops* with cod end mesh sizes of 70 mm or above, and estimated total effort by Danish trawlers, 1991–2021.

Year	Logbook data	
	Effort	LPUE
1991	2522342	0.168
1992	1965624	0.183
1993	663625	0.338
1994	1044387	0.373
1995	716551	0.613
1996	538889	0.531
1997	283424	0.829
1998	210432	0.822
1999	153844	0.624
2000	266899	0.386
2001	142374	0.450
2002	217053	0.797
2003	105864	0.775
2004	212114	0.641
2005	430272	0.746
2006	363866	0.778
2007	160590	0.741
2008	121981	1.090
2009	114319	1.137
2010	129625	0.957
2011	67864	0.943
2012	129148	0.581
2013	130833	0.038
2014	168866	0.059
2015	70415	0.114
2016	117517	0.013
2017	135650	0.011
2018	121761	0.011
2019	172904	0.038
2020	126608	0.139
2021	252096	0.319

Table 11.5.4. *Nephrops*, Fladen (FU 7): Mean sizes (CL mm) above and below 35 mm of male and female *Nephrops* in Scottish catches and landings, 1993–2021.

Year	Catches		Landings			
	< 35 mm CL		< 35 mm CL		> 35 mm CL	
	Males	Females	Males	Females	Males	Females
1993	na	na	30.4	29.6	38.7	38.2
1994	na	na	30.0	28.9	39.2	37.8
1995	na	na	30.6	29.8	39.9	38.1
1996	na	na	30.4	29.1	40.6	38.8
1997	na	na	30.2	29.1	40.9	38.8
1998	na	na	30.8	29.4	40.7	38.3
1999	na	na	30.9	29.6	40.5	38.5
2000	30.7	30.1	31.2	30.5	41.3	38.7
2001	30.1	29.4	30.7	29.7	39.6	38.0
2002	30.6	30.0	31.3	30.7	39.5	38.3
2003	30.9	29.8	31.2	30.1	40.0	38.1
2004	30.8	29.9	31.1	30.2	40.1	38.7
2005	30.9	30.0	31.2	30.1	40.1	38.2
2006	30.3	29.7	30.8	30.0	40.7	38.2
2007	29.8	29.2	30.4	29.5	40.8	38.8
2008	29.7	28.6	29.8	28.7	41.8	39.1
2009	30.7	29.5	31.2	29.9	39.7	38.7
2010	30.4	29.0	30.5	29.0	39.8	38.4
2011	31.7	29.6	31.7	29.6	41.2	38.6
2012	31.9	30.6	31.9	30.6	41.8	38.5
2013	31.4	30.2	31.4	30.2	42.2	39.0
2014	30.4	30.1	30.8	30.2	411.5	39.2
2015	32.3	31.2	32.3	31.2	41.5	40.0
2016	32.0	31.0	32.0	31.0	41.2	40.6
2017	29.5	29.1	29.7	29.4	41.4	39.7
2018	31.3	29.7	31.3	29.7	39.7	40.0
2019	30.8	29.1	30.9	29.2	38.8	39.4
2020	31.6	30.5	31.8	30.7	40.1	39.6
2021	31.5	30.8	31.7	30.9	40.4	38.4

na = not available

Table 11.5.5. *Nephrops*, FUs 7–9 and 34 (Fladen, Firth of Forth, Moray Firth and Devil's Hole: Mean weight (g) in the landings.

Year	Fladen	Firth of Forth	Moray Firth	Devil's Hole	Noup
1990	31.59	20.29	20.05	Na	Na
1991	26.50	20.03	18.53	Na	Na
1992	29.61	20.96	23.49	Na	Na
1993	25.38	24.30	23.42	Na	Na
1994	23.72	19.51	22.25	Na	Na
1995	27.51	19.55	20.59	Na	Na
1996	29.82	20.81	21.40	Na	Na
1997	32.08	18.87	20.43	Na	23.94
1998	31.37	18.23	20.47	Na	20.58
1999	30.55	20.05	21.79	Na	21.23
2000	36.35	21.83	25.44	Na	30.81
2001	25.10	21.22	24.18	Na	25.30
2002	27.93	19.62	27.68	Na	27.95
2003	30.15	22.31	23.32	Na	20.05
2004	30.98	22.45	27.57	Na	28.98
2005	29.05	22.33	23.84	Na	24.13
2006	29.25	21.43	22.34	22.93	25.97
2007	26.63	20.97	23.04	26.27	25.58
2008	28.18	17.23	25.29	30.08	33.18
2009	28.20	19.41	23.46	39.62	49.38
2010	26.38	19.76	26.94	31.08	51.93
2011	36.17	19.75	21.63	42.05	45.73
2012	36.91	21.66	23.16	Na	34.48
2013	34.90	19.30	24.95	Na	43.56
2014	43.11	24.30	28.94	50.09	68.31
2015	36.70	21.84	29.10	48.75	Na
2016	39.43	23.62	26.83	33.51	35.61
2017	25.37	23.07	26.34	42.94	27.67
2018	30.58	24.29	28.86	40.91	Na
2019	28.31	21.81	25.13	35.83	33.01
2020	35.26	28.75	26.63	36.20	Na
2021	35.68	23.78	29.41	34.32	35.56
Mean (2019–2021)	33.08	24.78	27.06	31.76*	-

*** Mean weight for Devil's Hole based on 2007–2010 range (WKNEPH, 2013)**

Na = not available

Table 11.5.6. *Nephrops*, Fladen (FU 7): Results of the 1992–2022 TV surveys

Year	Stations	Abundance	Mean density	95% confidence interval
		Millions	burrows/m2	millions
1992	69	3661	0.13	376
1993	74	4450	0.16	569
1994	59	6170	0.22	814
1995	61	4987	0.18	896
1996		No survey		
1997	56	2767	0.10	510
1998	60	3838	0.13	717
1999	62	4146	0.15	649
2000	68	3628	0.13	491
2001	50	4981	0.17	970
2002	54	6087	0.21	757
2003	55	5547	0.20	1076
2004	52	5725	0.20	1030
2005	72	4325	0.16	662
2006	69	4862	0.17	619
2007	82	7017	0.25	730
2008	74	7360	0.26	1019
2009	59	5457	0.19	772
2010	67	5224	0.19	710
2011	73	3382	0.12	435
2012	70	2748	0.10	392
2013	71	2902	0.10	336
2014	70	2990	0.11	412
2015	71	2569	0.09	320
2016	78	4449	0.16	662
2017	71	7036	0.25	968
2018	71	5656	0.20	689
2019	70	6129	0.22	802
2020	61	4589	0.16	688
2021	70	6336	0.23	697
2022	70	5550	0.20	700

Table 11.5.7. *Nephrops*, Fladen Ground (FU 7): Summary of TV results for most recent 3 years (2020–2022) showing strata surveyed, numbers of stations in each strata, mean density and observed variance, overall abundance and variance raised to stratum area. Proportion indicates relative amounts of overall raised variance attributable to each stratum.

Stratum (ranges of % silt clay)	Area (km^2)	Number of Stations	Mean burrow density (no./m^2)	Observed variance	Abundance (millions)	Stratum variance	Proportion of total variance
2020 TV survey							
>80	3248	10	0.196	0.002	637.6	2255	0.019
55<80	4967	11	0.224	0.008	1113.7	17548	0.148
40<55	4304	11	0.16	0.012	689.7	19867	0.168
<40	15634	29	0.138	0.009	2148.4	78539	0.664
Total	28153	61			4589.4	118209	1
2021 TV survey							
>80	3248	9	0.299	0.007	973	8540	0.07
55<80	4967	13	0.301	0.010	1497	20118	0.165
40<55	4304	13	0.274	0.010	1180	15191	0.125
<40	15634	35	0.172	0.011	2687	77714	0.639
Total	28153	70			6336	121563	1
2022 TV survey							
>80	3248	9	0.381	0.009	1238	10325	0.084
55<80	4967	14	0.273	0.015	1359	26779	0.219
40<55	4304	11	0.249	0.014	1072	23008	0.188
<40	15634	36	0.120	0.009	1882	62253	0.509
Total	28153	70			5550	122366	1

Table 11.5.8. *Nephrops*, Fladen (FU 7): Adjusted TV survey abundance, landings, total discard rate (proportion by number), dead discard rate and estimated harvest ratio 1992–2022.

Year	Adjusted abundance (millions)	95% CI	Harvest ratio	Landings numbers	Discards numbers	Removals numbers	Landings (tonnes)	Discards (tonnes)	Dead Discards (tonnes)	Discard rate	Mean weight in landings	Mean weight in discards	Dead discard rate
1992	3661	376	3.1	114	NA	NA	3363	NA	0	NA	29.61	NA	NA
1993	4450	569	3.1	138	NA	NA	3492	NA	0	NA	25.38	NA	NA
1994	6170	814	3.1	193	NA	NA	4568	NA	0	NA	23.72	NA	NA
1995	4987	896	4.7	233	NA	NA	6419	NA	0	NA	27.51	NA	NA
1996	NA	NA	NA	175	NA	NA	5210	NA	0	NA	29.82	NA	NA
1997	2767	510	7.0	192	NA	NA	6170	NA	0	NA	32.08	NA	NA
1998	3838	717	4.3	164	NA	NA	5136	NA	0	NA	31.37	NA	NA
1999	4146	649	5.1	213	NA	NA	6518	NA	0	NA	30.55	NA	NA
2000	3628	491	4.7	153	21	169	5570	340	255	12.0	36.35	16.24	9.3
2001	4981	970	5.1	221	43	253	5542	687	515	16.3	25.1	15.94	12.8
2002	6087	757	4.9	259	55	301	7245	820	615	17.4	27.93	14.97	13.7
2003	5547	1076	4.1	209	24	226	6294	349	262	10.1	30.15	14.83	7.8
2004	5725	1030	5.4	282	34	307	8730	506	379	10.6	30.98	15.06	8.2
2005	4325	662	9.3	368	46	403	10684	823	617	11.2	29.05	17.74	8.6
2006	4862	619	8.4	369	54	409	10791	798	599	12.7	29.25	14.87	9.8
2007	7017	730	7.0	447	55	488	11911	747	560	10.9	26.63	13.67	8.4
2008	7360	1019	6.1	434	18	448	12239	257	192	3.9	28.18	14.54	3.0
2009	5457	772	9.4	473	51	511	13327	707	530	9.7	28.20	13.85	7.5
2010	5224	711	9.9	492	34	517	12968	560	420	6.5	26.38	16.44	4.9
2011	3382	435	6.2	209	0	209	7559	0	0	0	36.17	NA	0
2012	2748	392	4.7	128	0	128	4415	0	0	0	36.91	NA	0
2013	2902	335	3.1	89	0	89	2951	0	0	0.024	34.90	NA	0.0181
2014	2990	412	3.5	102	3	104	4147	37	28	2.5	43.11	13.9	1.92

Year	Adjusted abundance (millions)	95% CI	Harvest ratio	Landings numbers	Discards numbers	Removals numbers	Landings (tonnes)	Discards (tonnes)	Dead Discards (tonnes)	Discard rate	Mean weight in landings	Mean weight in discards	Dead discard rate
2015	2569	320	1.97	51	0	51	1784	0	0	0	36.7	NA	0
2016	4449	662	1.43	63	0	63	2399	0	0	0.022	39.43	NA	0.0167
2017	7036	968	3.1	212	10	219	5155	115	86	4.4	25.37	11.66	3.4
2018	5656	689	2.8	155	5	159	4420	68	51	2.9	30.58	14.42	2.2
2019	6129	802	5.6	338	8	344	8931	100	75	2.2	28.31	13.32	1.64
2020	4589	688	3.7	166	2	168	5543	28	21	1.4	35.26	11.74	1.06
2021	6336	697	4.7	293	5	296	9559	66	50	1.69	35.68	13.19	1.28
2022	5550	700	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table 11.6.1 *Nephrops*. Firth of Forth (FU 8), Nominal Landings (tonnes) of *Nephrops*, 1981–2021, as reported to the WG.

Year	UK Scotland					UK	Total **
	Nephrops trawl	Other trawl	Creel	BMS	Sub-total	(E, W & NI)	
1981	947	60	0	0	1007	0	1007
1982	1138	57	0	0	1195	0	1195
1983	1681	43	0	0	1724	0	1724
1984	2078	56	0	0	2134	0	2134
1985	1907	61	0	0	1968	0	1968
1986	2204	59	0	0	2263	0	2263
1987	1583	90	2	0	1675	0	1675
1988	2455	74	0	0	2529	0	2529
1989	1834	53	0	0	1887	1	1888
1990	1900	30	0	0	1930	1	1931
1991	1362	43	0	0	1405	0	1405
1992	1715	41	0	0	1756	0	1756
1993	2349	17	0	0	2366	2	2368
1994	1827	17	0	0	1844	6	1850
1995	1707	53	0	0	1760	2	1762
1996	1621	66	0	0	1687	0	1687
1997	2136	55	0	0	2191	2	2193
1998	2105	37	0	0	2142	2	2144
1999	2193	10	1	0	2204	3	2207
2000	1775	9	0	0	1784	1	1785
2001	1484	34	0	0	1518	9	1527
2002	1302	31	1	0	1334	6	1340
2003	1116	8	0	0	1124	3	1127
2004	1650	4	0	0	1654	3	1657
2005	1974	0	4	0	1978	11	1989
2006	2438	3	12	0	2453	5	2458
2007	2627	10	7	0	2644	7	2651
2008	2435	2	8	0	2445	5	2450
2009	2620	8	26	0	2654	9	2663
2010	1923	5	13	0	1941	9	1950
2011	1789	6	89	0	1884	5	1889
2012	1944	17	126	0	2087	42	2129
2013	1409	24	58	0	1491	12	1503
2014	2344	4	14	0	2362	22	2384
2015	1784	2	43	0	1829	68	1897

Year	UK Scotland					UK	Total **
	Nephrops trawl	Other trawl	Creel	BMS	Sub-total	(E, W & NI)	
2016	1786	1	116	2	1903	32	1935
2017	2472	11	10	0	2493	61	2554
2018	2646	7	4	0	2657	41	2698
2019	2531	10	5	0	2546	39	2585
2020*	1768	3	0	0	1771	16	1787
2021*	1697	112	2	15	1811	9	1820

*** provisional na = not available**

**** There are no landings by other countries from this FU**

Table 11.6.2 *Nephrops*, Firth of Forth (FU 8): Landings, effort (days fishing) and LPUE (kg/day) for UK bottom trawlers landing in Scotland and fishing *Nephrops* with codend mesh sizes of 70 mm or above, 2000–2021.

Year	Landings (tonnes)	Effort (days)	LPUE (kg/day)
2000	1784	10508	169.8
2001	1518	11513	131.9
2002	1333	10394	128.2
2003	1124	8279	135.8
2004	1654	9505	174.0
2005	1974	7704	256.2
2006	2441	6174	395.4
2007	2637	6409	411.5
2008	2437	6440	378.4
2009	2628	5852	449.1
2010	1928	5054	381.5
2011	1795	4614	389.0
2012	1961	5058	387.7
2013	1433	4029	355.7
2014	2348	6812	344.7
2015	1786	6024	296.5
2016	1787	5224	342.1
2017	2483	5261	472.0
2018	2653	4886	543.0
2019	2541	5116	496.7
2020	1771	4159	425.8
2021*	1809	3494	517.7

*** provisional na = not available**

Table 11.6.3 *Nephrops*, Firth of Forth (FU 8): Mean sizes (CL mm) above and below 35 mm of male and female *Nephrops* in Scottish catches and landings, 1981–2021.

Year	Catches		Landings			
	<35 mm CL		<35 mm CL		>35 mm CL	
	Males	Females	Males	Females	Males	Females
1981	na	na	31.5	31.0	39.7	38.7
1982	na	na	30.4	30.1	40.0	39.1
1983	na	na	31.1	30.8	40.2	38.7
1984	na	na	30.3	29.7	39.4	38.4
1985	na	na	30.6	29.9	39.4	38.2
1986	na	na	29.7	29.2	39.1	38.5
1987	na	na	29.9	29.6	39.1	38.2
1988	na	na	28.5	28.5	39.1	39.0
1989	na	na	29.2	28.9	38.7	38.9
1990	28.9	27.8	29.8	28.6	38.3	38.8
1991	28.7	27.5	29.8	28.7	38.3	38.7
1992	29.5	27.9	30.2	28.7	38.1	38.7
1993	28.7	28.0	30.3	29.5	39.0	38.6
1994	25.7	25.1	29.1	28.5	38.8	37.8
1995	27.9	27.1	29.4	28.9	38.7	37.9
1996	28.0	27.4	29.8	28.8	38.6	38.6
1997	27.2	27.0	29.2	28.7	38.8	38.2
1998	27.7	26.4	29.0	27.9	38.5	38.4
1999	27.2	26.5	29.6	28.8	38.0	37.9
2000	28.5	27.2	30.6	29.8	38.2	38.3
2001	28.1	27.0	30.6	29.2	38.0	37.9
2002	27.1	26.3	29.8	29.3	38.3	37.9
2003	27.2	25.4	30.2	29.1	38.1	38.0
2004	28.6	27.8	30.7	30.0	38.4	37.6
2005	27.6	26.9	30.3	30.0	38.7	38.2
2006	27.3	27.0	29.8	29.9	38.7	37.8
2007	29.2	28.3	29.8	28.6	39.1	38.6
2008	27.7	27.2	28.1	26.9	39.4	37.9
2009	27.5	26.2	29.7	28.5	38.3	38.0
2010	28.3	26.9	29.8	28.4	38.6	38.2
2011	28.6	27.5	30.0	28.3	38.8	38.2
2012	28.4	28.0	30.4	29.3	39.0	38.1
2013	28.3	27.4	29.6	28.8	38.8	37.9
2014	29.6	29.1	31.1	30.3	38.6	38.1
2015	27.9	28.3	29.5	29.3	39.6	38.5

Year	Catches		Landings			
	<35 mm CL		<35 mm CL		>35 mm CL	
	Males	Females	Males	Females	Males	Females
2016	29.3	28.6	30.5	29.7	39.4	38.5
2017	29.6	28.1	30.9	29.3	38.5	38.9
2018	29.2	28.6	30.1	29.5	39.1	39.1
2019	28.1	27.0	29.7	28.1	39.2	38.5
2020	30.5	29.7	31.4	30.3	39.5	39.4
2021	29.9	28.4	30.9	29.2	39.0	38.4

na = not available

Table 11.6.4. *Nephrops*, Firth of Forth (FU 8): Results of the 1993–2021 TV surveys.

Year	Stations	Mean Density	Abundance	95% conf interval
		Burrows/m²	millions	millions
1993	37	0.61	555	142
1994	30	0.49	448	78
1995		no survey		
1996	27	0.41	375	88
1997		no survey		
1998	32	0.32	292	81
1999	49	0.51	463	78
2000	53	0.48	443	70
2001	46	0.46	419	79
2002	41	0.56	508	119
2003	36	0.84	767	138
2004	37	0.69	630	141
2005	54	0.78	710	143
2006	43	0.91	827	125
2007	49	0.76	692	132
2008	38	0.97	881	297
2009	45	0.80	732	142
2010	39	0.75	682	147
2011	45	0.58	533	87
2012	66	0.57	522	64
2013	51	0.73	668	125
2014	51	0.47	428	80
2015	51	0.73	664	127
2016	50	0.87	797	146
2017	52	0.73	670	133

Year	Stations	Mean Density	Abundance	95% conf interval
		Burrows/m²	millions	millions
2018	50	1.12	1025	190
2019	50	0.95	865	135
2020	34	1.22	1119	180
2021	41	0.92	837	107
2022		no survey		

Table 11.6.5. *Nephrops*, Firth of Forth (FU 8): Summary of TV results for most recent 3 years (2019–2021) showing strata surveyed, numbers of stations in each strata, mean density and observed variance, overall abundance and variance raised to stratum area. Proportion indicates relative amounts of overall raised variance attributable to each stratum.

Stratum	Area (km²)	Number of Stations	Mean burrow density (no./m²)	Observed variance	Abundance (millions)	Stratum variance	Proportion of total variance
2019 TV survey							
M & SM	170	8	0.950	0.243	162	886	0.196
MS(west)	139	9	0.593	0.246	82	529	0.117
MS(mid)	211	12	1.264	0.306	266	1130	0.25
MS(east)	395	21	0.898	0.266	355	1982	0.438
Total	915	50			865	4527	1
2020 TV survey							
M & SM	170	6	1.438	0.795	245.1	3852	0.475
MS(west)	139	5	1.407	0.339	195.4	1309	0.162
MS(mid)	211	8	1.41	0.358	296.9	1986	0.245
MS(east)	395	15	0.967	0.092	381.9	954	0.118
Total	915	34			1119.3	8102	1
2021 TV survey							
M & SM	170	6	1.017	0.097	173	470	0.165
MS(west)	139	5	0.654	0.173	91	666	0.234
MS(mid)	211	12	0.865	0.175	182	644	0.227
MS(east)	395	18	0.989	0.123	391	1062	0.374
Total	915	41			837	2843	1

Table 11.6.1 *Nephrops*. Firth of Forth (FU 8), Nominal Landings (tonnes) of *Nephrops*, 1981–2021, as reported to the WG.

Year	UK Scotland					UK	Total **
	Nephrops trawl	Other trawl	Creel	BMS	Sub-total	(E, W & NI)	
1981	947	60	0	0	1007	0	1007
1982	1138	57	0	0	1195	0	1195
1983	1681	43	0	0	1724	0	1724
1984	2078	56	0	0	2134	0	2134
1985	1907	61	0	0	1968	0	1968
1986	2204	59	0	0	2263	0	2263

Year	UK Scotland					UK	Total **
	Nephrops trawl	Other trawl	Creel	BMS	Sub-total	(E, W & NI)	
1987	1583	90	2	0	1675	0	1675
1988	2455	74	0	0	2529	0	2529
1989	1834	53	0	0	1887	1	1888
1990	1900	30	0	0	1930	1	1931
1991	1362	43	0	0	1405	0	1405
1992	1715	41	0	0	1756	0	1756
1993	2349	17	0	0	2366	2	2368
1994	1827	17	0	0	1844	6	1850
1995	1707	53	0	0	1760	2	1762
1996	1621	66	0	0	1687	0	1687
1997	2136	55	0	0	2191	2	2193
1998	2105	37	0	0	2142	2	2144
1999	2193	10	1	0	2204	3	2207
2000	1775	9	0	0	1784	1	1785
2001	1484	34	0	0	1518	9	1527
2002	1302	31	1	0	1334	6	1340
2003	1116	8	0	0	1124	3	1127
2004	1650	4	0	0	1654	3	1657
2005	1974	0	4	0	1978	11	1989
2006	2438	3	12	0	2453	5	2458
2007	2627	10	7	0	2644	7	2651
2008	2435	2	8	0	2445	5	2450
2009	2620	8	26	0	2654	9	2663
2010	1923	5	13	0	1941	9	1950
2011	1789	6	89	0	1884	5	1889
2012	1944	17	126	0	2087	42	2129
2013	1409	24	58	0	1491	12	1503
2014	2344	4	14	0	2362	22	2384
2015	1784	2	43	0	1829	68	1897
2016	1786	1	116	2	1903	32	1935
2017	2472	11	10	0	2493	61	2554
2018	2646	7	4	0	2657	41	2698
2019	2531	10	5	0	2546	39	2585
2020*	1768	3	0	0	1771	16	1787
2021*	1697	112	2	15	1811	9	1820

*** provisional na = not available**

**** There are no landings by other countries from this FU**

Table 11.6.2 *Nephrops*, Firth of Forth (FU 8): Landings, effort (days fishing) and LPUE (kg/day) for UK bottom trawlers landing in Scotland and fishing *Nephrops* with codend mesh sizes of 70 mm or above, 2000–2021.

Year	Landings (tonnes)	Effort (days)	LPUE (kg/day)
2000	1784	10508	169.8
2001	1518	11513	131.9
2002	1333	10394	128.2
2003	1124	8279	135.8
2004	1654	9505	174.0
2005	1974	7704	256.2
2006	2441	6174	395.4
2007	2637	6409	411.5
2008	2437	6440	378.4
2009	2628	5852	449.1
2010	1928	5054	381.5
2011	1795	4614	389.0
2012	1961	5058	387.7
2013	1433	4029	355.7
2014	2348	6812	344.7
2015	1786	6024	296.5
2016	1787	5224	342.1
2017	2483	5261	472.0
2018	2653	4886	543.0
2019	2541	5116	496.7
2020	1771	4159	425.8
2021*	1809	3494	517.7

*** provisional na = not available**

Table 11.6.3 *Nephrops*, Firth of Forth (FU 8): Mean sizes (CL mm) above and below 35 mm of male and female *Nephrops* in Scottish catches and landings, 1981–2021.

Year	Catches		Landings			
	<35 mm CL		<35 mm CL		>35 mm CL	
	Males	Females	Males	Females	Males	Females
1981	na	na	31.5	31.0	39.7	38.7
1982	na	na	30.4	30.1	40.0	39.1
1983	na	na	31.1	30.8	40.2	38.7
1984	na	na	30.3	29.7	39.4	38.4
1985	na	na	30.6	29.9	39.4	38.2
1986	na	na	29.7	29.2	39.1	38.5
1987	na	na	29.9	29.6	39.1	38.2
1988	na	na	28.5	28.5	39.1	39.0
1989	na	na	29.2	28.9	38.7	38.9
1990	28.9	27.8	29.8	28.6	38.3	38.8
1991	28.7	27.5	29.8	28.7	38.3	38.7
1992	29.5	27.9	30.2	28.7	38.1	38.7
1993	28.7	28.0	30.3	29.5	39.0	38.6
1994	25.7	25.1	29.1	28.5	38.8	37.8
1995	27.9	27.1	29.4	28.9	38.7	37.9
1996	28.0	27.4	29.8	28.8	38.6	38.6
1997	27.2	27.0	29.2	28.7	38.8	38.2
1998	27.7	26.4	29.0	27.9	38.5	38.4
1999	27.2	26.5	29.6	28.8	38.0	37.9
2000	28.5	27.2	30.6	29.8	38.2	38.3
2001	28.1	27.0	30.6	29.2	38.0	37.9
2002	27.1	26.3	29.8	29.3	38.3	37.9
2003	27.2	25.4	30.2	29.1	38.1	38.0
2004	28.6	27.8	30.7	30.0	38.4	37.6
2005	27.6	26.9	30.3	30.0	38.7	38.2
2006	27.3	27.0	29.8	29.9	38.7	37.8
2007	29.2	28.3	29.8	28.6	39.1	38.6
2008	27.7	27.2	28.1	26.9	39.4	37.9
2009	27.5	26.2	29.7	28.5	38.3	38.0
2010	28.3	26.9	29.8	28.4	38.6	38.2
2011	28.6	27.5	30.0	28.3	38.8	38.2
2012	28.4	28.0	30.4	29.3	39.0	38.1
2013	28.3	27.4	29.6	28.8	38.8	37.9
2014	29.6	29.1	31.1	30.3	38.6	38.1
2015	27.9	28.3	29.5	29.3	39.6	38.5

Year	Catches		Landings			
	<35 mm CL		<35 mm CL		>35 mm CL	
	Males	Females	Males	Females	Males	Females
2016	29.3	28.6	30.5	29.7	39.4	38.5
2017	29.6	28.1	30.9	29.3	38.5	38.9
2018	29.2	28.6	30.1	29.5	39.1	39.1
2019	28.1	27.0	29.7	28.1	39.2	38.5
2020	30.5	29.7	31.4	30.3	39.5	39.4
2021	29.9	28.4	30.9	29.2	39.0	38.4

na = not available

Table 11.6.4. *Nephrops*, Firth of Forth (FU 8): Results of the 1993–2021 TV surveys.

Year	Stations	Mean Density	Abundance	95% conf interval
		Burrows/m^2	millions	millions
1993	37	0.61	555	142
1994	30	0.49	448	78
1995		no survey		
1996	27	0.41	375	88
1997		no survey		
1998	32	0.32	292	81
1999	49	0.51	463	78
2000	53	0.48	443	70
2001	46	0.46	419	79
2002	41	0.56	508	119
2003	36	0.84	767	138
2004	37	0.69	630	141
2005	54	0.78	710	143
2006	43	0.91	827	125
2007	49	0.76	692	132
2008	38	0.97	881	297
2009	45	0.80	732	142
2010	39	0.75	682	147
2011	45	0.58	533	87
2012	66	0.57	522	64
2013	51	0.73	668	125
2014	51	0.47	428	80
2015	51	0.73	664	127
2016	50	0.87	797	146
2017	52	0.73	670	133

Year	Stations	Mean Density	Abundance	95% conf interval
		Burrows/m²	millions	millions
2018	50	1.12	1025	190
2019	50	0.95	865	135
2020	34	1.22	1119	180
2021	41	0.92	837	107
2022		no survey		

Table 11.6.5. *Nephrops*, Firth of Forth (FU 8): Summary of TV results for most recent 3 years (2019–2021) showing strata surveyed, numbers of stations in each strata, mean density and observed variance, overall abundance and variance raised to stratum area. Proportion indicates relative amounts of overall raised variance attributable to each stratum.

Stratum	Area (km²)	Number of Stations	Mean burrow density (no./m²)	Observed variance	Abundance (millions)	Stratum variance	Proportion of total variance
2019 TV survey							
M & SM	170	8	0.950	0.243	162	886	0.196
MS(west)	139	9	0.593	0.246	82	529	0.117
MS(mid)	211	12	1.264	0.306	266	1130	0.25
MS(east)	395	21	0.898	0.266	355	1982	0.438
Total	915	50			865	4527	1
2020 TV survey							
M & SM	170	6	1.438	0.795	245.1	3852	0.475
MS(west)	139	5	1.407	0.339	195.4	1309	0.162
MS(mid)	211	8	1.41	0.358	296.9	1986	0.245
MS(east)	395	15	0.967	0.092	381.9	954	0.118
Total	915	34			1119.3	8102	1
2021 TV survey							
M & SM	170	6	1.017	0.097	173	470	0.165
MS(west)	139	5	0.654	0.173	91	666	0.234
MS(mid)	211	12	0.865	0.175	182	644	0.227
MS(east)	395	18	0.989	0.123	391	1062	0.374
Total	915	41			837	2843	1

Table 11.6.6. *Nephrops*, Firth of Forth (FU 8): Adjusted TV survey abundance, landings, total discard rate (proportion by number), dead discard rate and estimated harvest ratio 1993–2021.

Year	Adjusted abundance (millions)	95% CI	Harvest ratio	Landings numbers	Discards numbers	Removals numbers	Landings (tonnes)	Discards (tonnes)	Dead Discards (tonnes)	Discard rate	Mean weight in landings	Mean weight in discards	Dead discard rate
1993	555	142	24	97	49	134	2368	567	426	33	24.3	11.64	27
1994	448	78	51	95	180	230	1850	1584	1188	66	19.51	8.79	59
1995	NA	NA	NA	90	59	134	1762	620	465	40	19.55	10.54	33
1996	375	88	37	81	78	140	1687	930	697	49	20.81	11.85	42
1997	NA	NA	NA	116	56	158	2193	494	371	33	18.87	8.79	27
1998	292	81	56	118	60	163	2144	578	434	34	18.23	9.6	28
1999	463	78	40	110	97	183	2207	938	704	47	20.05	9.63	40
2000	443	70	34	82	90	150	1785	1032	774	52	21.83	11.42	45
2001	419	79	25	72	45	106	1527	436	327	39	21.22	9.59	32
2002	508	119	21	68	52	107	1340	421	316	43	19.62	8.16	36
2003	767	138	12.4	51	59	95	1127	546	410	54	22.31	9.25	47
2004	630	140	16.4	74	40	103	1657	406	304	35	22.45	10.25	29
2005	710	143	19.4	89	65	138	1989	602	452	42	22.33	9.28	35
2006	827	126	27	115	142	221	2458	1510	1133	55	21.43	10.67	48
2007	692	132	23	126	43	159	2651	614	461	25	20.97	14.34	20
2008	881	297	21	142	58	186	2450	796	597	29	17.23	13.65	24
2009	732	142	26	137	71	190	2663	573	430	34	19.41	8.09	28
2010	682	147	19.2	99	43	131	1950	407	305	30	19.76	9.55	24
2011	533	87	22	100	24	118	1889	231	173	19.5	19.75	9.56	15.3
2012	522	64	25	100	38	129	2129	379	284	27	21.66	10.10	22
2013	668	126	15.6	81	31	104	1503	301	226	27	19.30	9.82	22
2014	428	80	29	102	30	124	2384	353	265	23	24.30	11.66	18.3

Year	Adjusted abundance (millions)	95% CI	Harvest ratio	Landings numbers	Discards numbers	Removals numbers	Landings (tonnes)	Discards (tonnes)	Dead Discards (tonnes)	Discard rate	Mean weight in landings	Mean weight in discards	Dead discard rate
2015	664	127	16.8	90	29	112	1897	311	234	24	21.84	10.74	19.5
2016	797	146	12.3	85	17	98	1935	167	123	16.4	23.62	9.86	12.8
2017	670	133	19.7	111	28	132	2554	280	210	20	23.07	10.07	15.8
2018	1025	190	12.9	114	24	132	2698	275	206	17.4	24.29	11.42	13.6
2019	865	135	18.3	127	42	158	2585	411	308	25	21.81	9.76	19.9
2020	1119	180	6.1	64	5	68	1787	53	40	6.9	28.75	10.83	5.5
2021	837	107	10.8	82	12	90	1820	128	85	12.8	23.78	9.69	9.7
2022	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table 11.7.1. *Nephrops*, Moray Firth (FU 9), Nominal Landings (tonnes) of *Nephrops*, 1981–2021, as reported to the WG.

Year	UK Scotland				UK *	Total **
	Nephrops trawl	Other trawl	Creel	Sub-total	England	
1981	1299	117	0	1416	0	1416
1982	1033	86	0	1119	0	1119
1983	850	91	0	941	0	941
1984	960	209	0	1169	0	1169
1985	1908	173	0	2081	0	2081
1986	1932	211	0	2143	0	2143
1987	1724	268	0	1992	0	1992
1988	1637	322	0	1959	0	1959
1989	2102	474	0	2576	0	2576
1990	1698	339	0	2037	0	2037
1991	1285	235	0	1520	0	1520
1992	1285	306	0	1591	0	1591
1993	1505	304	0	1809	0	1809
1994	1179	358	0	1537	0	1537
1995	967	312	0	1279	0	1279
1996	1084	364	1	1449	2	1451
1997	1103	343	0	1446	1	1447
1998	739	289	4	1032	0	1032
1999	813	194	2	1009	0	1009
2000	1341	196	2	1539	0	1539
2001	1186	213	2	1401	0	1401
2002	883	247	2	1132	0	1132
2003	873	196	11	1080	0	1080
2004	1222	103	8	1333	0	1333
2005	1526	64	12	1602	3	1605
2006	1751	42	11	1804	1	1805
2007	1818	17	6	1841	2	1843
2008	1444	68	3	1515	0	1515
2009	1033	31	2	1066	1	1067
2010	1026	28	9	1063	0	1063
2011	1358	23	9	1390	1	1391
2012	834	24	8	866	0	866
2013	497	116	7	620	3	623
2014	1183	56	2	1241	12	1253
2015	774	40	0	814	2	816
2016	1105	37	4	1146	<0.5	1146
2017	943	191	8	1142	1	1143
2018	1203	183	9	1395	2	1397
2019	1150	191	13	1354	2	1356
2020	800	154	7	961	2	963
2021*	1100	117	4	1221	0	1221

*** provisional na = not available**

**** No landings by non UK countries from this FU**

Table 11.7.2. *Nephrops*, Moray Firth (FU 9): landings, effort (days fishing) and LPUE (kg/day) for UK bottom trawlers landing in Scotland and fishing *Nephrops* with codend mesh sizes of 70 mm or above, 2000–2021

Year	Landings (tonnes)	Effort (days)	LPUE (kg/day)
2000	1537	7943	193.5
2001	1399	7219	193.8
2002	1130	7495	150.8
2003	1069	5934	180.1
2004	1325	6200	213.7
2005	1590	4805	330.9
2006	1793	4588	390.8
2007	1835	4758	385.7
2008	1512	4328	349.4
2009	1064	3546	300.1
2010	1054	3589	293.7
2011	1381	3880	355.9
2012	858	3079	278.7
2013	613	2954	207.5
2014	1239	4099	302.3
2015	814	3755	216.8
2016	1142	3577	319.3
2017	1134	5044	224.8
2018	1386	4579	302.7
2019	1341	4343	308.8
2020	954	3518	271.2
2021*	1217	3182	382.5

*** provisional na = not available**

Table 11.7.3. *Nephrops*, Moray Firth (FU 9): Mean sizes (CL mm) above and below 35 mm of male and female *Nephrops* in Scottish catches and landings, 1981–2021.

Year	Catches		Landings			
	<35 mm CL		<35 mm CL		=>35 mm CL	
	Males	Females	Males	Females	Males	Females
1981	na	na	30.5	28.2	39.1	37.7
1982	na	na	30.2	29.0	40.0	37.9
1983	na	na	29.9	29.1	40.6	38.3
1984	na	na	29.7	29.3	39.4	38.1
1985	na	na	28.9	28.7	38.7	37.8
1986	na	na	28.7	27.8	39.1	38.4
1987	na	na	29.0	28.3	39.4	38.6
1988	na	na	29.1	28.7	38.9	38.4
1989	na	na	29.8	28.8	40.1	39.4
1990	28.8	28.1	30.3	29.1	38.4	38.7
1991	28.3	27.4	30.1	28.6	38.2	38.2
1992	29.4	28.6	31.0	30.5	38.3	38.0
1993	29.8	29.9	31.3	30.9	38.6	37.7
1994	28.9	30.1	30.8	31.0	39.4	37.5
1995	25.8	25.0	29.9	29.3	39.1	38.0
1996	29.3	28.4	30.6	29.7	38.5	38.0
1997	28.5	27.9	29.5	28.9	38.8	38.2
1998	28.7	28.2	30.1	29.3	38.8	38.2
1999	29.5	28.8	30.4	29.7	38.9	37.6
2000	29.8	29.1	31.5	30.6	39.2	38.3
2001	30.0	29.2	30.9	30.2	39.5	37.9
2002	27.2	27.0	31.2	30.9	41.0	38.7
2003	29.3	29.2	30.3	30.1	39.8	38.0
2004	29.3	28.4	31.3	30.8	39.0	39.2
2005	30.0	28.7	31.0	29.6	39.2	38.5
2006	29.7	28.9	30.6	29.6	39.3	38.6
2007	30.1	28.8	30.3	29.0	39.4	38.6
2008	29.3	27.7	30.2	28.2	39.8	40.2
2009	29.7	28.9	30.7	29.3	39.6	38.5
2010	29.7	29.1	31.1	30.5	40.0	38.9
2011	28.6	28.4	29.4	29.0	39.5	38.4
2012	29.5	29.1	30.5	29.9	39.2	38.5
2013	30.7	29.3	30.9	29.5	39.6	38.4
2014	30.2	29.8	31.6	30.8	40.3	39.0
2015	29.8	29.4	31.5	30.6	40.6	39.1
2016	29.3	28.6	30.7	29.8	40.1	38.5
2017	30.6	29.6	30.7	29.8	40.0	39.7
2018	31.5	30.7	31.6	30.8	39.7	38.8
2019	30.1	29.6	30.3	29.7	40.3	38.5
2020	30.4	29.4	31.0	30.0	40.1	38.3
2021	31.2	31.1	31.4	31.3	40.0	38.1

na = not available

Table 11.7.4. ***Nephrops*****, Moray Firth (FU 9): Results of the 1993–2022 TV surveys**

Year	Stations	Mean density	Abundance	95% confidence interval
		burrows/m²	millions	millions
1993	31	0.16	345	78
1994	29	0.32	702	176
1995			no survey	
1996	27	0.21	465	90
1997	34	0.12	262	55
1998	31	0.15	323	95
1999	52	0.18	400	87
2000	44	0.17	386	98
2001	45	0.16	345	112
2002	31	0.24	521	121
2003	32	0.33	730	314
2004	42	0.29	626	186
2005	42	0.40	869	198
2006	50	0.21	445	124
2007	40	0.24	531	156
2008	45	0.21	481	151
2009	50	0.19	415	140
2010	43	0.18	406	116
2011	37	0.17	372	160
2012	44	0.14	299	90
2013	55	0.21	469	106
2014	52	0.15	331	90
2015	52	0.16	347	84
2016	53	0.18	388	87
2017	55	0.19	412	106
2018	55	0.19	417	126
2019	55	0.17	376	146
2020			no survey	
2021	46	0.30	658	153
2022	45	0.18	396	116

Table 11.7.5. ***Nephrops*****, Moray Firth (FU 9): Summary of TV results for most recent 3 years (2019–2022) showing strata surveyed, numbers of stations in each strata, mean density and observed variance, overall abundance and variance raised to stratum area. Proportion indicates relative amounts of overall raised variance attributable to each stratum.**

Stratum	Area (km²)	Number of Stations	Mean burrow density (no./m²)	Observed variance	Abundance (millions)	Stratum variance	Proportion of total variance
2019 TV survey							
M & SM	169	2	0.39	0.23	66	3279	0.615
MS(west)	682	20	0.12	0.03	84	754	0.141
MS(mid)	698	17	0.18	0.01	123	339	0.064
MS(east)	646	16	0.16	0.04	103	963	0.18
Total	2195	55			376	5335	1
2021 TV survey							
M & SM	169	3	0.42	0.01	71	92	0.016
MS(west)	682	17	0.22	0.07	148	1892	0.322
MS(mid)	698	12	0.31	0.03	214	1151	0.196
MS(east)	646	14	0.35	0.09	225	2738	0.466
Total	2195	46			658	5872	1
2022 TV survey							
M & SM	169	3	0.18	0.04	30	350	0.104
MS(west)	682	15	0.17	0.05	115	1615	0.482
MS(mid)	698	13	0.118	0.004	82.6	165	0.049
MS(east)	646	14	0.26	0.04	169	1221	0.364
Total	2195	46			396	3350	1

Table 11.7.6. *Nephrops*, Moray Firth (FU 9): Adjusted TV survey abundance, landings, discard rate (proportion by number), dead discard rate (proportion by number) and estimated harvest ratio 1993–2022.

Year	Adjusted abundance (millions)	95% CI	Harvest ratio	Landings numbers	Discards numbers	Removals numbers	Landings (tonnes)	Discards (tonnes)	Dead Discards (tonnes)	Discard rate	Mean weight in landings	Mean weight in discards	Dead discard rate
1993	345	78	26	77	19	91	1809	214	161	19.8	23.42	11.26	15.6
1994	702	176	11.4	69	15	80	1537	153	115	17.8	22.25	10.21	14.0
1995	NA	NA	NA	62	72	116	1279	502	376	54	20.59	6.93	47
1996	465	90	21	68	41	98	1451	492	369	37	21.4	12.11	31
1997	262	55	33	71	22	87	1447	230	172	24	20.43	10.42	18.9
1998	323	95	18.1	50	11	58	1032	89	67	17.6	20.47	8.29	13.8
1999	400	87	12.8	46	6	51	1009	55	41	12.0	21.79	8.63	9.3
2000	386	98	20	61	23	78	1539	269	201	27	25.44	11.73	22
2001	345	112	19.3	58	11	66	1401	125	94	16.3	24.18	11.04	12.8
2002	521	121	11.7	41	27	61	1132	220	165	40	27.68	8.18	33
2003	730	314	7.1	46	7	52	1080	70	52	13.7	23.32	9.51	10.6
2004	626	186	10.5	48	23	66	1333	272	204	33	27.57	11.62	27
2005	869	198	8.8	67	12	76	1605	122	92	15.0	23.84	10.31	11.7
2006	445	124	20	81	12	90	1805	117	87	12.8	22.34	9.86	9.9
2007	531	156	16.0	80	7	85	1843	95	72	7.9	23.04	13.95	6.0
2008	481	151	13.7	60	8	66	1515	74	55	11.4	25.29	9.60	8.8
2009	415	140	11.6	45	4	48	1067	33	25	7.6	23.46	8.72	5.8
2010	406	115	11.5	39	10	47	1063	104	78	19.8	26.94	10.63	15.7
2011	372	161	18.9	63	10	70	1391	102	77	13.9	21.63	10.12	10.8
2012	299	90	13.7	37	6	41	866	54	41	13.2	23.16	9.72	10.3
2013	469	106	5.8	26	1	27	623	10	8	3.3	24.95	11.21	2.5
2014	331	90	14.7	43	7	49	1253	87	65	14.6	28.94	11.79	11.3

Year	Adjusted abundance (millions)	95% CI	Harvest ratio	Landings numbers	Discards numbers	Removals numbers	Landings (tonnes)	Discards (tonnes)	Dead Discards (tonnes)	Discard rate	Mean weight in landings	Mean weight in discards	Dead discard rate
2015	347	84	9.1	28	5	32	816	56	42	15.1	29.1	11.35	11.8
2016	388	87	12.7	42	9	49	1146	95	71	18.0	26.83	10.16	14.2
2017	412	106	10.5	42	1	43	1143	12	9	2.6	26.34	10.74	1.99
2018	417	126	11.7	48	0	49	1397	4	3	0.87	28.86	9.58	0.66
2019	376	146	14.8	55	1	56	1356	10	8	1.86	25.13	9.84	1.40
2020	NA	NA	7.4^	36	2	38	963	17	13	5.5	26.63	7.88	4.2
2021	658	153	6.4	41	1	42	1221	7	5	1.64	29.41	10.14	1.23
2022	396	116	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

^ The harvest rate in 2020 was calculated using an interpolated value for abundance (average of 2019 and 2021).

Table 11.8.1. *Nephrops*, Noup (FU 10): Nominal landings (tonnes) of *Nephrops*, 1981–2021, as reported to the WG.

Year	*Nephrops* Trawl	Other trawl	Creel	Sub Total	Other UK	Total
1981	12	23	0	35	0	35
1982	12	7	0	19	0	19
1983	10	6	0	16	0	16
1984	76	35	0	111	0	111
1985	1	21	0	22	0	22
1986	45	22	0	67	0	67
1987	13	32	0	45	0	45
1988	23	53	0	76	0	76
1989	24	60	0	84	0	84
1990	101	117	0	218	0	218
1991	111	86	0	197	0	197
1992	58	130	0	188	0	188
1993	200	176	0	376	0	376
1994	307	187	0	494	0	494
1995	163	116	0	279	0	279
1996	181	164	0	345	0	345
1997	185	131	1	317	0	317
1998	184	72	0	256	0	256
1999	211	67	0	278	0	278
2000	196	78	0	274	0	274
2001	88	89	0	177	0	177
2002	246	157	0	403	0	403
2003	258	78	0	336	0	336
2004	174	54	0	228	0	228
2005	81	84	0	165	0	165
2006	44	89	0	133	0	133
2007	46	107	0	153	0	153
2008	74	98	0	172	0	172
2009	24	63	0	87	0	87
2010	4	35	0	39	0	39
2011	27	41	0	68	0	68
2012	2	11	0	13	0	13
2013	4	12	0	16	0	16
2014	3	11	1	15	0	15
2015	1	14	0	15	0	15
2016	9	14	0	23	0	23

Year	*Nephrops* Trawl	Other trawl	Creel	Sub Total	Other UK	Total
2017	0	9	0	9	0	9
2018	0	4	0	4	0	4
2019	0	21	0	21	0	21
2020	0	11	0	11	0	11
2021*	0	14	0	14	0	14

*** provisional**

Table 11.8.2. *Nephrops*, Noup (FU 10): Landings (tonnes), effort (days fishing) and LPUE (kg/day) for UK bottom trawlers landing in Scotland and fishing *Nephrops* with codend mesh sizes of 70 mm or above, 2000–2021.

Year	Landings (tonnes)	Effort (days)	LPUE (kg/day)
2000	274	1622	168.9
2001	177	1383	128.0
2002	403	2036	197.9
2003	336	1434	234.3
2004	228	899	253.6
2005	165	730	226.0
2006	133	612	217.3
2007	153	591	258.9
2008	172	746	230.6
2009	87	871	99.9
2010	39	813	48.0
2011	68	776	87.6
2012	13	574	22.6
2013	16	454	35.2
2014	14	673	20.8
2015	15	514	29.2
2016	23	520	44.2
2017	9	568	15.8
2018	4	744	5.4
2019	21	642	32.7
2020	11	339	32.4
2021*	14	442	31.7

*** provisional**

Table 11.8.3. *Nephrops*, Noup (FU 10): Mean sizes (CL mm) above and below 35 mm of male and female *Nephrops* in landings, 1997–2021. No females in samples in 2010 and no sampling in 2015, 2018 and 2020.

Year	Landings			
	<35 mm CL		=>35 mm CL	
	Males	Females	Males	Females
1997	29.7	28.3	40.4	38.2
1998	30.4	29.8	38.8	38.6
1999	30.4	30.1	39.2	37.8
2000	31.8	30.1	38.2	39.1
2001	31.4	29.5	38.7	37.9
2002	30.8	29.9	39.7	38.5
2003	29.3	30.4	39.9	38.5
2004	31.4	30.0	40.2	38.8
2005	31.0	29.3	39.3	38.4
2006	30.8	30.2	40.4	38.7
2007	30.7	29.4	40.2	38.7
2008	31.9	30.6	40.3	39.3
2009	33.2	33.2	42.6	42.7
2010	33.3	na	42.6	na
2011	32.8	32.7	43.3	40.1
2012	32.4	31.8	40.7	40.1
2013	34.0	32.4	43.7	39.7
2014	33.3	33.0	46.6	43.2
2015	na	na	na	na
2016	33.2	32.1	38.5	43.9
2017	31.0	31.6	38.0	41.5
2018	na	na	na	na
2019	32.6	32.0	38.6	46.0
2020	na	na	na	na
2021	32.4	31.2	39.7	38.2

na = not available

Table 11.8.4. *Nephrops*, Noup (FU 10): Results of the 1994, 1999, 2006, 2007, 2014 and 2019 TV surveys (absolute conversion factor = 1.35, from Fladen).

Year	Stations	Mean density	Abundance	95% confidence interval
		burrows/m²	millions	millions
1994	10	0.47	185	67
1995		no survey		
1996		no survey		
1997		no survey		
1998		no survey		
1999	10	0.22	89	31
2000		no survey		
2001		no survey		
2002		no survey		
2003		no survey		
2004		no survey		
2005	2	poor visibility, limited survey - see text		
2006	7	0.13	55	35
2007	9	0.11	44	19
2008		no survey		
2009		no survey		
2010		no survey		
2011		no survey		
2012		no survey		
2013		no survey		
2014	12	0.13	51	22
2015		no survey		
2016		no survey		
2017		no survey		
2018		no survey		
2019	11	0.22	90	46
2020		no survey		
2021		no survey		
2022		no survey		

Table 11.9.1. *Nephrops* Norwegian Deep (FU 32): Landings (tonnes) by country, 1993–2021, estimated Danish discards (2003–2021), and TAC (EU) (2004-2022).

Year	Denmark	Danish discards		Norway			Sweden	UK	Netherlands	Total	TAC
		dead	live	Trawl	Creel	Sub-total					
1993	220			102	1	103		16		339	
1994	584			161	0	161		10		755	
1995	418			68	1	69		2		489	
1996	868			73	1	74		10		952	
1997	689			56	8	64		7		760	
1998	743			88	1	89		4		836	
1999	972			119	15	134		13		1119	
2000	871			143	0	143	37	34		1085	
2001	1026			72	13	85	26	53		1190	
2002	1043			42	21	63	13	52		1171	
2003	996	145	48	68	11	79	1	14		1090	
2004	835	200	67	72	8	80	1	6		922	1000
2005	979	194	65	89	13	102	2	6		1089	1000
2006	939	126	42	62	19	81	1	7	5	1033	1300
2007	652	64	21	77	20	97	5	1		755	1300
2008	505			112	30	142	24	4		675	1300
2009	331	29	10	107	31	138	2	6		477	1200
2010	282	36	12	82	41	123	1	1		407	1200
2011	322			29	40	69	1	3		395	1200
2012	234	35	12	25	50	75	1	0		310	1200
2013	128	51	17	18	45	63	0	0		191	1000
2014	143	4	1	15	47	62	0	0		205	1000
2015	110	5	2	8	74	82	0	0		192	1000
2016	80	1	0	7	90	97	0	0	1	178	1000
2017	53	1	0	9	85	94	0	0	0	147	1000
2018	34	0	0	10	93#	103	0	0		137	800
2019	91	1	0	22	78#	100	0	0	0	191	600
2020	81	1	0	25	69#	94	3	1	0	179	600
2021*	129	1	0	26	54#	80	7		0	216	200
2022											200

*** Provisional**

 # Contains some landings from gillnets

Table 11.9.2. *Nephrops* Norwegian Deep (FU 32): Danish effort (kW days, days at sea, fishing days) and LPUE (kg/kW day) for bottom trawlers catching *Nephrops*, 1993–2021.

Year	kW days ('1000)	Days at sea	Fishing days	LPUE
1993	888	1974	1542	248
1994	1439	3572	2824	406
1995	1010	2464	1950	414
1996	1732	4000	3307	501
1997	1982	4189	3466	348
1998	1467	3245	2654	506
1999	2262	4658	3790	430
2000	2662	5068	4161	327
2001	3510	6426	5467	292
2002	3102	5737	4859	336
2003	3500	6294	5416	285
2004	2443	4298	3657	342
2005	2787	5078	4353	351
2006	3023	5274	4516	311
2007	1782	3052	2557	366
2008	1682	2623	2349	300
2009	1496	2334	2304	221
2010	1090	1795	1753	259
2011	1136	1840	1188	283
2012	907	1474	1265	258
2013	862	1449	1227	149
2014	752	1233	1105	190
2015	574	924	793	192
2016	462	728	644	173
2017	410	602	521	129
2018	313	441	387	109
2019	712	996	888	128
2020	628	892	773	129
2021	462	577	604	279

Table 11.9.3. *Nephrops* Norwegian Deep (FU 32): Biomass index from Norwegian bottom trawl survey (shrimp survey) in FU 32 (mean, SD, 25th percentile, median, and 75th percentile), for 2006–2022. Data from the 2016 survey were discarded due to technical problems with the gear that year.

Year	mean	SD	25th percentile	median	75th percentile
2006	1447	760	913	1274	1796
2007	992	335	758	942	1169
2008	297	120	214	275	356
2009	293	106	217	275	348
2010	586	177	464	562	687
2011	406	125	315	390	475
2012	718	310	505	653	865
2013	447	151	337	424	528
2014	390	336	175	296	492
2015	610	281	408	549	756
2016	na	na	na	na	na
2017	426	126	203	264	346
2018	318	104	338	407	498
2019	174	63	246	302	373
2020	139	49	129	163	206
2021	134	57	104	132	167
2022	426	126	94	124	163

Table 11.10.1 *Nephrops* in FU 33: (Off Horns Reef) Landings (tonnes) by country, 1993–2021.

Year	Belgium	Denmark	Germany	Netherl.	UK	Total *
1993	0	159		na	1	160
1994	0	137		na	0	137
1995	3	158		3	1	164
1996	1	74		2	0	77
1997	0	274		2	0	276
1998	4	333	8	12	1	358
1999	22	683	14	12	6	738
2000	13	537	12	39	9	610
2001	52	667	11	61	+	791
2002	21	772	13	51	4	861
2003	15	842	4	67	1	929
2004	37	1097	24	109	1	1268
2005	16	803	31	191	9	1050
2006	97	710	151	314	15	1288
2007	118	610	201	496	42	1467
2008	130	362	160	386	58	1096
2009	121	231	150	491	170	1163
2010	56	180	206	295	69	806
2011	163	396	202	403	28	1191
2012	181	394	132	376	2	1084
2013	156	310	174	304	2	946
2014	229	387	161	360	9	1146
2015	299	371	142	187	4	1003
2016	430	642	201	320	43	1636
2017	423	511	197	336	5	1472
2018	280	48	210	236	2	776
2019	462	220	329	599	2	1612
2020	397	164	128	489	7	1186
2021**	287	349	193	541	0.5	1371

na = not available; + < 0.5 tonnes

*** Totals for 1993–94 exclusive of landings by the Netherlands**

**** Preliminary**

Table 11.10.2. *Nephrops*, Off Horn's Reef (FU 33): Results of the 2017 to 2021 TV surveys (absolute conversion factor = 1.1, from FU 3 & 4).

Year	Stations	Mean density	Abundance	95% confidence interval
		burrows/m²	millions	millions
2017	59	0.13	728	137
2018	85	0.07	427	84
2019	60	0.07	417	117
2021	28	0.22	1279	308

Table 11.11.1. *Nephrops*, Devil's Hole (FU 34): Nominal landings (tonnes) of *Nephrops* 1986–2021 as reported to the WG. Scottish data only from 1986 to 2009.

Year	UK Scotland				UK (E, W & NI)	Denmark	Netherlands	Total
	Nephrops trawl	Other trawl	Creel	Sub-total				
1986	20	3	0	23				23
1987	2	3	0	5				5
1988	1	1	0	2				2
1989	15	13	0	28				28
1990	20	6	0	26				26
1991	64	21	0	85				85
1992	78	28	0	106				106
1993	23	21	0	44				44
1994	79	50	0	129				129
1995	37	95	0	132				132
1996	40	89	0	129				129
1997	30	70	0	100				100
1998	15	73	0	88				88
1999	80	122	0	202				202
2000	89	95	0	184				184
2001	159	112	0	271				271
2002	240	103	0	343				343
2003	518	157	0	675				675
2004	398	90	0	488				488
2005	253	125	0	378				378
2006	359	89	0	448				448
2007	649	68	0	717				717
2008	844	93	0	937				937
2009	1297	8	0	1305				1305
2010	816	22	0	838	25	1	1	865
2011	406	16	0	422	6	4		432
2012	546	4	0	550	37	10		597
2013	65	41	0	106	11	3		120

Year	UK Scotland				UK (E, W & NI)	Denmark	Netherlands	Total
	Nephrops trawl	Other trawl	Creel	Sub-total				
2014	293	14	0	307	13			320
2015	383	18	0	401	39	<0.5		440
2016	738	6	0	744	36			780
2017	398	122	0	520	28			548
2018	218	86	0	304	14			318
2019	1027	103	0	1130	37			1167
2020	855	55	0	910	70			980
2021*	799	40	0	839	36			875

*** Provisional**

Table 11.11.2. *Nephrops*, Devils Hole (FU 34): Landings, effort (days fishing) and LPUE (kg/day) for UK bottom trawlers landing in Scotland and fishing *Nephrops* with cod end mesh sizes of 70 mm or above, 2000–2021.

Year	Landings (tonnes)	Effort (days)	LPUE (kg/day)
2000	184	3391	54.3
2001	271	3142	86.3
2002	343	2022	169.6
2003	675	2614	258.2
2004	488	1551	314.6
2005	378	1545	244.7
2006	448	1440	311.1
2007	717	1824	393.1
2008	937	1673	560.1
2009	1305	1921	679.3
2010	838	1465	572.0
2011	422	1041	405.4
2012	550	1255	438.2
2013	106	438	242.0
2014	307	758	405.0
2015	401	1222	328.2
2016	744	1640	453.7
2017	520	1088	477.9
2018	304	620	490.3
2019	1130	1291	875.3
2020	910	1152	789.9
2021*	839	1004	835.7

*** Provisional**

Table 11.11.3. *Nephrops*, Devil's Hole (FU 34): Mean sizes (CL mm) above and below 35 mm of male and female *Nephrops* in Scottish catches and landings, 2006–2021. Samples not available in 2012 and 2013.

Year	Landings			
	< 35 mm CL		=> 35 mm CL	
	Males	Females	Males	Females
2006	29.7	29.8	39.7	38.1
2007	30.4	28.7	40.5	39.2
2008	31	30.5	40.3	39.6
2009	31.7	31.1	41.3	40.6
2010	32.1	29.7	39.1	38.8
2011	31.7	30.7	43.7	40.4
2012	na	na	na	na
2013	na	na	na	na
2014	33.0	34.0	42.0	41.4
2015	33.0	31.4	41.2	39.9
2016	31.7	30.6	41.0	39.1
2017	32.1	31.1	41.9	41.8
2018	32.3	31.1	43.8	40.7
2019	32.2	31.4	39.8	40.9
2020	32.0	30.6	39.9	41.9
2021	31.7	31.0	40.2	40.8

na = not available

Table 11.11.4. *Nephrops*, Devil's Hole (FU 34): Results of the TV surveys (2003–2021).

Year	Stations	Mean density	95% confidence interval
		burrows/m²	burrows/m²
2003	20	0.09	0.02
2004		no survey	
2005	29	0.09	0.04
2006		no survey	
2007		no survey	
2008		no survey	
2009	12	0.28	0.13
2010	19	0.24	0.08
2011	14	0.16	0.09
2012	15	0.14	0.06
2013		no survey	
2014	13	0.13	0.04
2015	17	0.16	0.06
2016		no survey	
2017	16	0.09	0.04
2018	15	0.21	0.09
2019	20	0.29	0.09
2020		no survey	
2021	10	0.28	0.11
2022		no survey	

Table 11.12.1. *Nephrops* landings (tonnes) from Subarea 27.4 outside FUs.

Year	Belgium	Denmark	Germany	Netherlands	Sweden	UK (England)	UK (Scotland)	Total
2011	411	53	208	137	0	36	322	1167
2012	57	27	132	128	0	44	202	590
2013	31	8	84	152	0	57	78	409
2014	51	31	115	69	0	28	98	392
2015	173	25	105	154	0	36	117	610
2016	217	23	219	290	0	53	164	966
2017	270	35	352	319	0	61	158	1195
2018	121	29	143	118	0	33	181	625
2019	96	25	190	184	0	34	194	724
2020	83	45	77	112	0	55	160	531
2021	109	89	101	127	0	52	158	636

Table 11.12.2. *Nephrops* reported discards (tonnes) from Subarea 27.4 outside FUs.

Year	Belgium	Denmark	Germany	Netherlands	Sweden	UK (England)	UK (Scotland)	Total
2012	-	18.2	-	-	-	-	-	18.2
2013	-	-	-	-	-	-	-	-
2014	-	0.5	-	-	-	-	-	0.5
2015	-	1.4	-	-	-	-	-	1.4
2016	-	0.1	-	550.6	-	-	1.8	552.5
2017	-	0.1	-	62.9	-	-	8.2	71.2
2018	-	0.1	-	176.4	-	-	-	176.5
2019	-	0.3	-	605.0	-	-	0.7	606.1
2020	-	0.3	-	114.9	-	-	-	115.2
2021	-	0.3	-	41.6	-	-	-	41.9

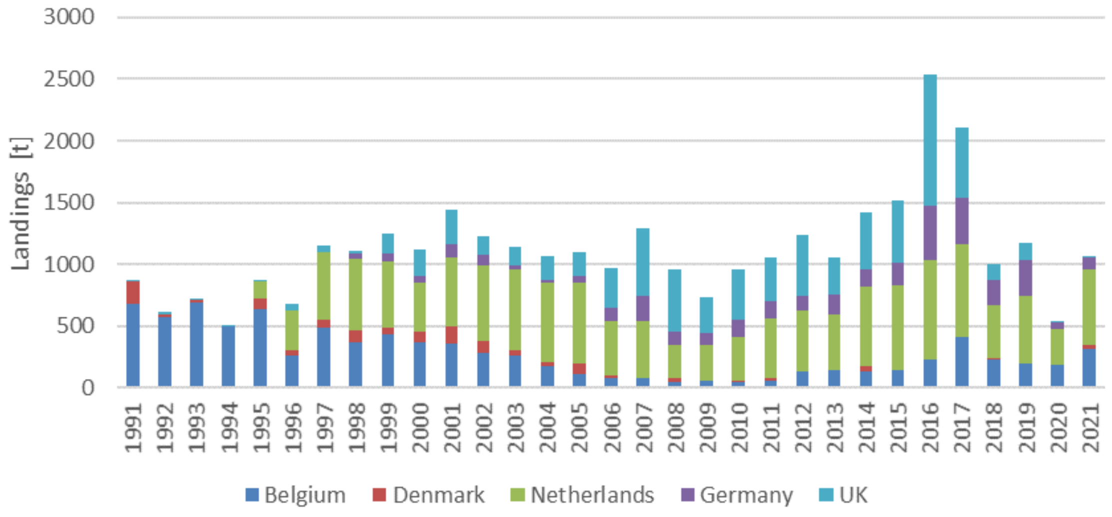


Figure 11.3.1. FU 5 Botney Cut/Silver Pit: Annual landings by country.

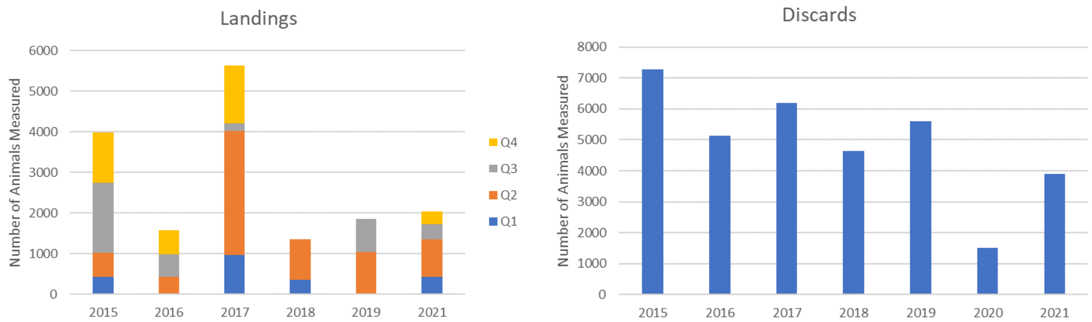


Figure 11.3.2. FU 5 Botney Cut/Silver Pit: Number of length measurements in Dutch landings and discards.

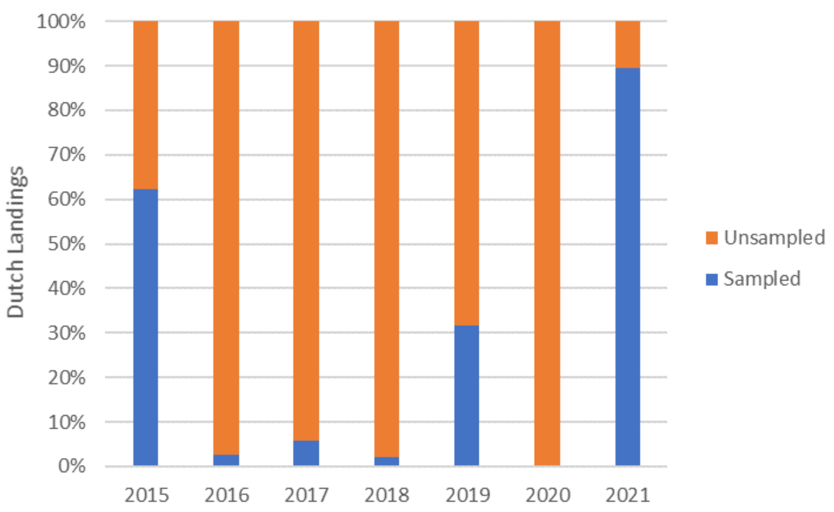


Figure 11.3.3. FU 5 Botney Cut/Silver Pit: Annual UK landings as percent of total international landings (blue), and number of UK *Nephrops* directed trawlers (red).

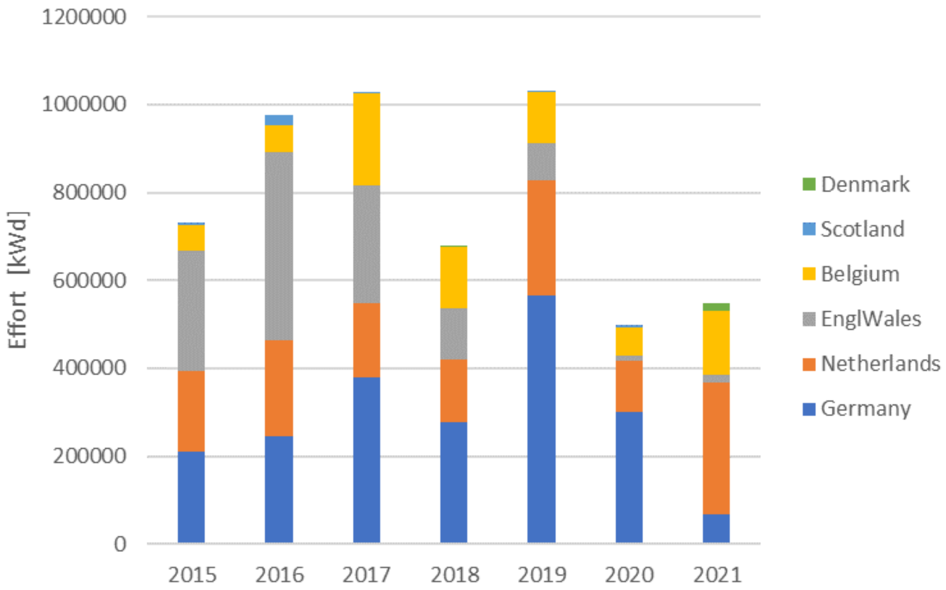


Figure 11.3.4. FU 5 Botney Cut/Silver Pit: Annual targeted effort by country, associated with landings from OTB_CRU_70-99_0_0_all metier.

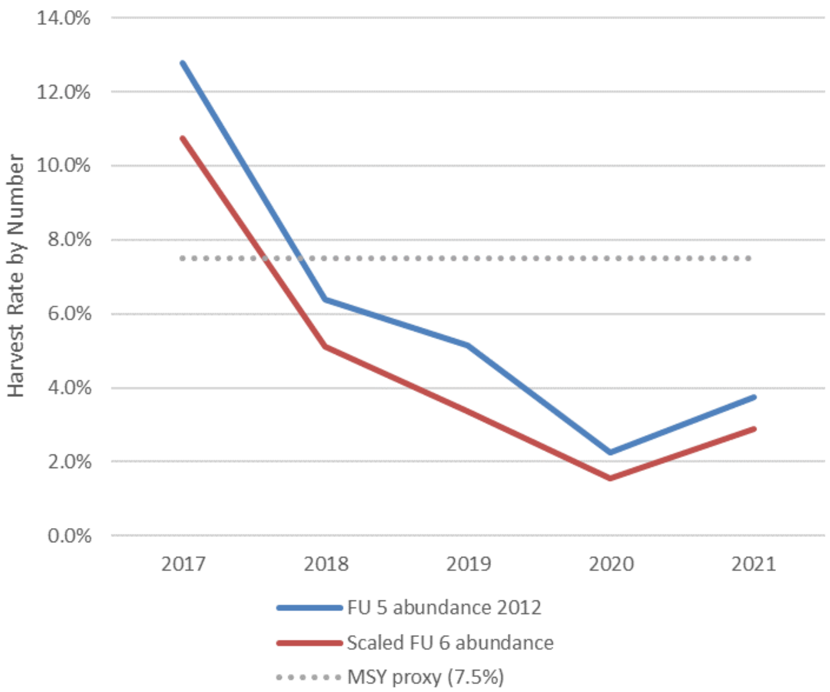


Figure 11.3.5. FU 5 Botney Cut/Silver Pit: Harvest rates based on annual landings and dead discards, together with 2019 & 2021 mean weights in landings and discards, and the 2012 abundance in FU 5 (blue line), or the scaled annual abundance in FU 6 (red line; see Section 11.3.5).

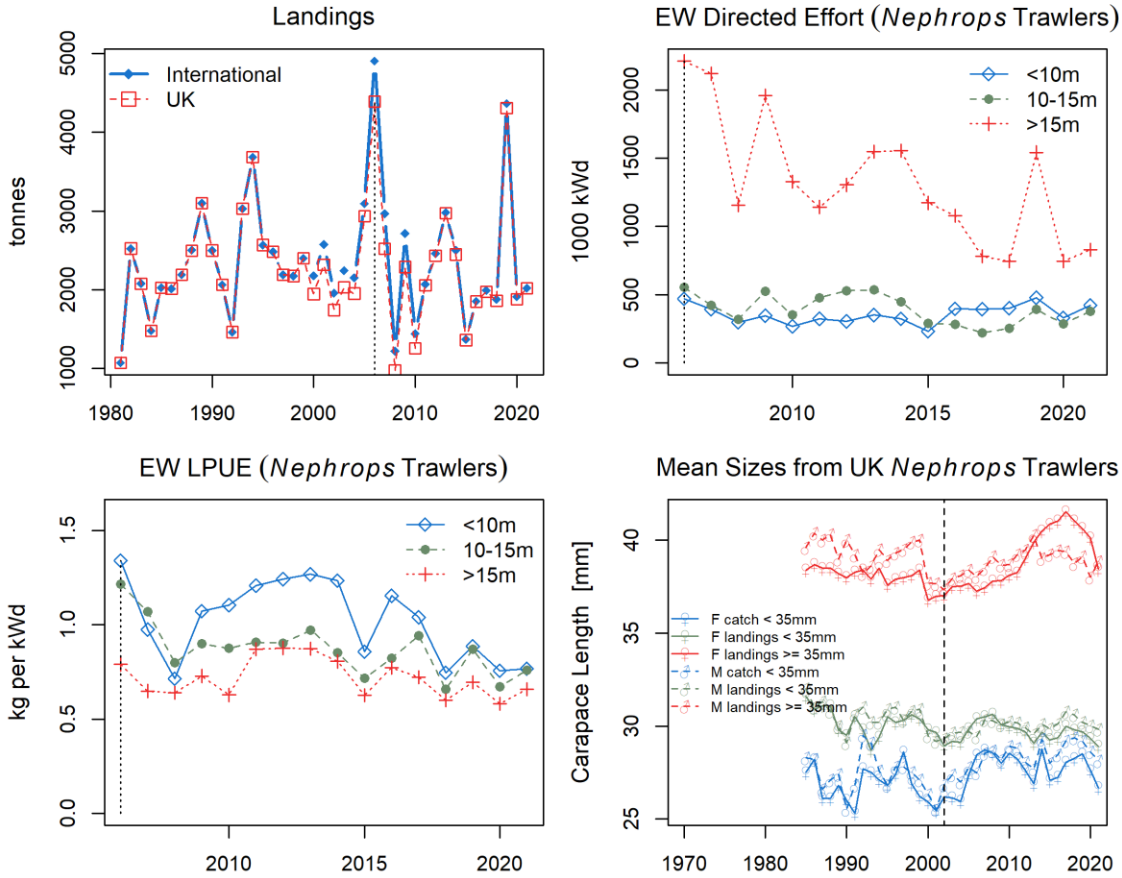


Figure 11.4.1. *Nephrops* in FU 6: Landings, directed effort, directed LPUE and mean sizes of different catch components.

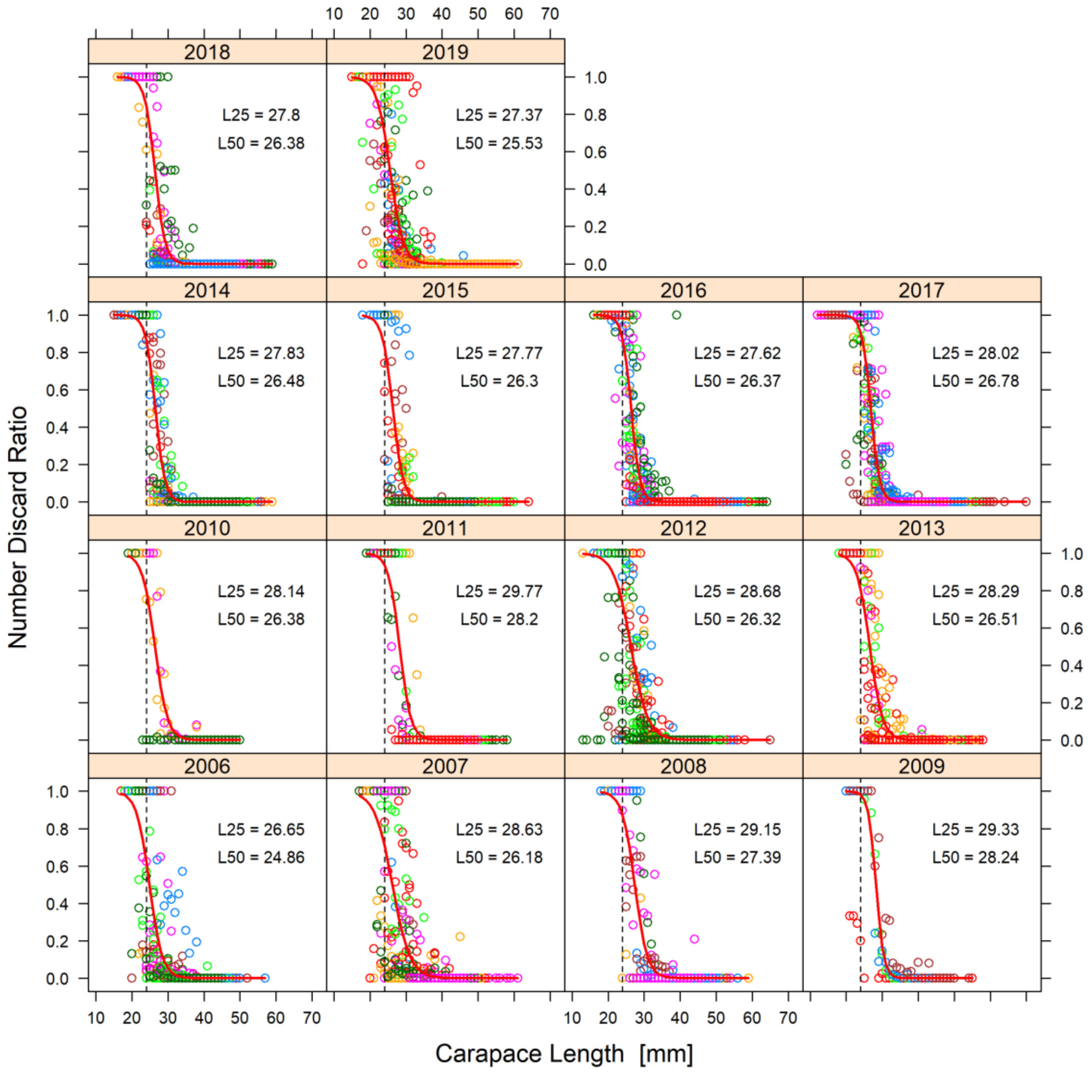


Figure 11.4.2. ***Nephrops*** **in FU 6, annual discard ogives: The different point shapes represent different sampling trips within any year.**

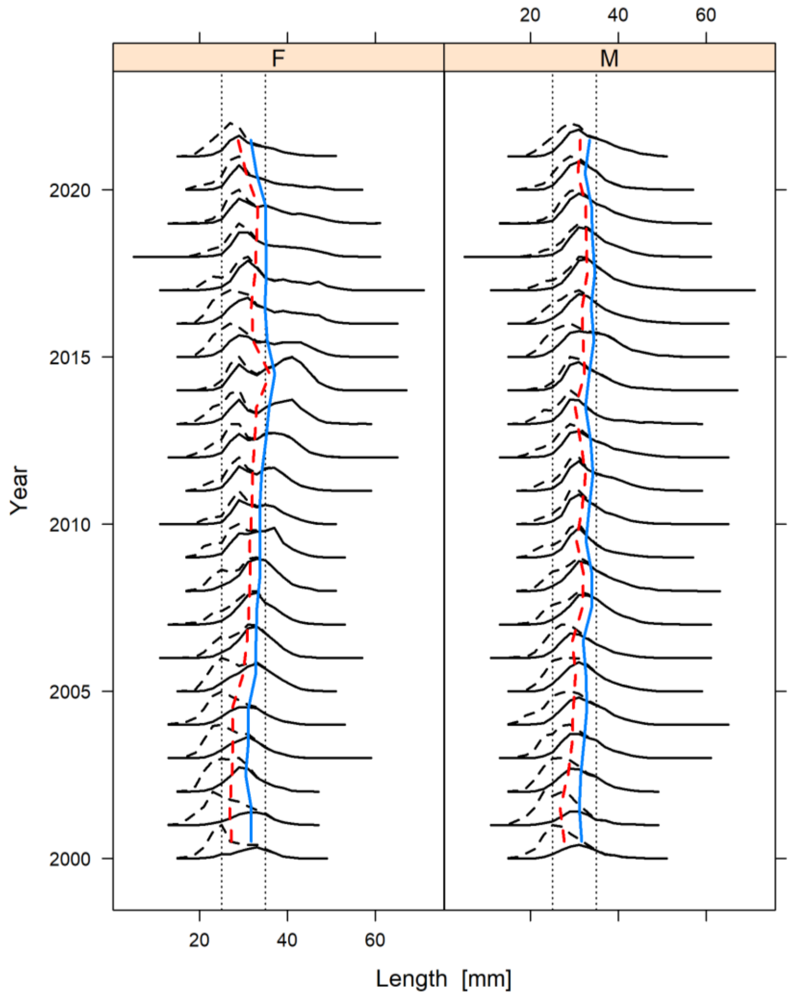


Figure 11.4.3. ***Nephrops*** **in FU 6: Annual length frequencies for landings (solid black lines) and catch (dashed black lines) by sex, together with mean size of the landings (blue lines) and catch (red lines). The minimum conservation reference size (MCRS) of 25 mm carapace length, and 35 mm reference size are indicated by the vertical dotted lines.**

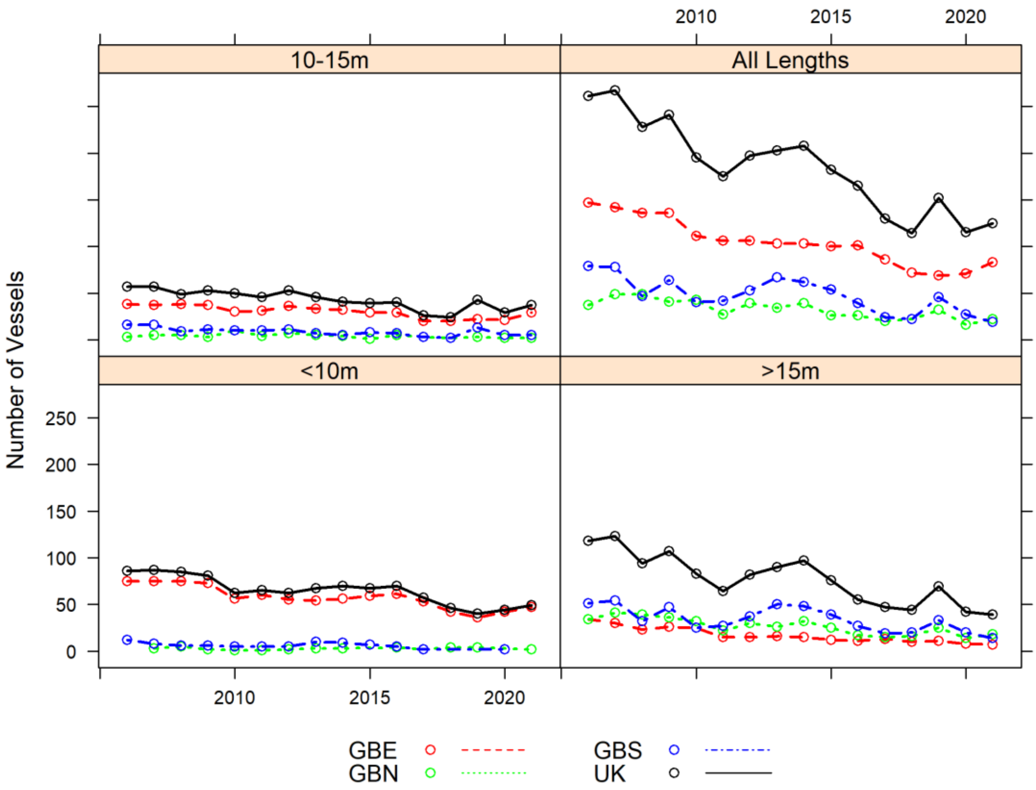


Figure 11.4.4. ***Nephrops*** **in FU 6: Number of participating UK vessels by length class.**

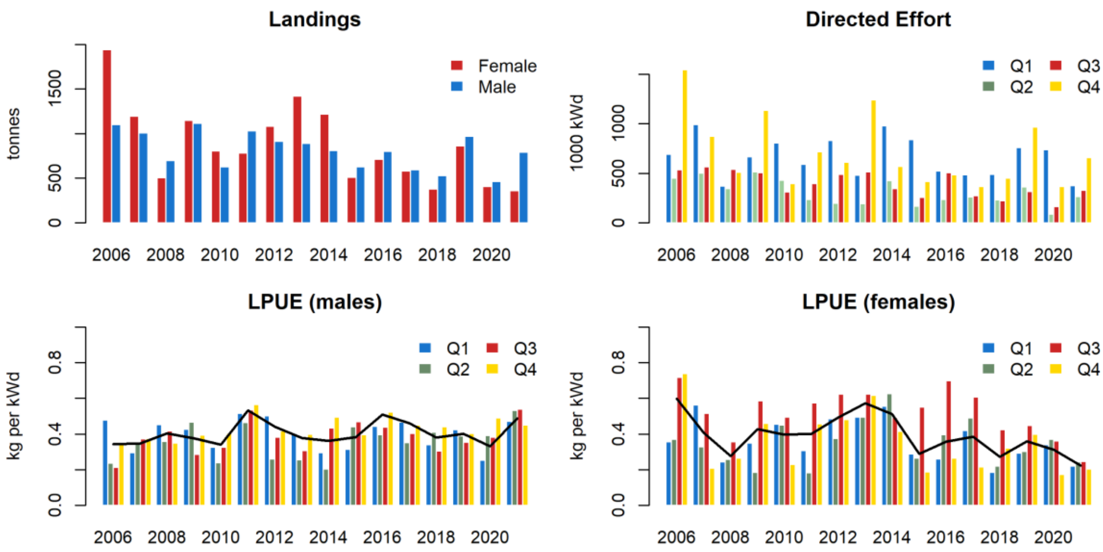


Figure 11.4.5. ***Nephrops*** **in FU 6: Annual landings by sex, directed effort by quarter, and LPUE by sex and quarter.**

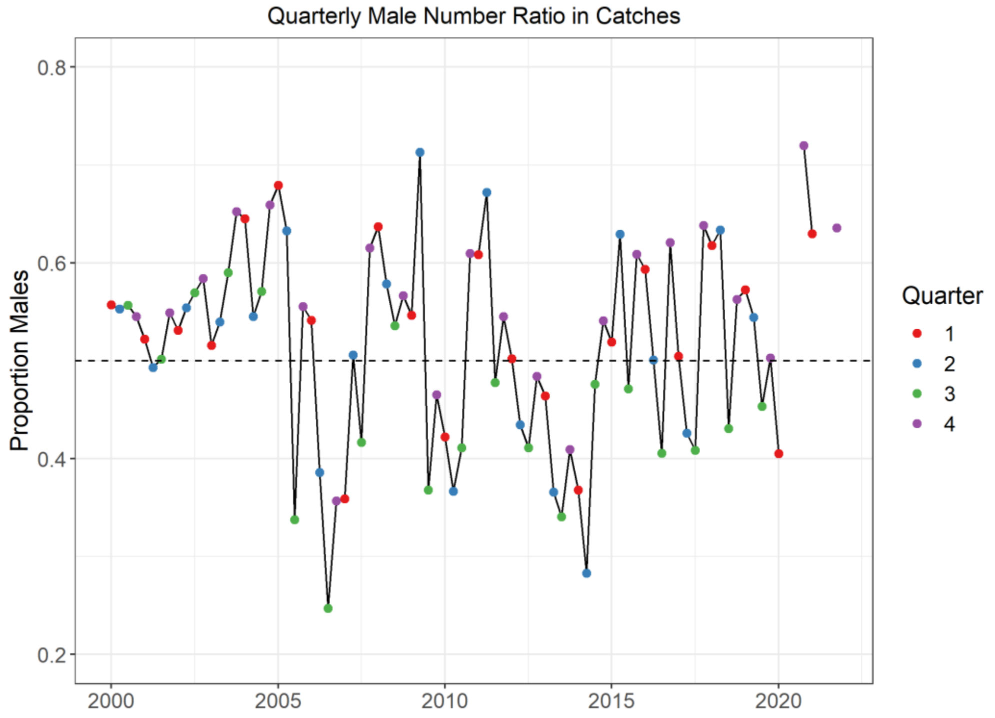


Figure 11.4.6. ***Nephrops*** **in FU 6: Quarterly sex ratio in the catches. Insufficient sampling data are available for quarters 2 to 4 in 2020.**

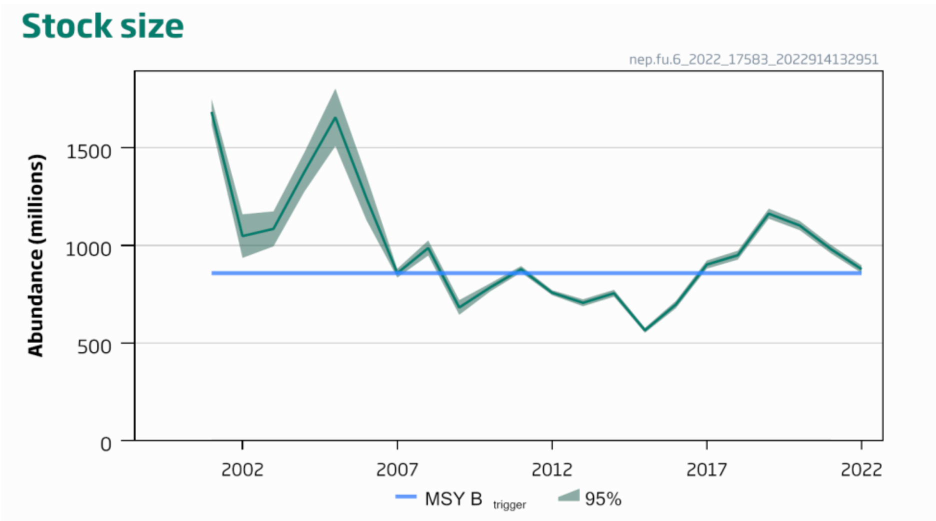


Figure 11.4.7. ***Nephrops*** **in FU 6: Time series of UWTV results. The blue line is the proxy for MSY B$_{trigger}$, defined as the abundance estimate for 2007. The shading around the abundance line indicates the 95% confidence interval (based on random resampling).**

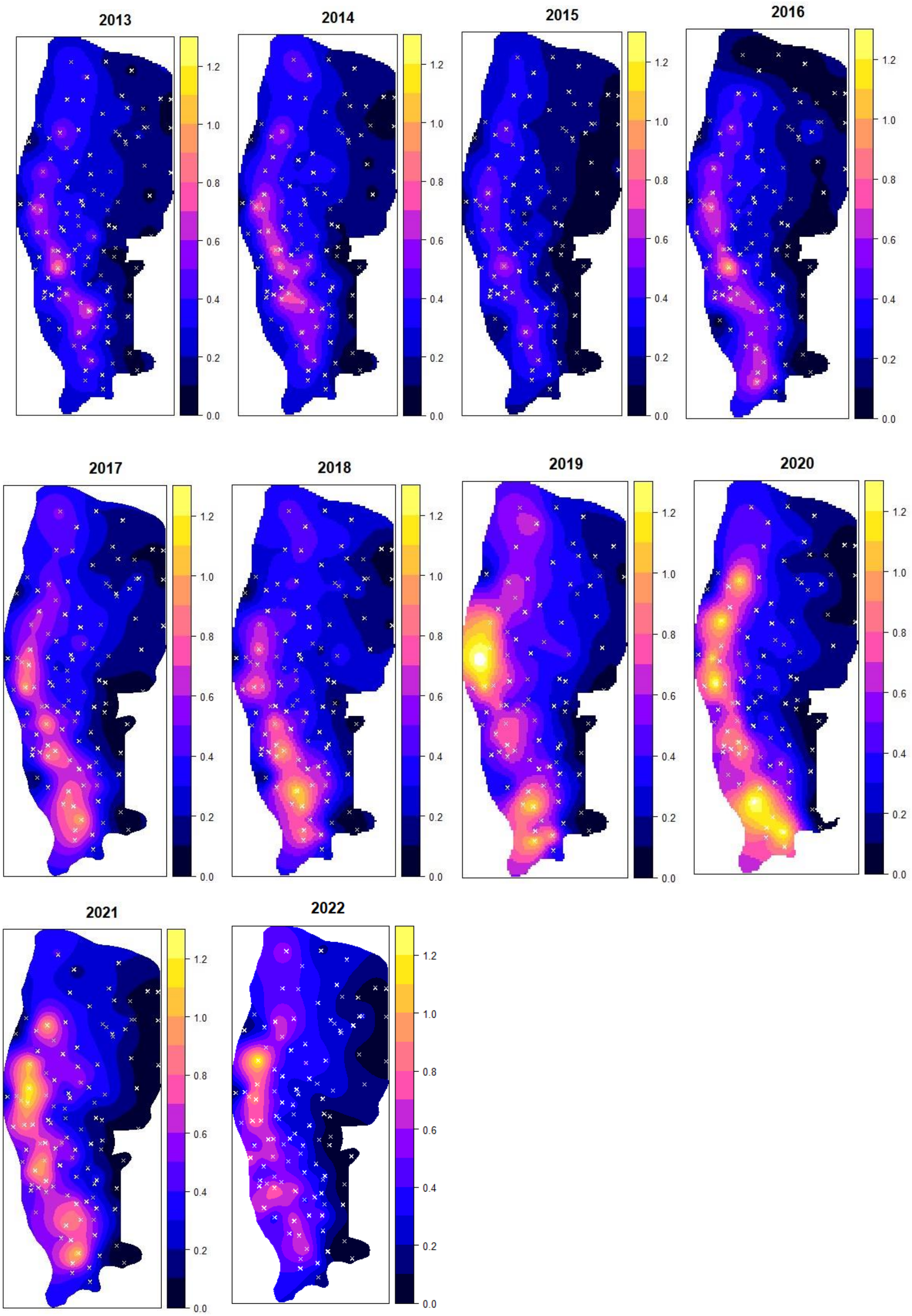


Figure 11.4.8. ***Nephrops*** **in FU 6: Number density (burrows per m²) from the UWTV survey.**

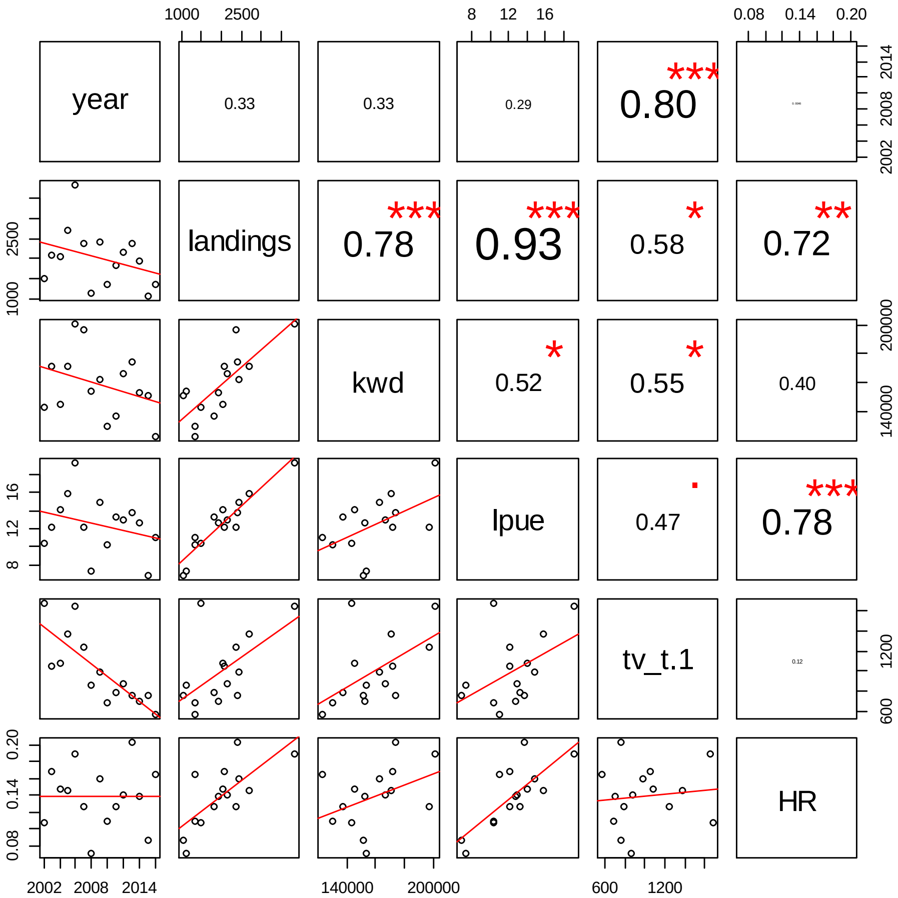


Figure 11.4.9. ***Nephrops*** **in FU 6. Scatterplot matrices of** ***Nephrops*** **metrics, where the UWTV survey lagged by 1 year (i.e., UWTV survey in the year preceding the fishery statistics).**

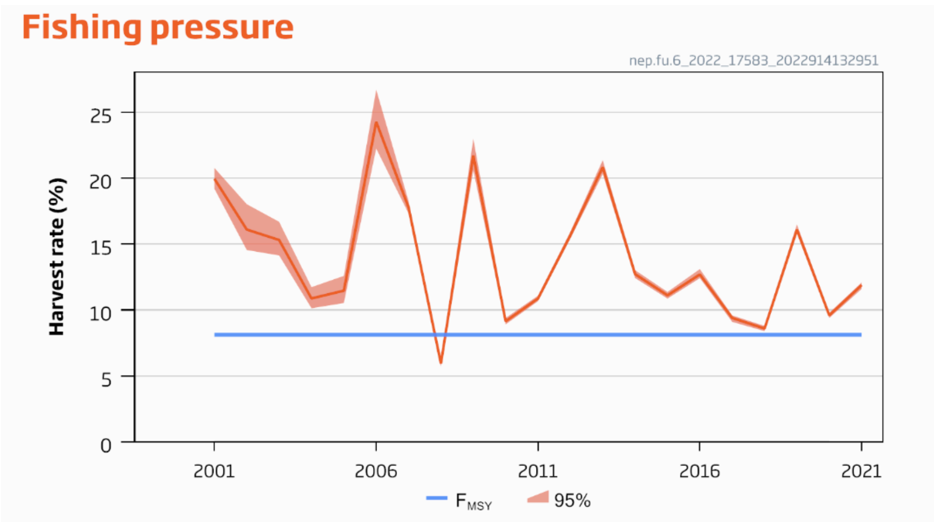


Figure 11.4.10. ***Nephrops*** **in FU 6: Observed harvest rate (total removals divided by abundance estimate).**

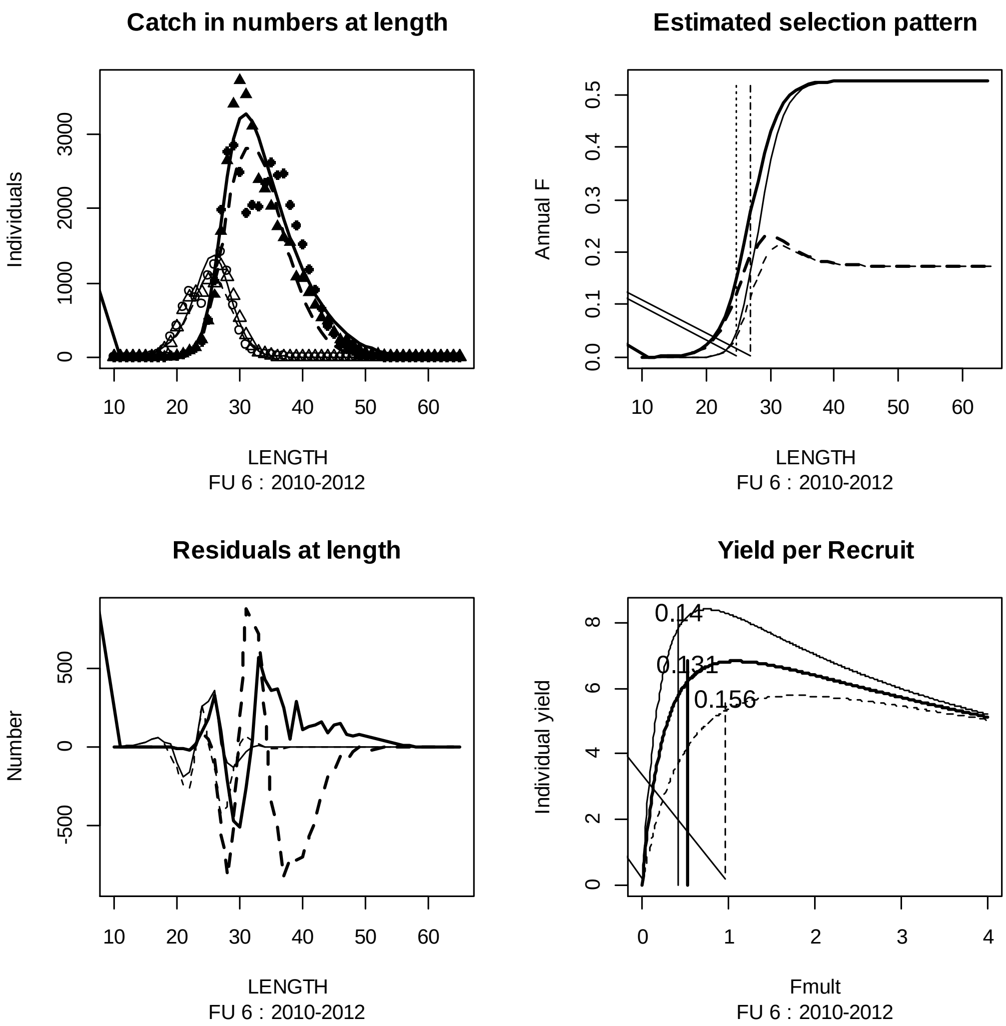


Figure 11.4.11. *Nephrops* in FU 6: Separable Cohort analysis model fit. Solid lines are for males, dashed lines are females, thick lines represent the landings component, the thin lines represent the discarded component. The top left panel gives observed and predicted numbers at length in the discards and landings, top right gives the fishing mortality at length with the vertical lines representing length at 25% selection and 50% selection. Bottom left shows residual numbers (observed-expected) at length. The bottom right gives the Yield Per recruit against fishing mortality, the thick solid line gives the combined value and vertical lines represent $F_{0.1}$ for the three curves.

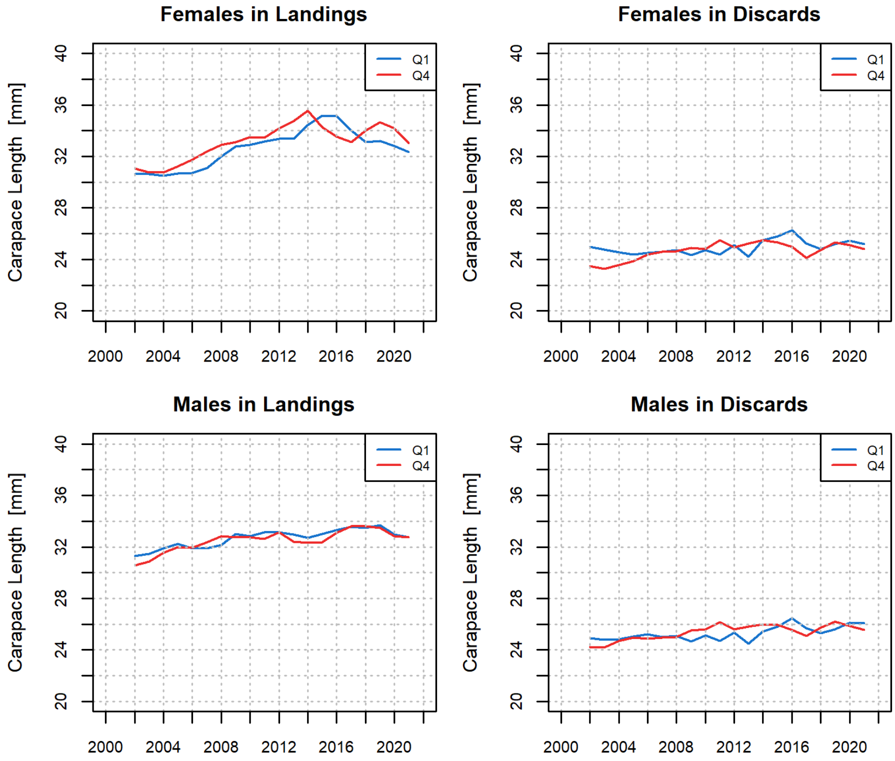


Figure 11.4.11. ***Nephrops*** **in FU 6: Average carapace lengths of females and males in landings and discards in quarters one and four. Values are three-year running means in periods ending in the year for which they are plotted.**

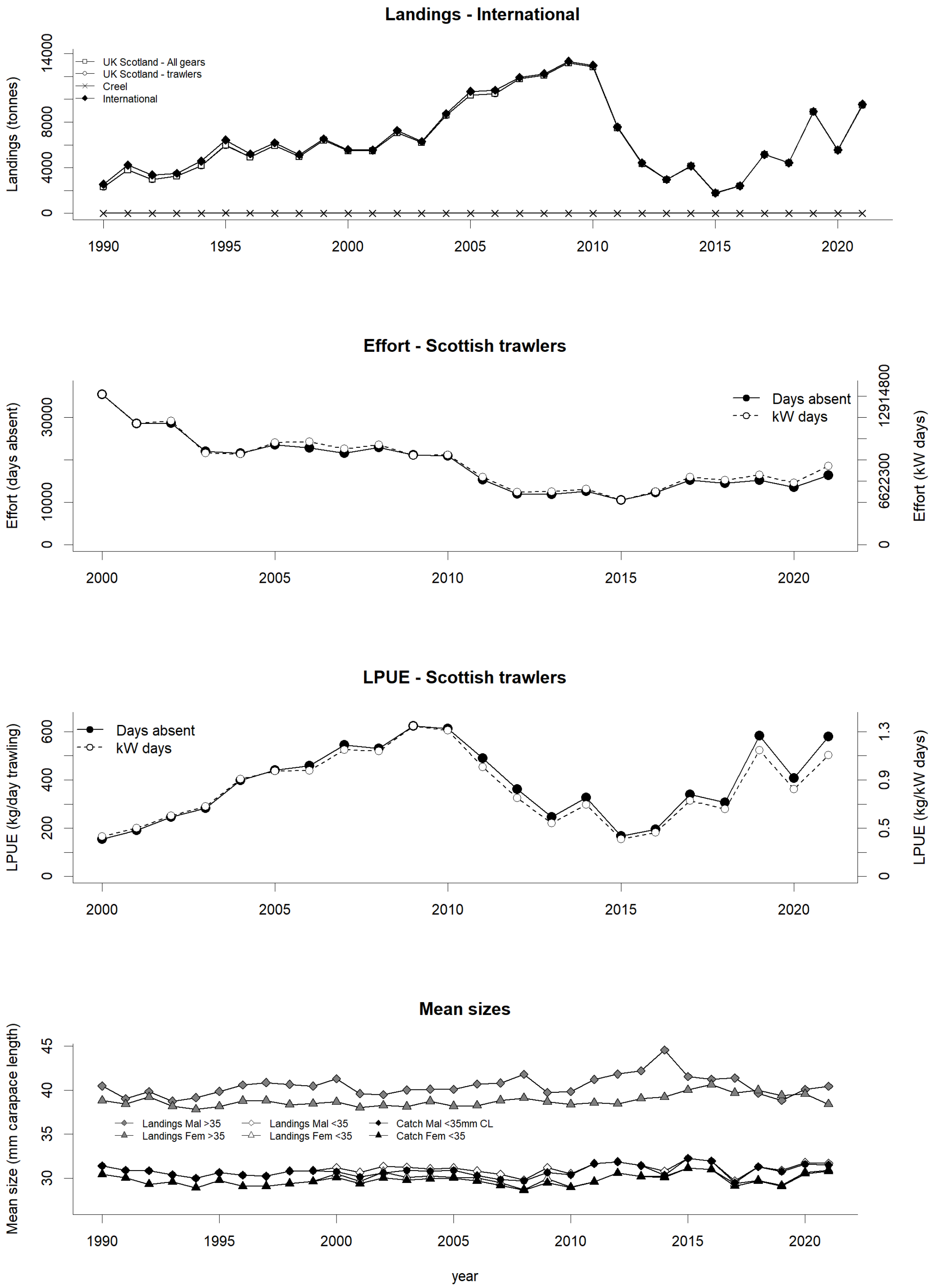
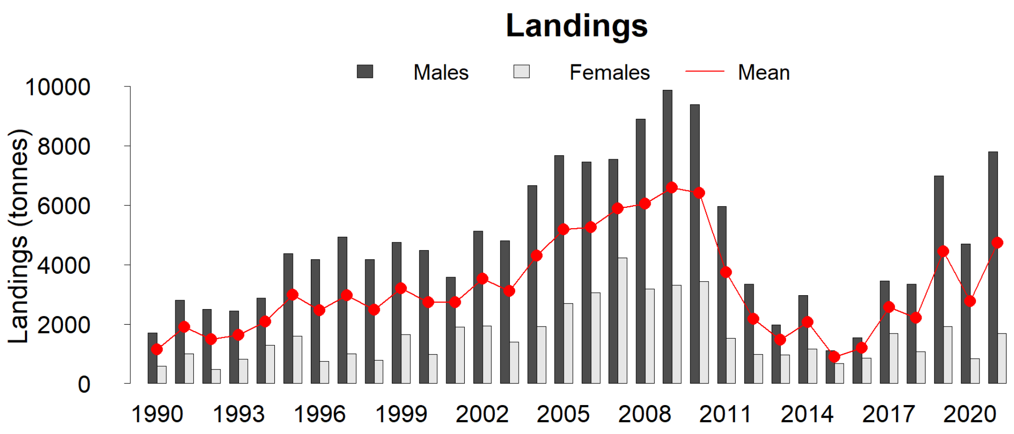


Figure 11.5.1 ***Nephrops*****, Fladen (FU 7), Long term landings, effort, LPUE and mean sizes. Note that the effort and LPUE from Scottish trawlers cover a shorter period 2000–2021.**



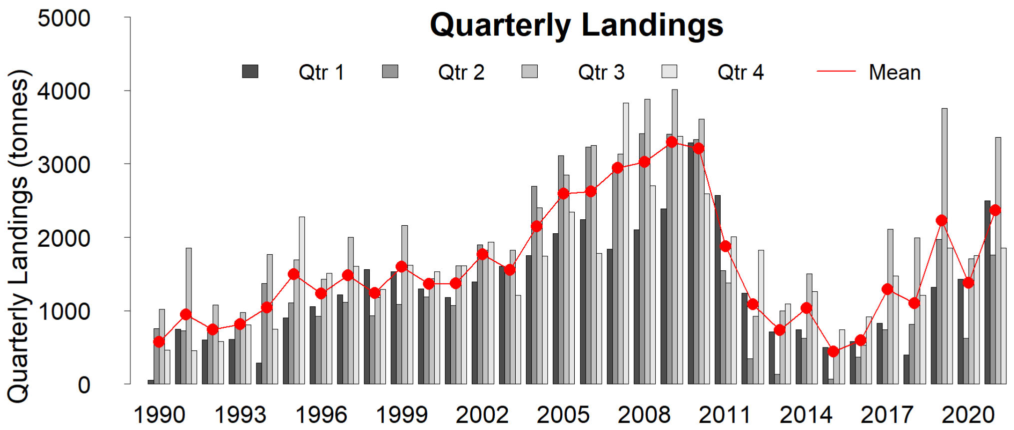


Figure 11.5.2 *Nephrops*, Fladen (FU 7), Landings by quarter and sex from Scottish *Nephrops* trawlers.

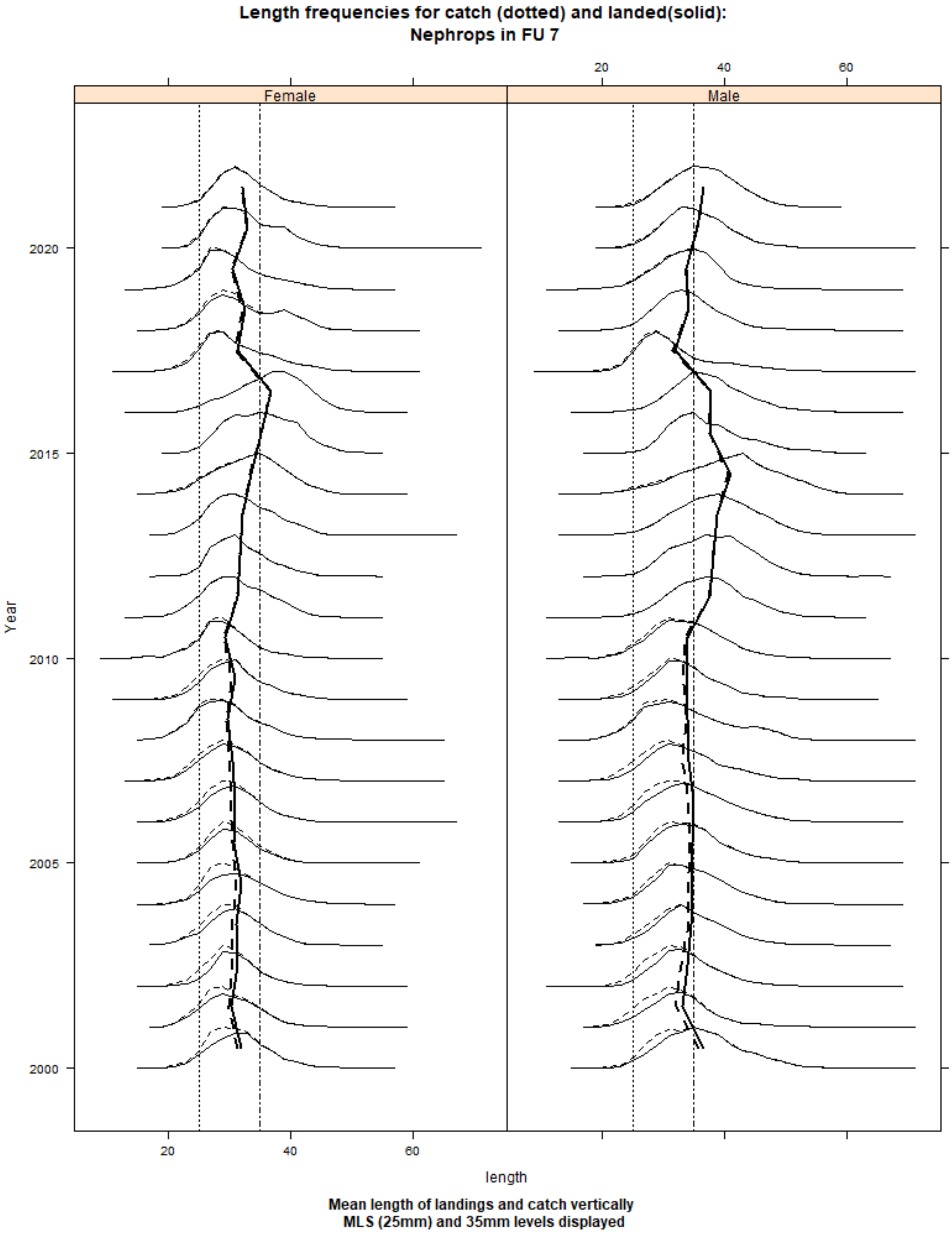
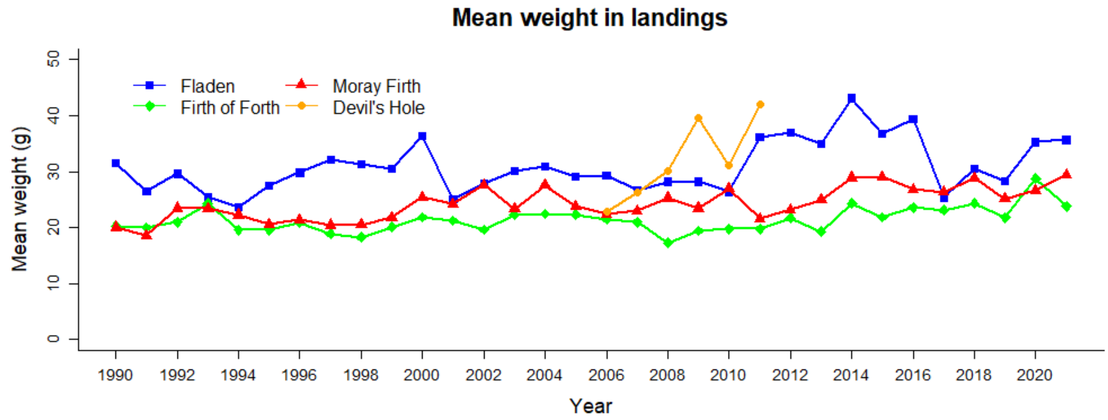


Figure11.5.3 *Nephrops* Fladen Ground (FU 7) Length composition of catch of males (right) and females left from 2000 (bottom) to 2021 (top). Mean sizes of catch and landings are displayed vertically.



11.5.4 *Nephrops,* (FUs 7–9 and 34, Fladen, Firth of Forth, Moray Firth and Devil's Hole). Individual mean weight (g) in the landings from 1990–2021 (Scottish market sampling data). FU 34 data only shown for 2006–2011.

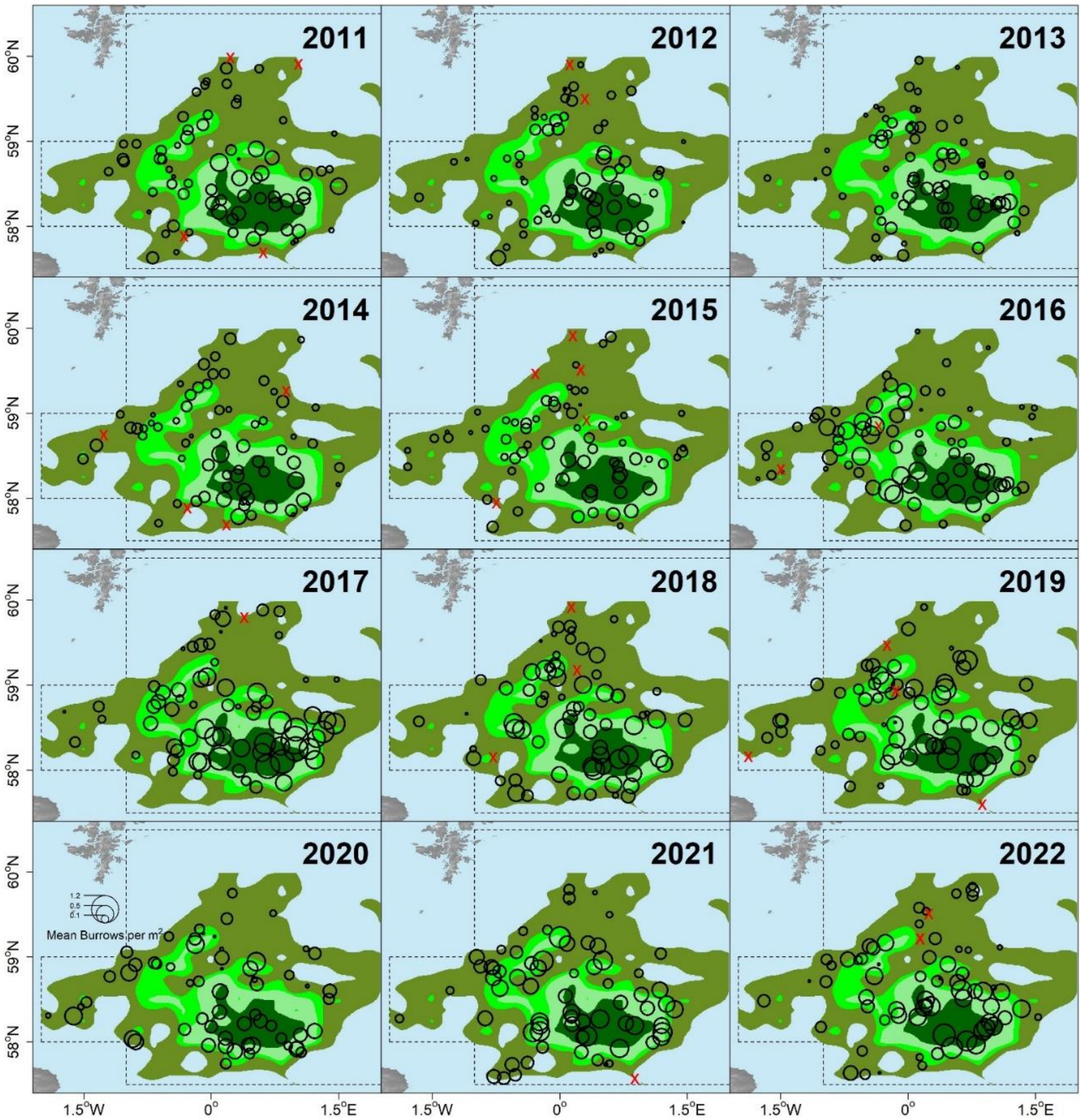


Figure 11.5.5 *Nephrops*, Fladen (FU 7). TV survey distribution and relative density (2011–2022). Green and brown areas represent areas of suitable sediment for *Nephrops*. Density proportional to circle radius. Red crosses represent zero observations.

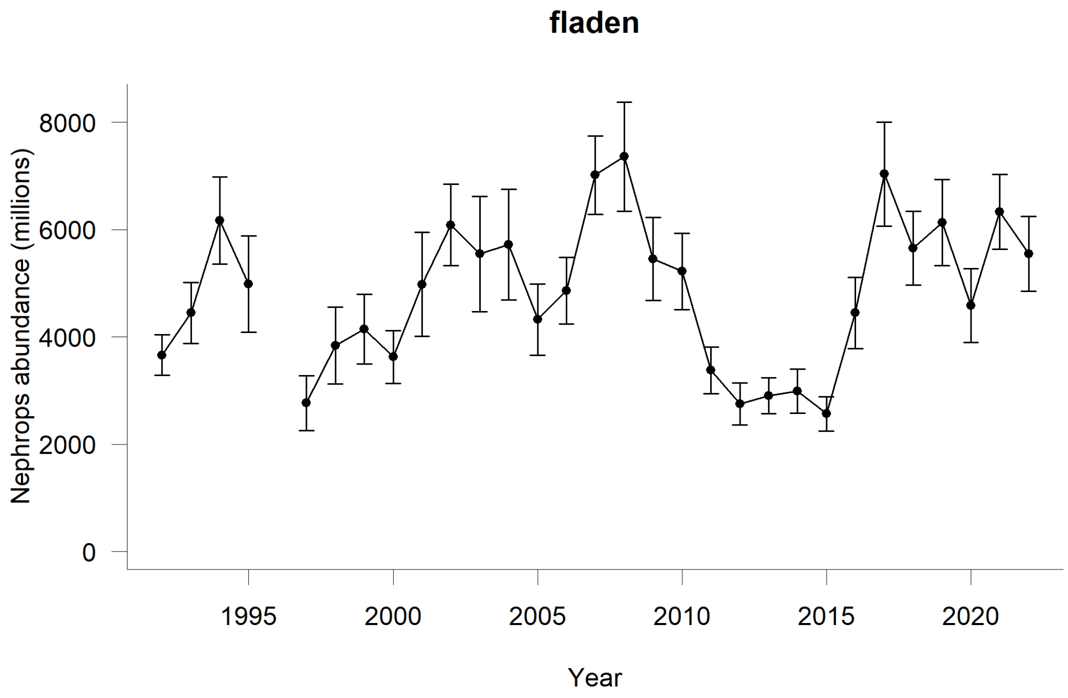


Figure 11.5.6 *Nephrops*, Fladen (FU 7), Time series of TV survey abundance estimates with 95% confidence intervals, 1992–2022.

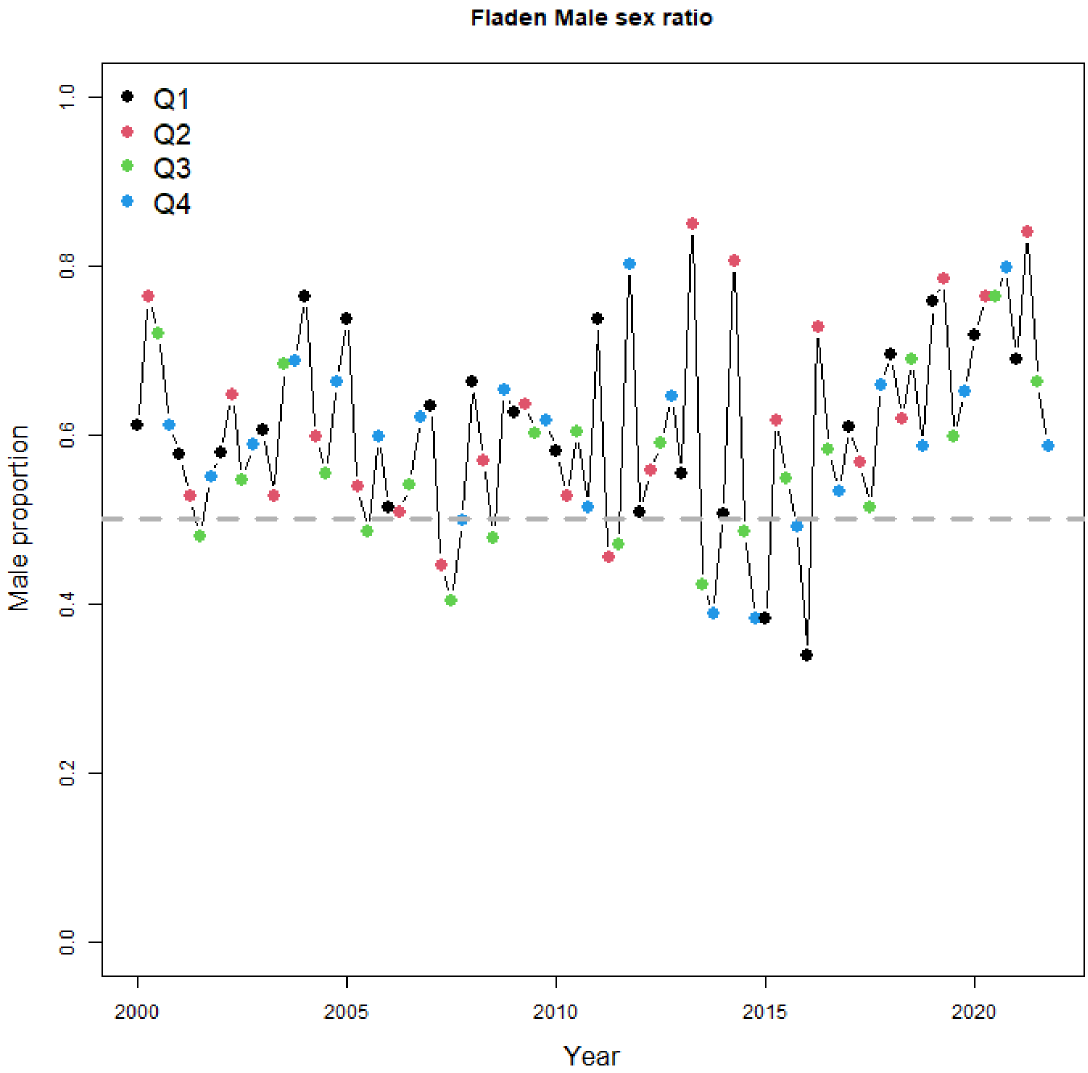


Figure 11.5.7 *Nephrops*, Fladen (FU 7), Quarterly sex ratio (by number) in catches.

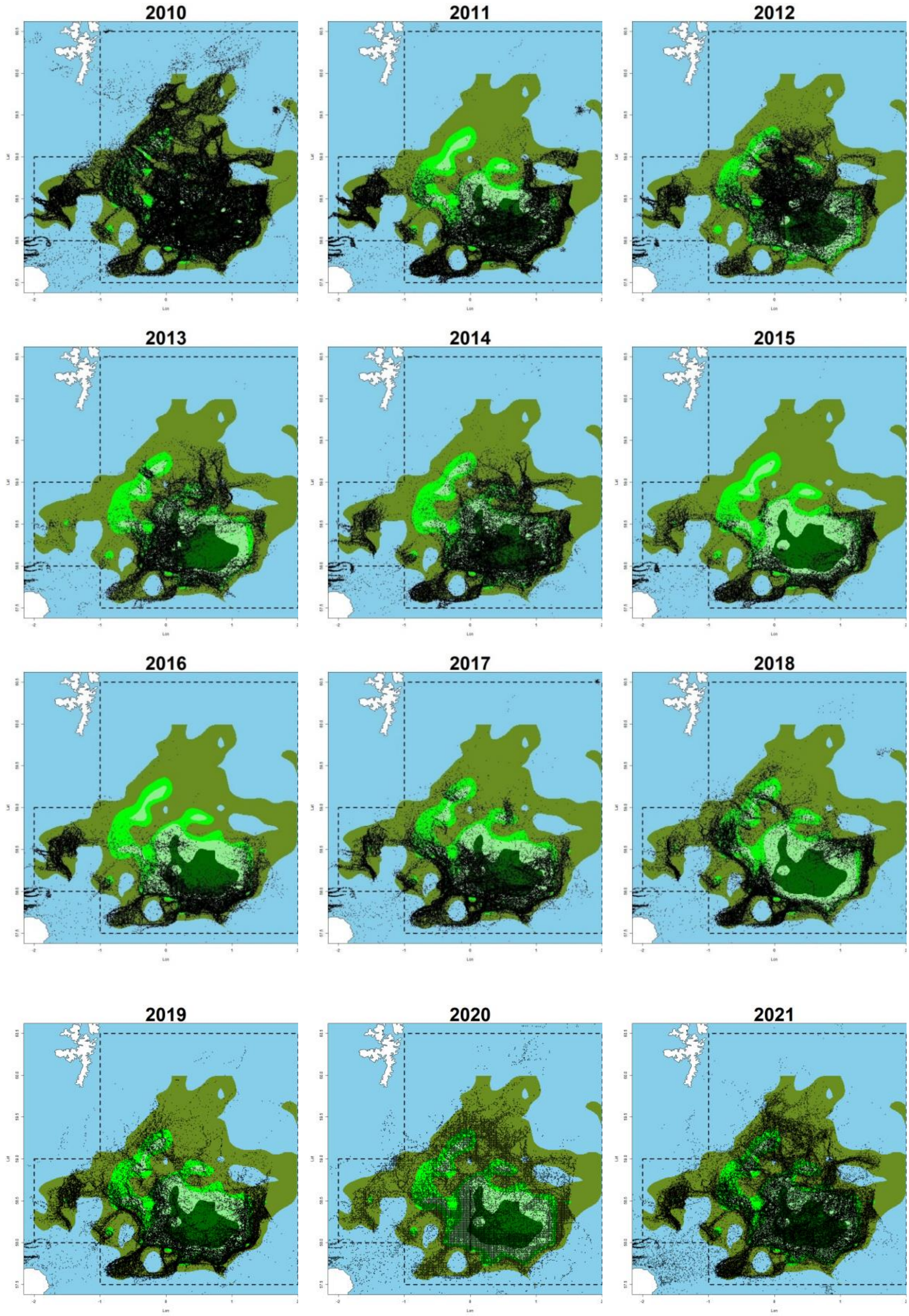


Figure 11.5.8 *Nephrops*, Fladen (FU 7), VMS distribution of vessels in Fladen (2010–2021). Points in figure correspond to fishing pings (speed < 5 kn) associated with trips made by otter trawlers landing more than 25% of *Nephrops* by weight.

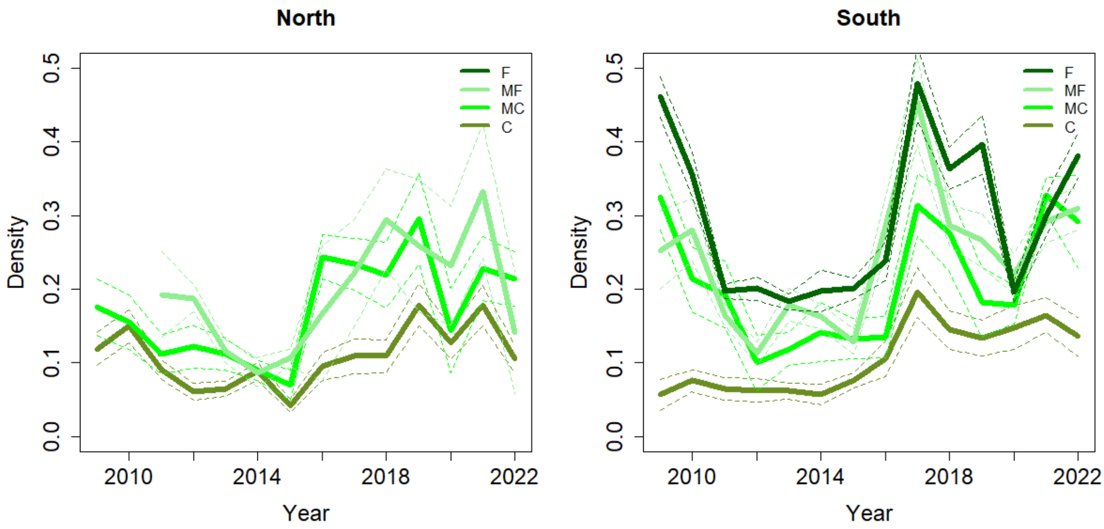


Figure 11.5.9 ***Nephrops*****, Fladen (FU 7), UWTV density by sediment type in the North (left plot) and South (right plot) of Fladen (split at the 58.75 N latitude line). F: fine sediment (silt and clay > 80%); MF: medium fine sediment (55% < silt and clay < 80); MC: medium coarse sediment (40% < silt and clay < 55); C: coarse sediment (silt and clay < 40%).**

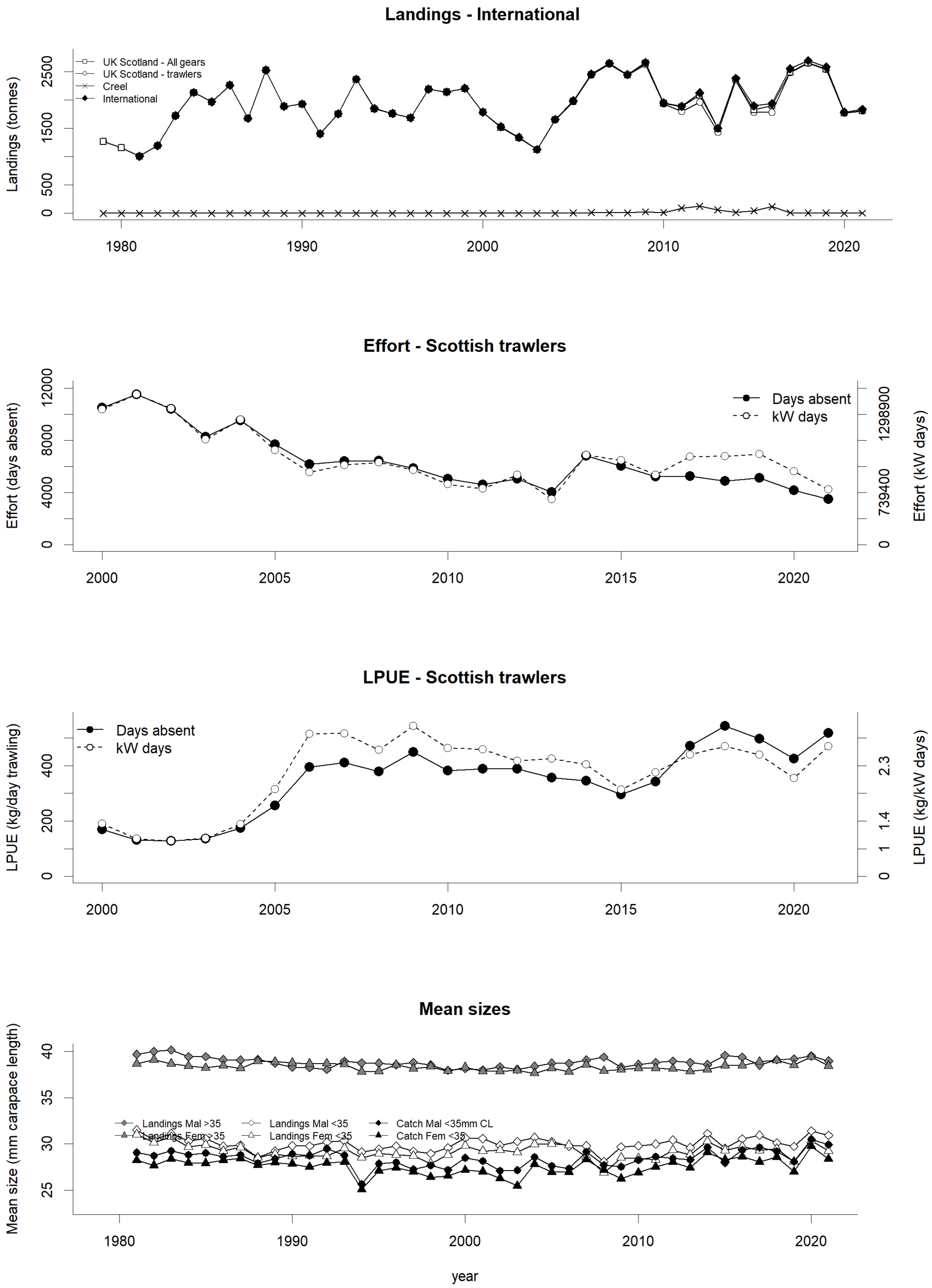
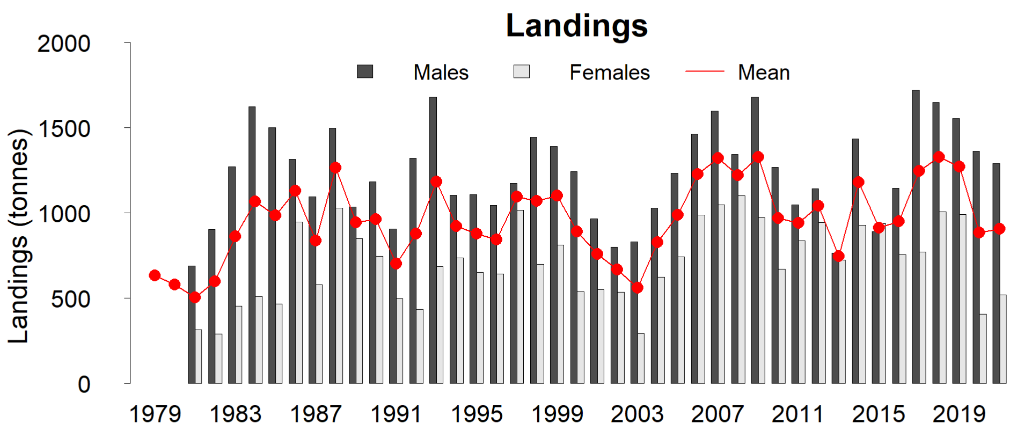


Figure 11.6.1 ***Nephrops*****, Firth of Forth (FU 8), Long term landings and mean sizes. Note that the effort and LPUE from Scottish trawlers cover a shorter period 2000–2021.**



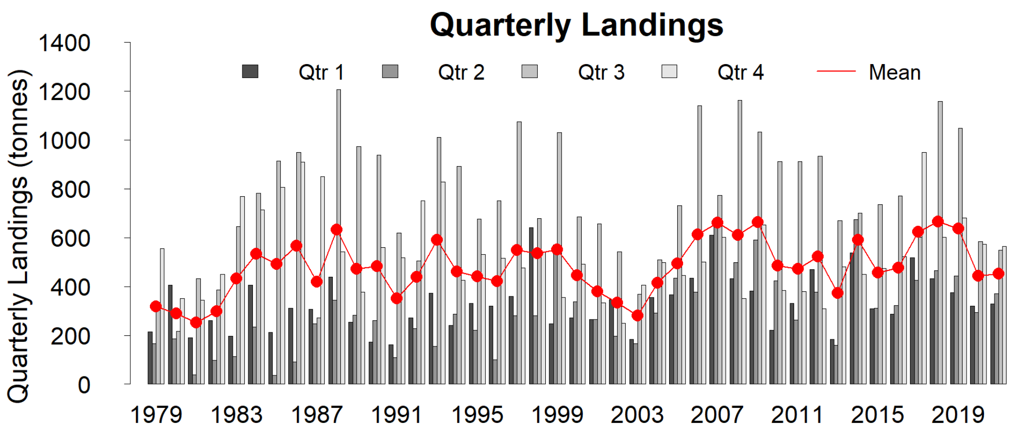


Figure 11.6.2 *Nephrops*, Firth of Forth (FU 8), Landings by quarter and sex from Scottish *Nephrops* trawlers.

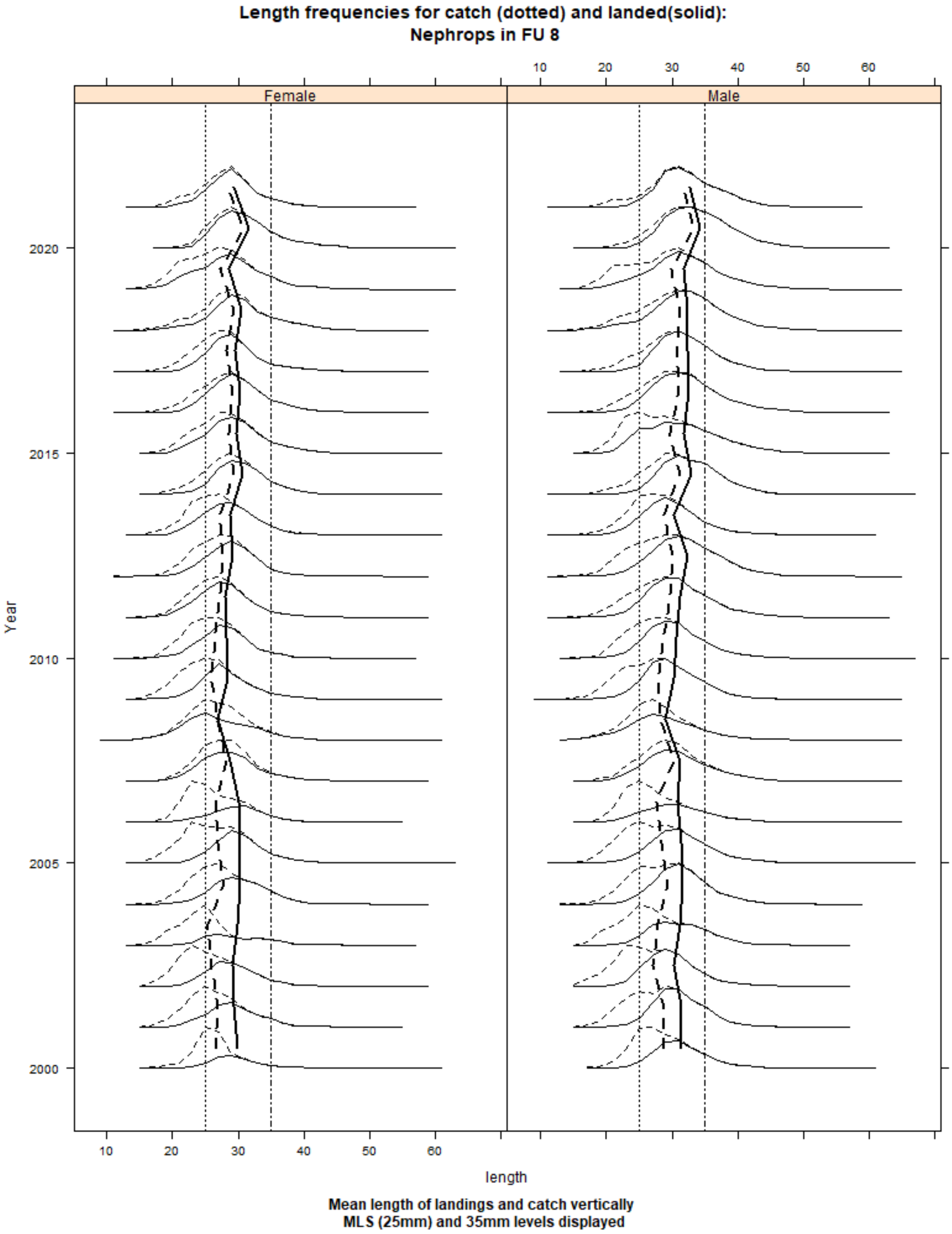


Figure 11.6.3 ***Nephrops*** **Firth of Forth (FU 8) Length composition of catch of males (right) and females left from 2000 (bottom) to 2021 (top). Mean sizes of catch and landings are displayed vertically.**

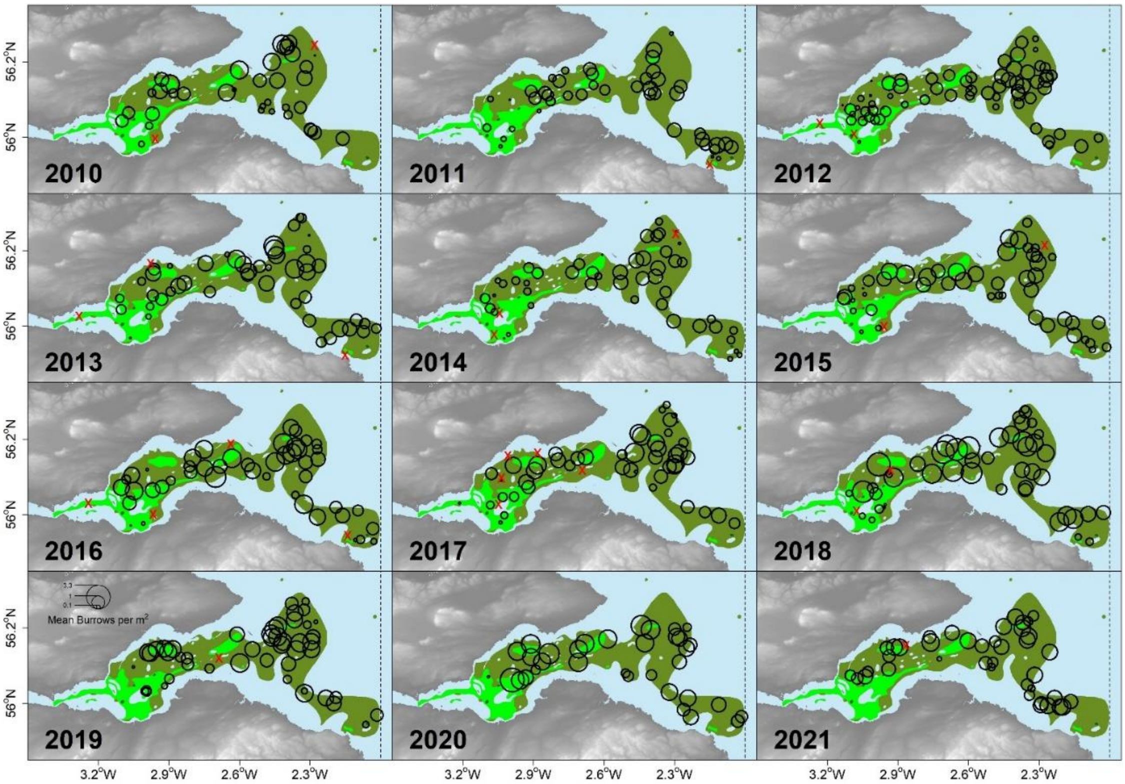


Figure 11.6.4 ***Nephrops*****, Firth of Forth (FU 8). TV survey distribution and relative density (2010–2021). There was no TV survey in 2022. Green and brown areas represent areas of suitable sediment for *Nephrops*. Density proportional to circle radius. Red crosses represent zero observations.**

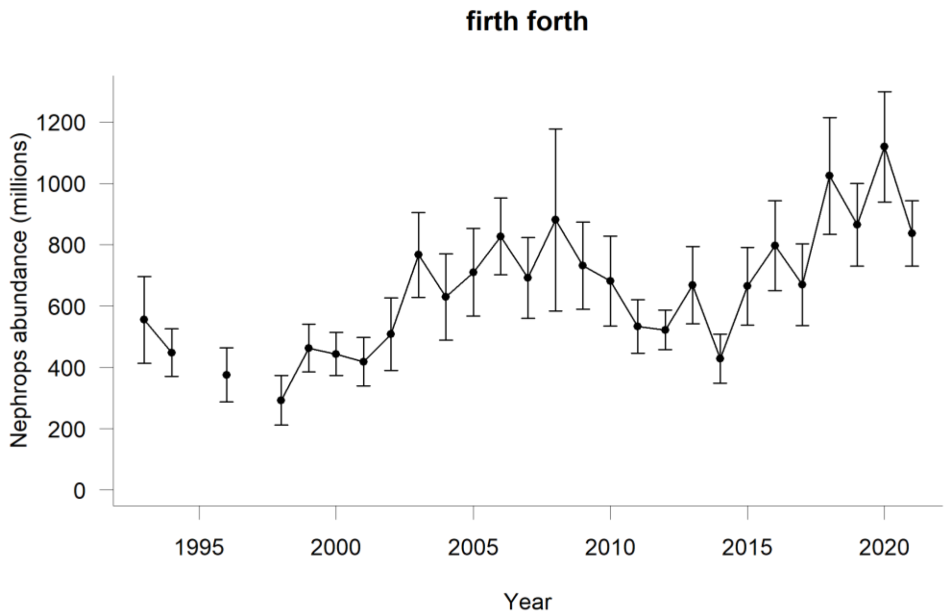


Figure 11.6.5 ***Nephrops*****, Firth of Forth (FU 8), Time series of TV survey abundance estimates with 95% confidence intervals, 1993–2021.**

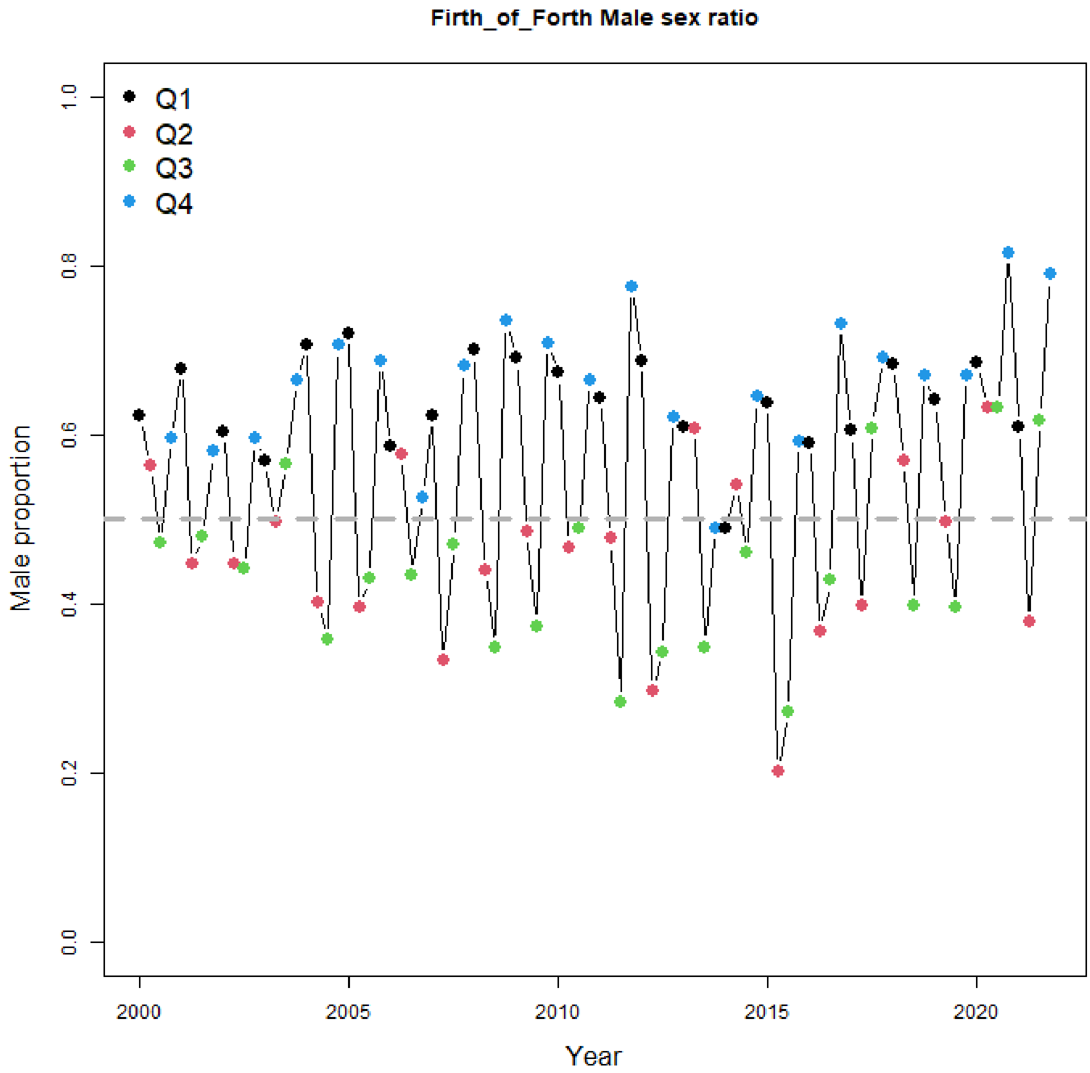


Figure 11.6.6 ***Nephrops*****, Firth of Forth (FU 8), Quarterly sex ratio (by number) in catches.**

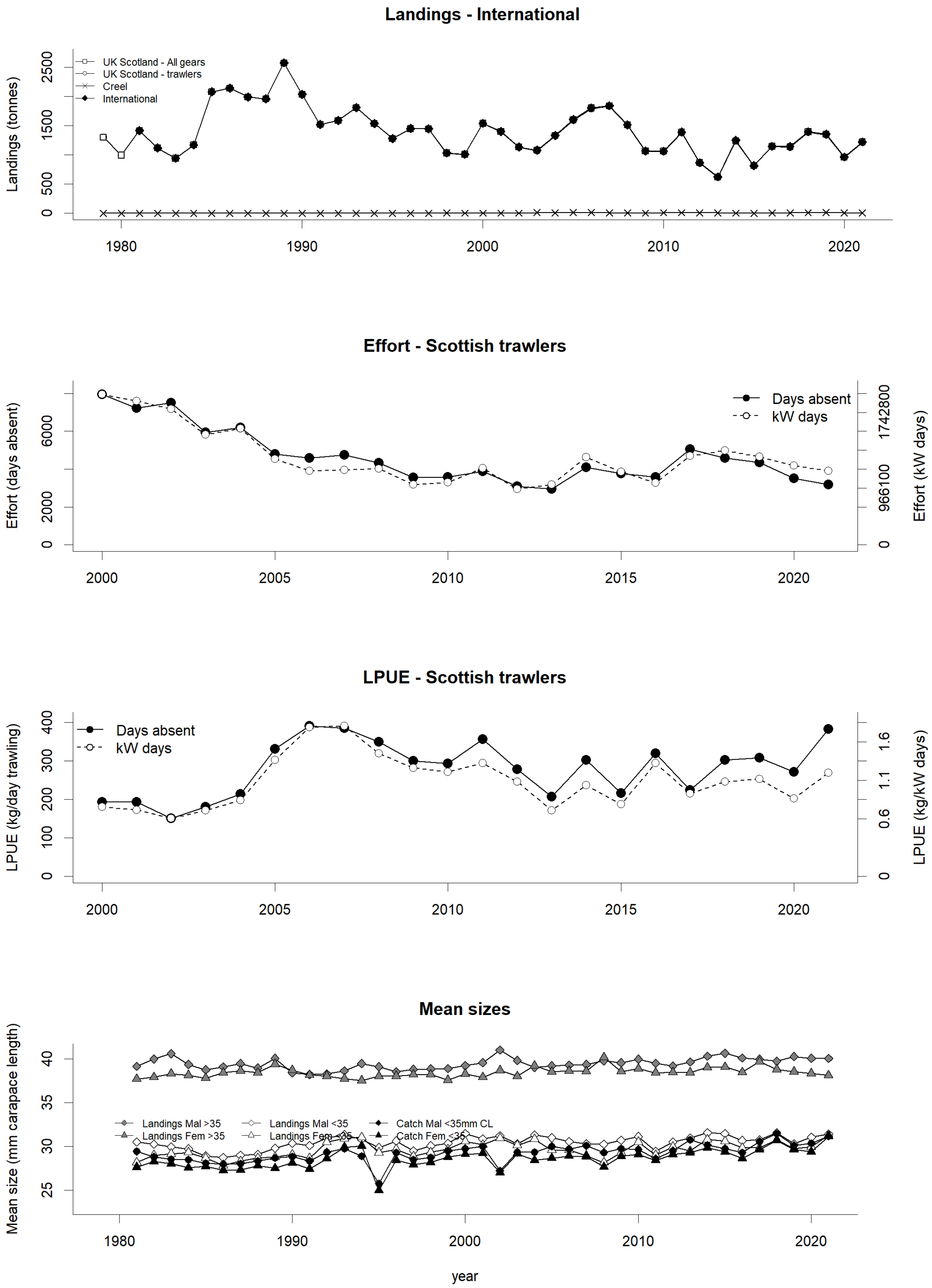
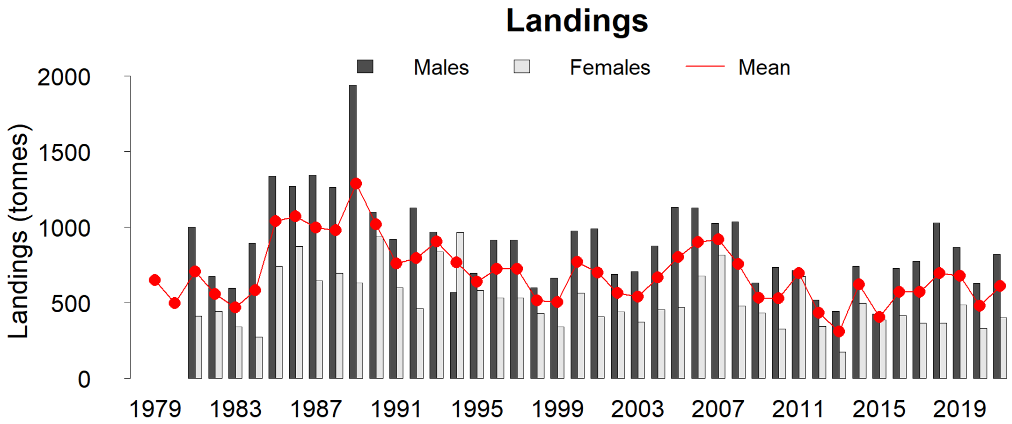


Figure 11.7.1 ***Nephrops*****, Moray Firth (FU 9), Long term landings and mean sizes. Note that the effort and LPUE from Scottish trawlers cover a shorter period 2000–2021.**



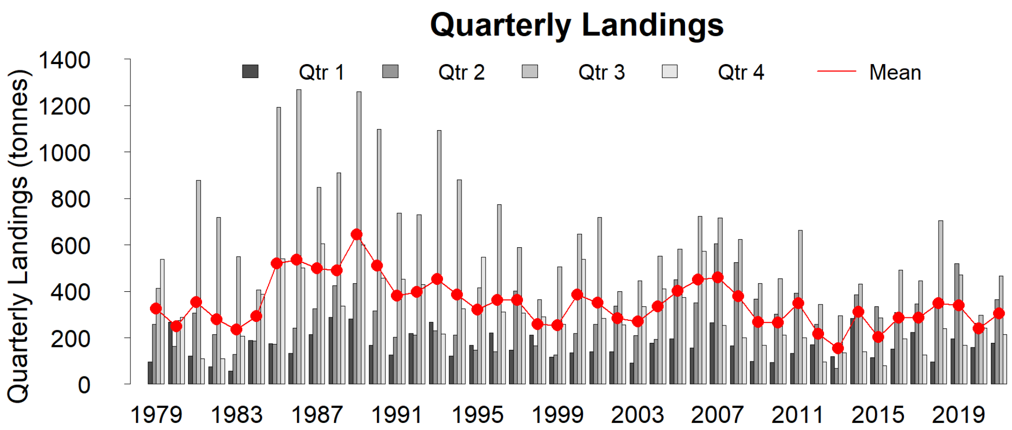


Figure 11.7.2 *Nephrops*, Moray Firth (FU 9), Landings by quarter and sex from Scottish *Nephrops* trawlers.

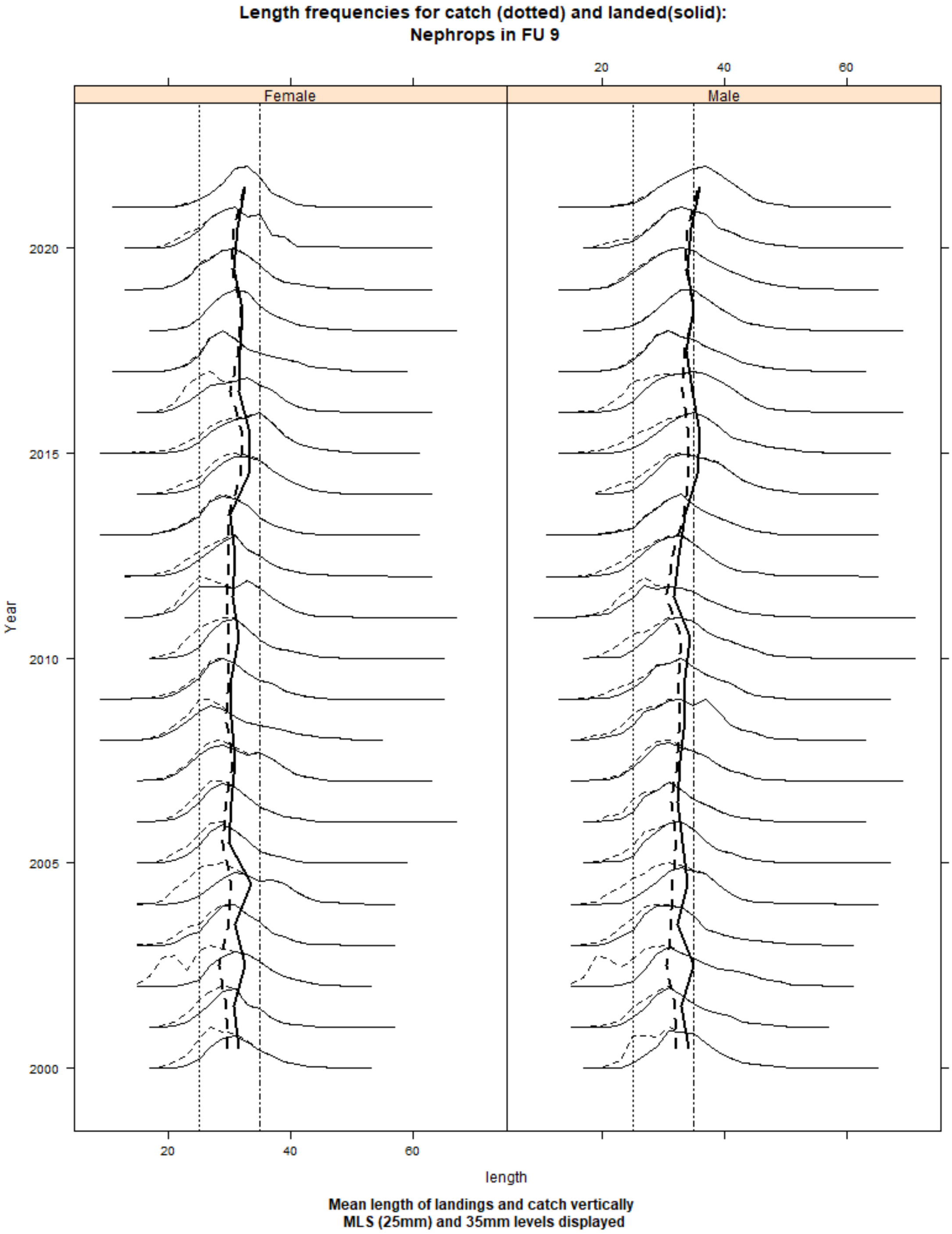


Figure 11.7.3 ***Nephrops*** **Moray Firth (FU 9) Length composition of catch of males (right) and females left from 2000 (bottom) to 2021 (top). Mean sizes of catch and landings are displayed vertically.**

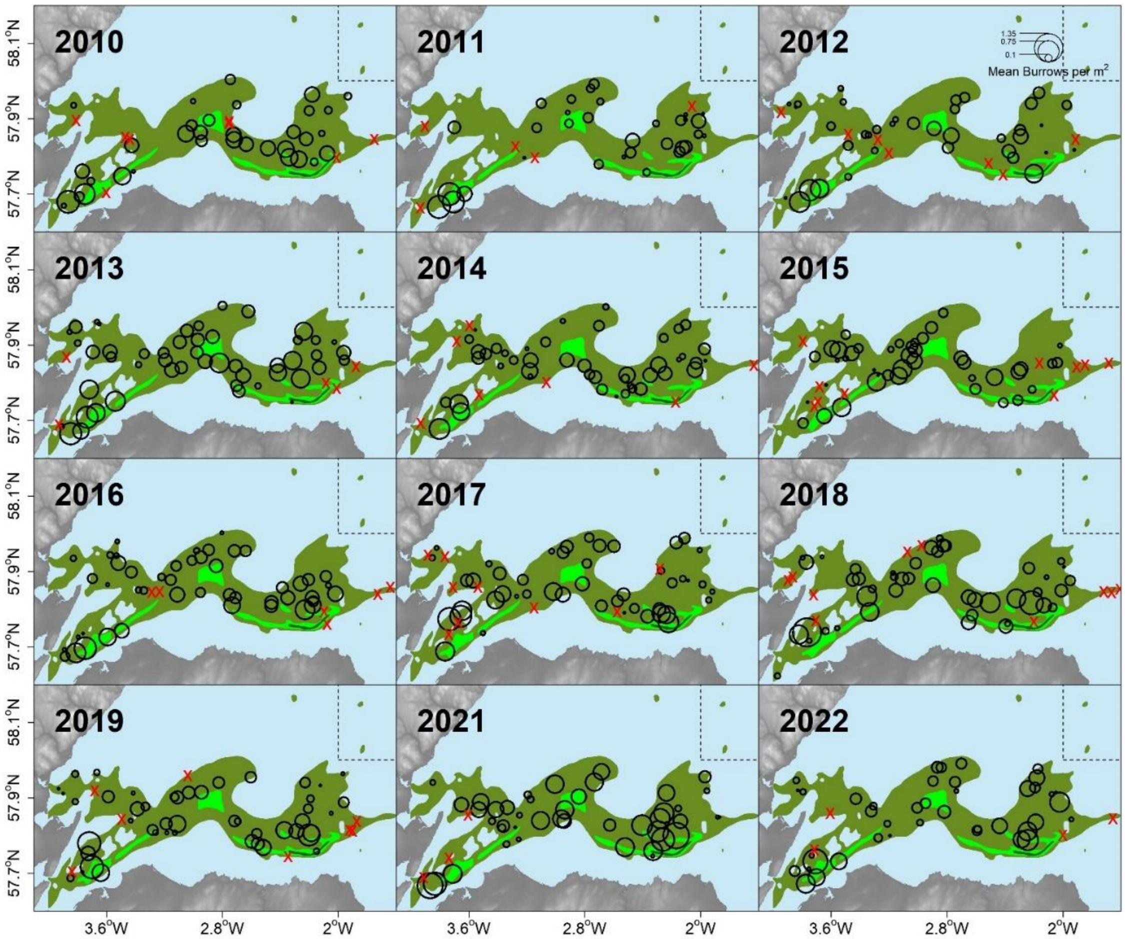


Figure 11.7.4 ***Nephrops*****, Moray Firth (FU 9). TV survey distribution and relative density (2010–2022). There was no TV survey in 2020. Green and brown areas represent areas of suitable sediment for *Nephrops*. Density proportional to circle radius. Red crosses represent zero observations.**

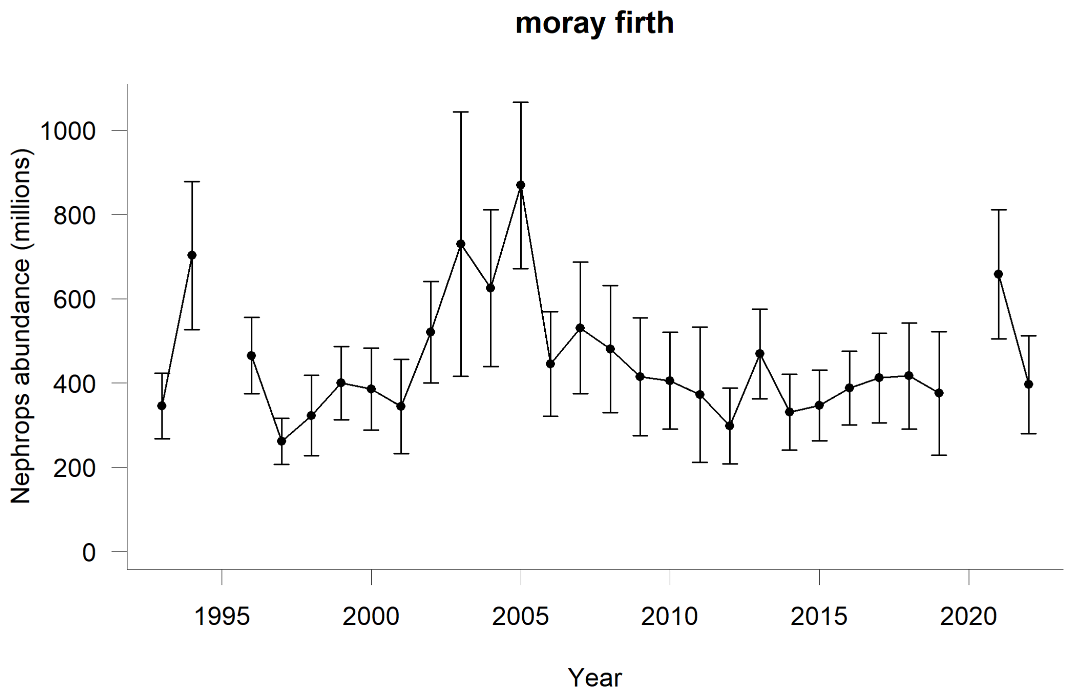


Figure 11.7.5 ***Nephrops*****, Moray Firth (FU 9), Time series of TV survey abundance estimates with 95% confidence intervals, 1993–2022.**

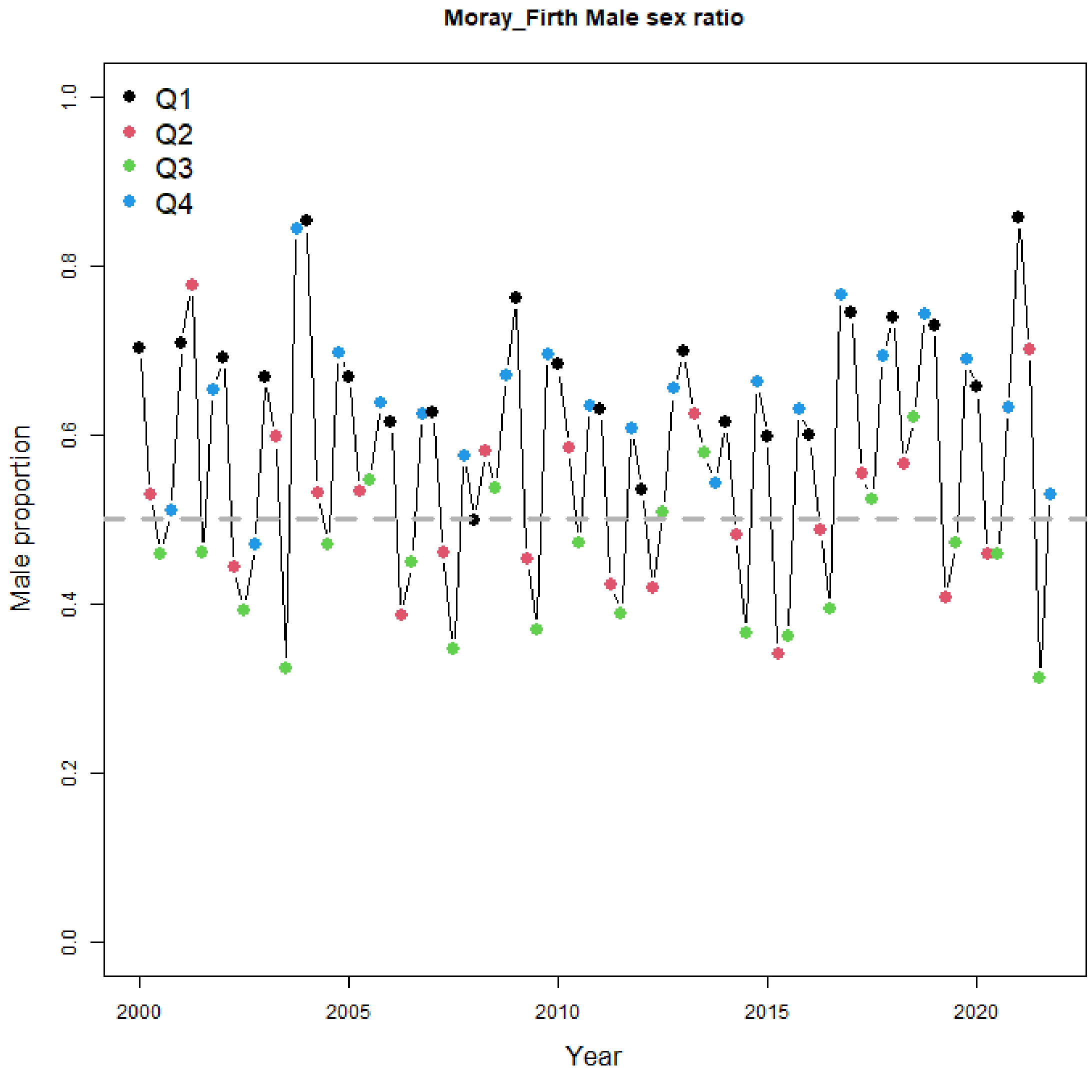


Figure 11.7.6 ***Nephrops*****, Moray Firth (FU 9), Quarterly sex ratio (by number) in catches.**

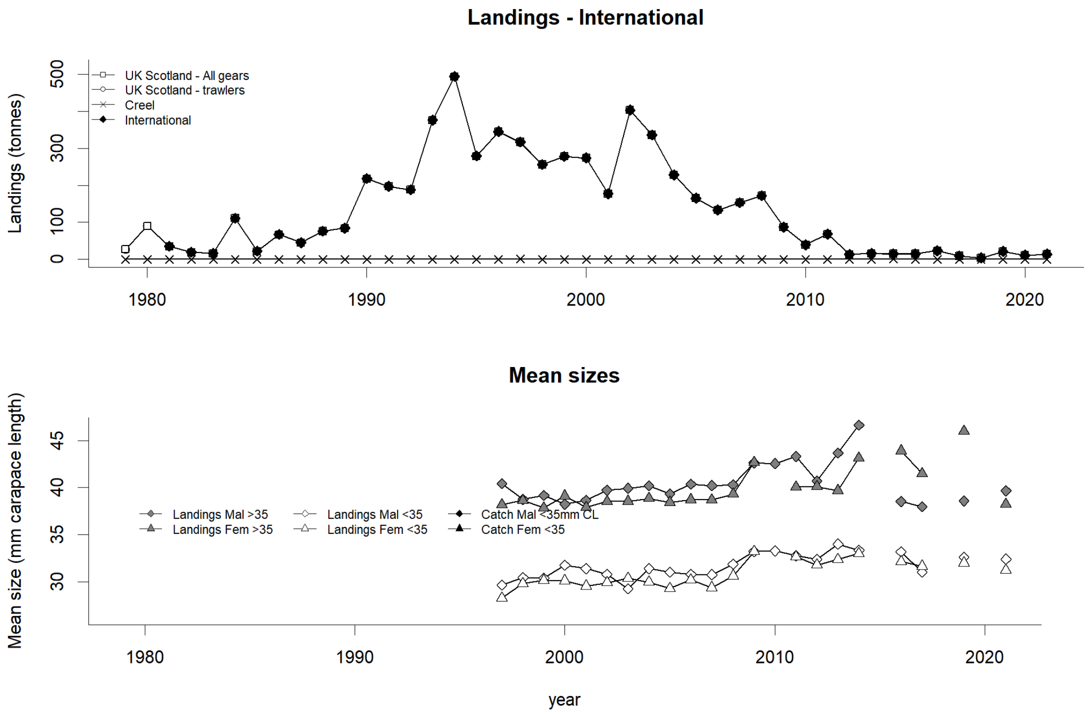


Figure 11.8.1 ***Nephrops*****, Noup (FU 10), Long term landings and mean sizes (no females in samples in 2010 and no samples in 2015, 2018 and 2020).**

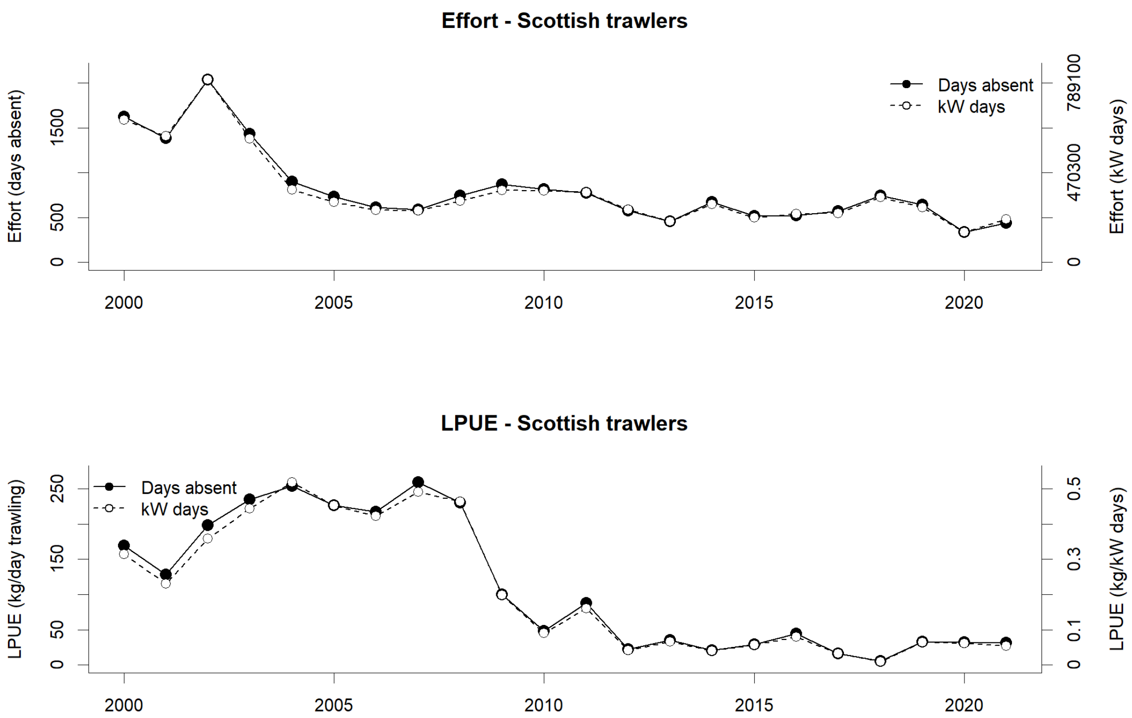


Figure 11.8.2 ***Nephrops*****, Noup (FU 10), Effort (days, kWday) and LPUE (kg/day, kg/kWdays), data from year 2000.**

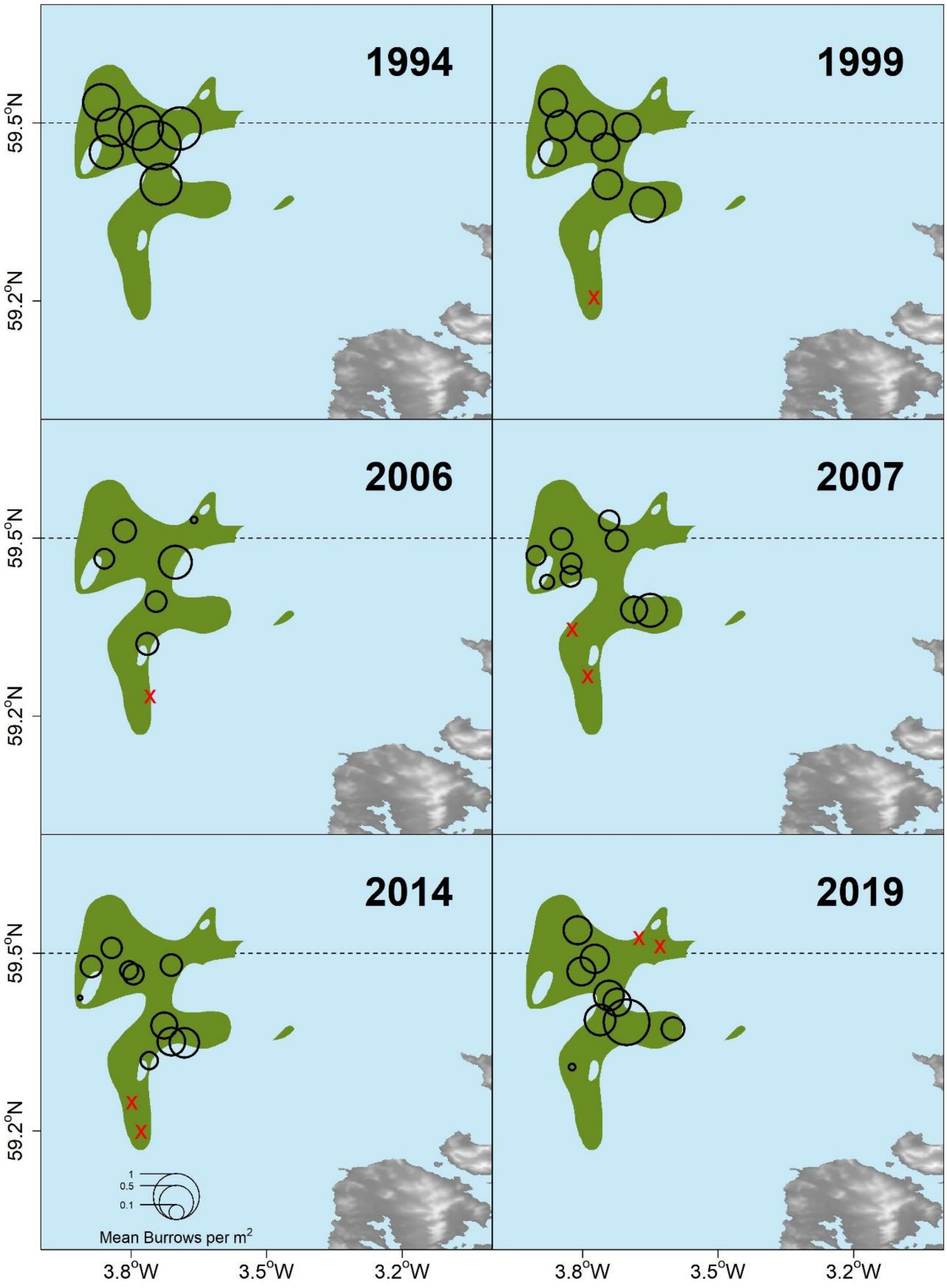


Figure 11.8.3 *Nephrops*, Noup (FU 10). TV survey distribution and relative density (1994, 1999, 2006, 2007, 2014 and 2019). Green and brown areas represent areas of suitable sediment for *Nephrops*. Density proportional to circle radius. Red crosses represent zero observations.

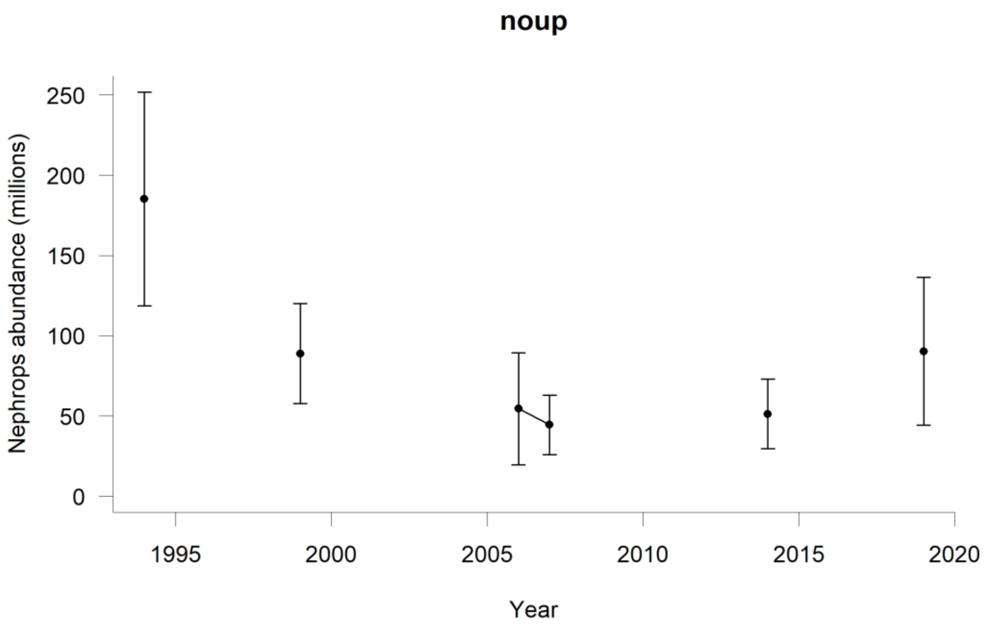


Figure 11.8.4 *Nephrops*, Noup (FU 10), Time series of TV survey abundance estimates (absolute conversion factor = 1.35, from Fladen), with 95% confidence intervals, 1994, 1999, 2006–2007, 2014 and 2019.

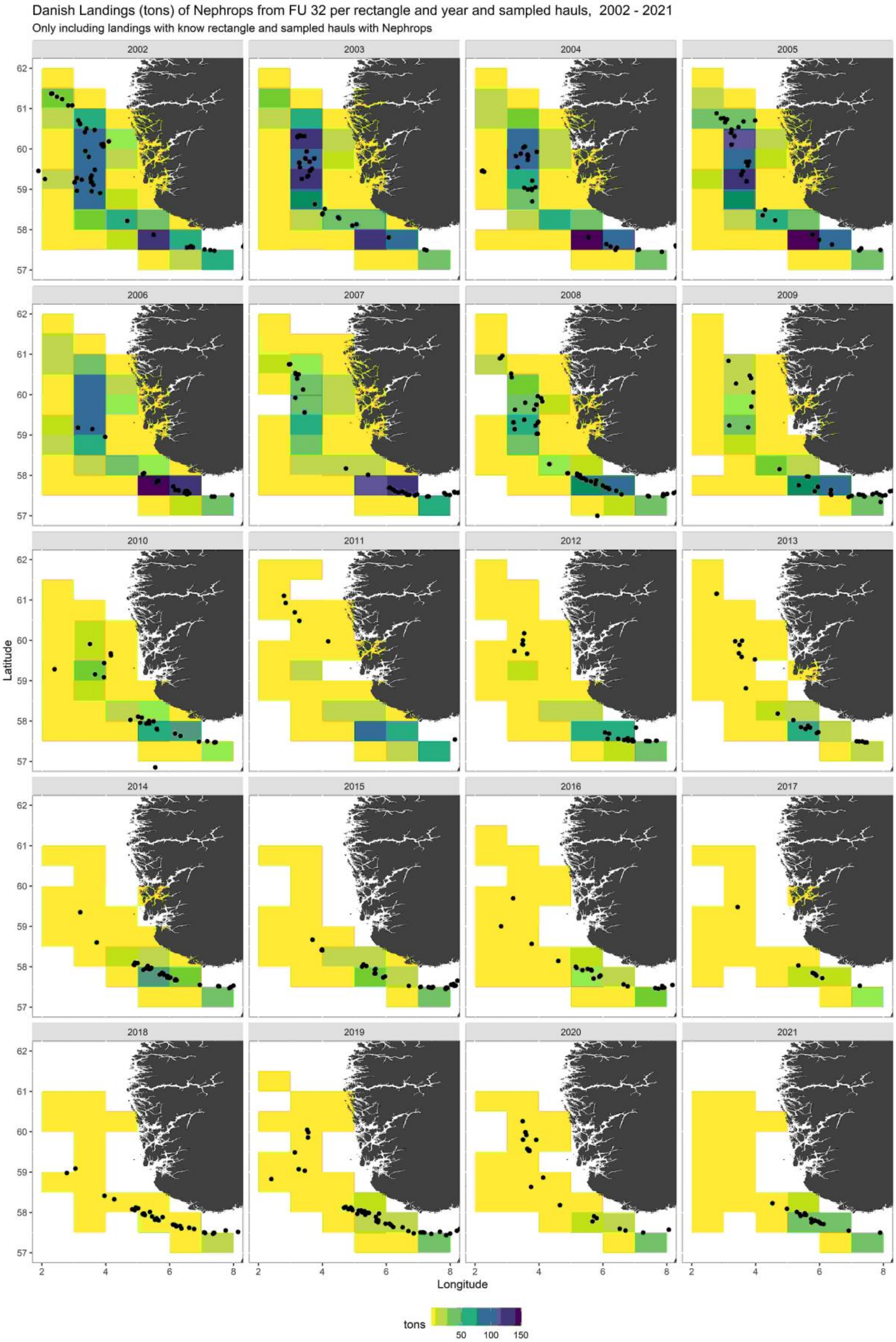


Figure 11.9.1. *Nephrops* Norwegian Deep (FU 32). Danish landings of *Nephrops* by ICES statistical square, 2000–2021. Dots represent hauls with *Nephrops* from the Danish at-sea-sampling program.

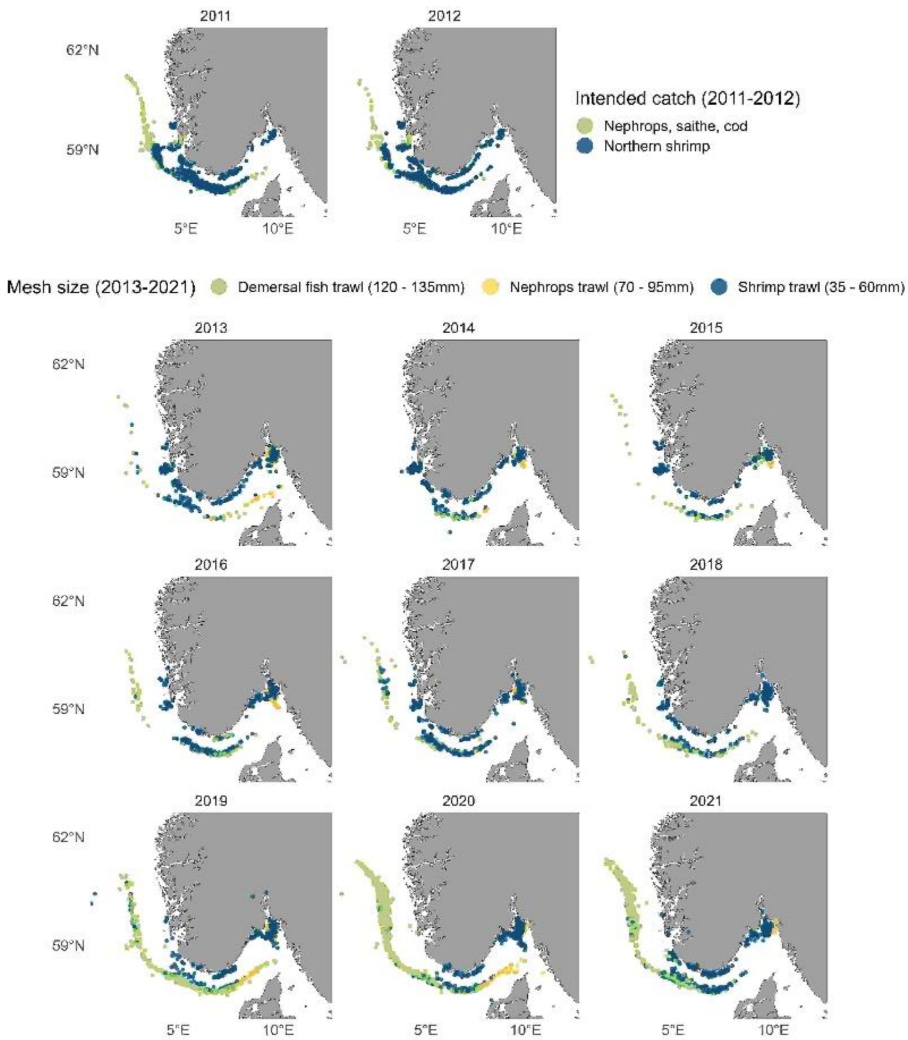


Figure 11.9.2. *Nephrops* Norwegian Deep (FU 32): Positions of trawl hauls with *Nephrops* in the catch from Norwegian bottom trawlers ≥ 15 m (large mesh and small mesh shrimp trawlers), 2011–2021. Information on mesh size was not available in 2011–2012, and type of trawl was determined from information on intended catch.

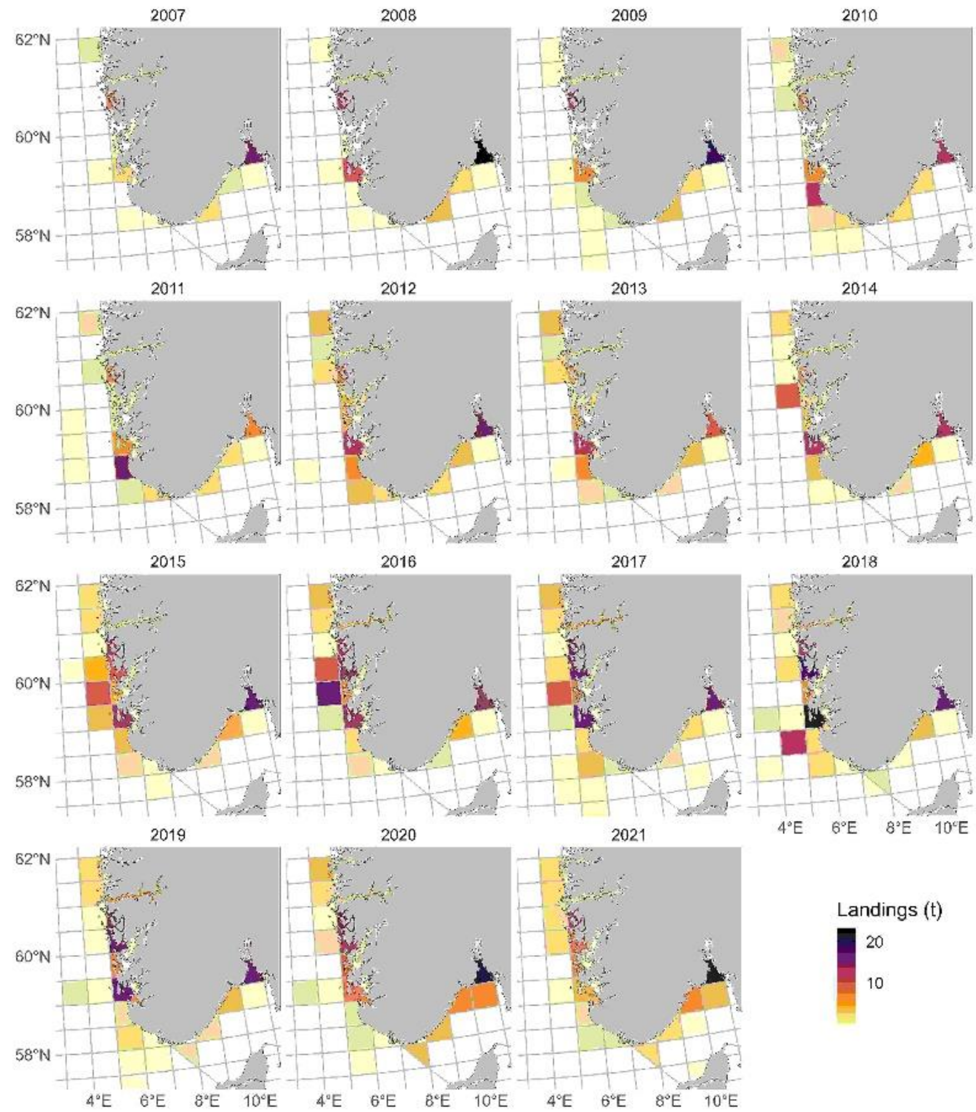


Figure 11.9.3. ***Nephrops*** **Norwegian Deep (FU 32): Norwegian creel landings by ICES statistical square, 2009–2021.**

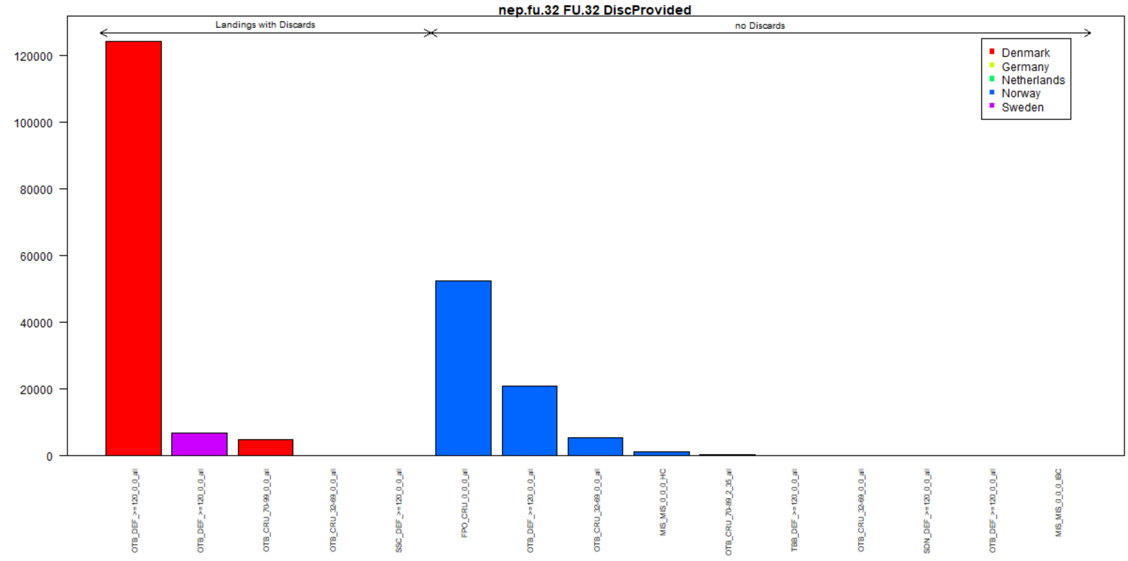


Figure 11.9.4. ***Nephrops*** **Norwegian Deep (FU 32): Landings (kg) by country and métier in 2021 associated with discards as uploaded into InterCatch.**

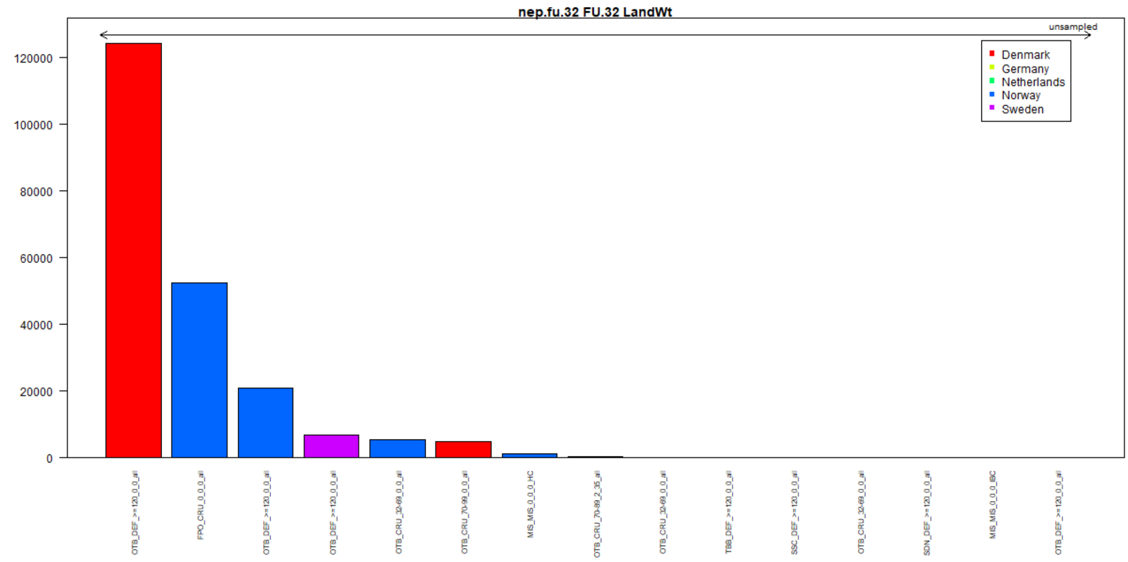


Figure 11.9.5. ***Nephrops*** **Norwegian Deep (FU 32): Landings (kg) by country and métier in 2021 with length samples as uploaded into InterCatch.**

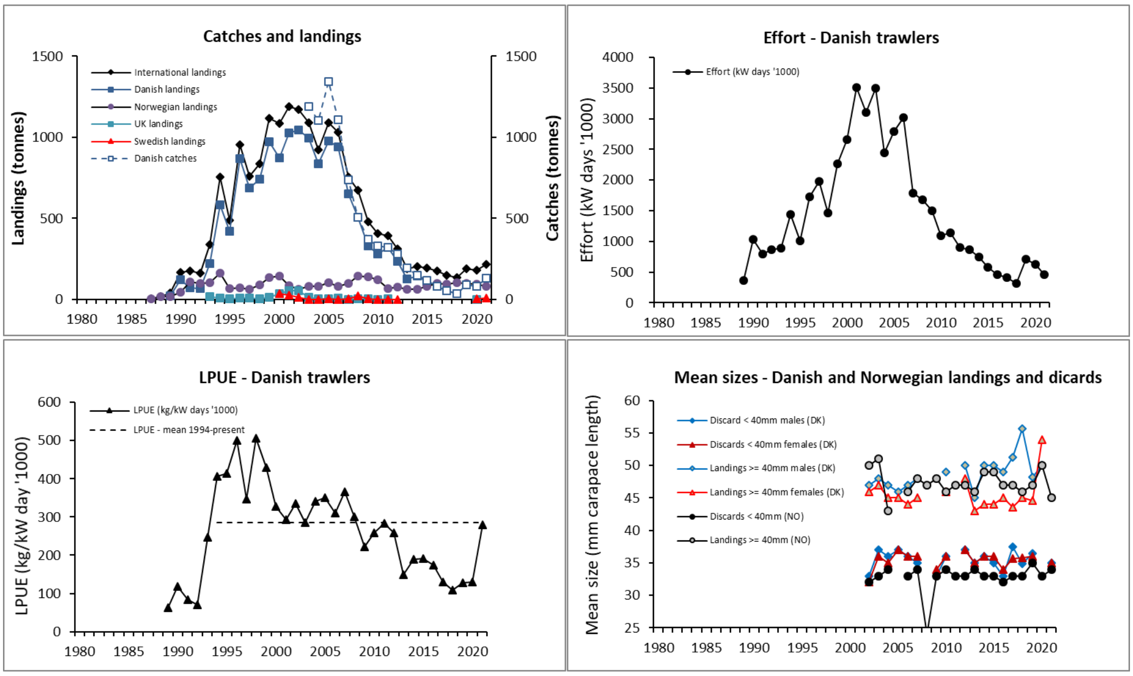


Figure 11.9.6. *Nephrops* Norwegian Deep (FU 32). Catches and landings, Danish effort, Danish LPUE, and mean size in discards (< 40 mm) and landings (≥ 40 mm). Mean sizes in Norwegian (NO) landings and discards are from inspections by the Norwegian Coast Guard of both Norwegian and Danish vessels and catches.

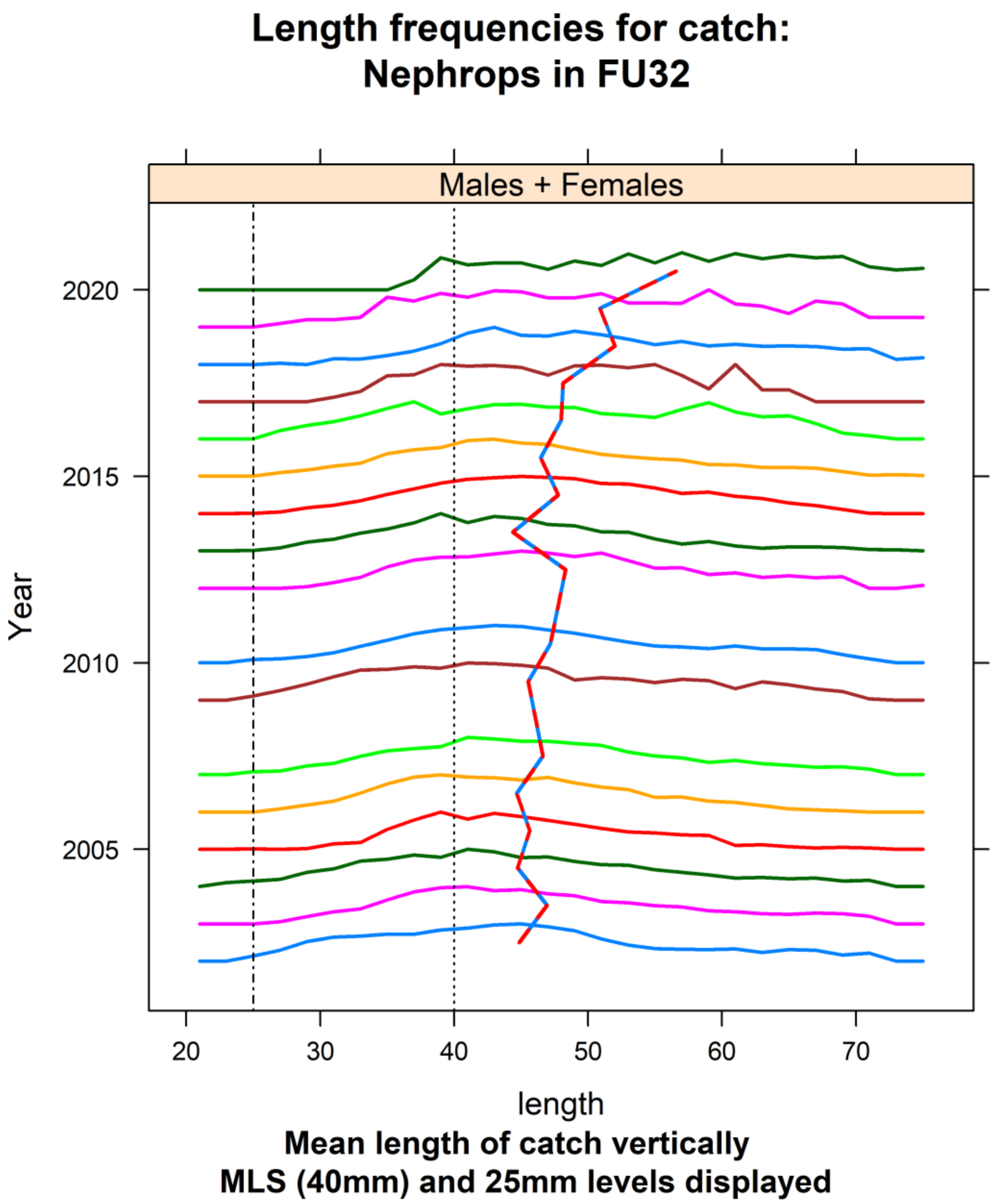


Figure 11.9.7. *Nephrops* Norwegian Deep (FU 32): Size distribution in Danish catches, 2002–2020. There was no Danish sampling of discards in 2020. The figure was not updated this year as there was no Danish sampling of landings in 2021.

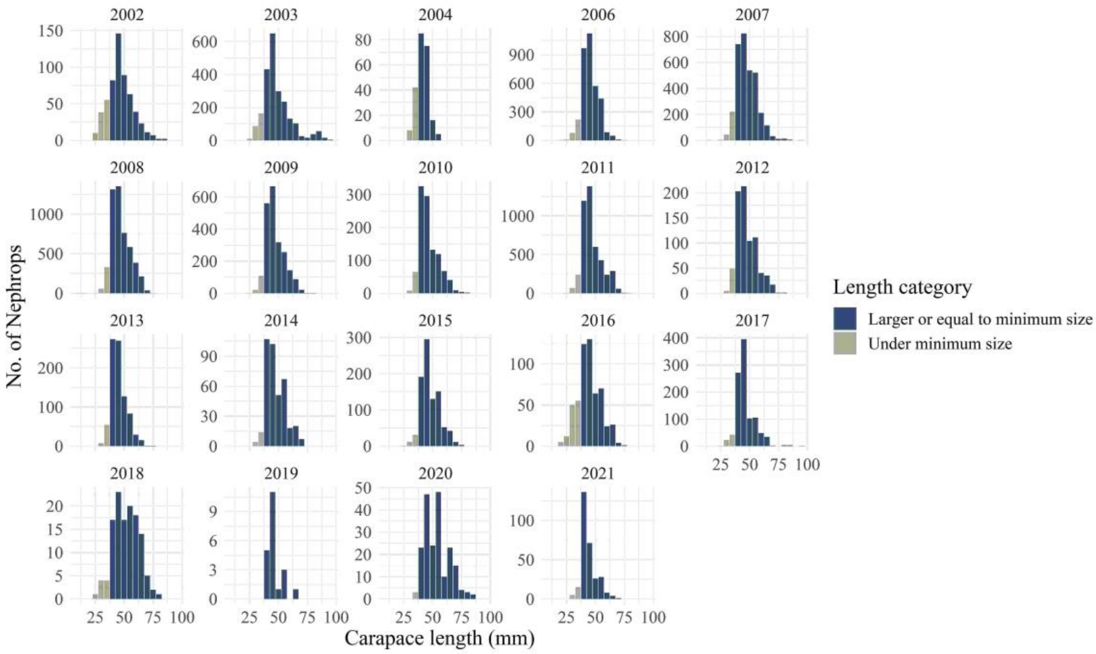


Figure 11.9.8. *Nephrops* Norwegian Deep (FU 32): Annual length frequency distributions from inspections by the Norwegian Coast Guard of Danish and Norwegian trawlers, 2002–2021.

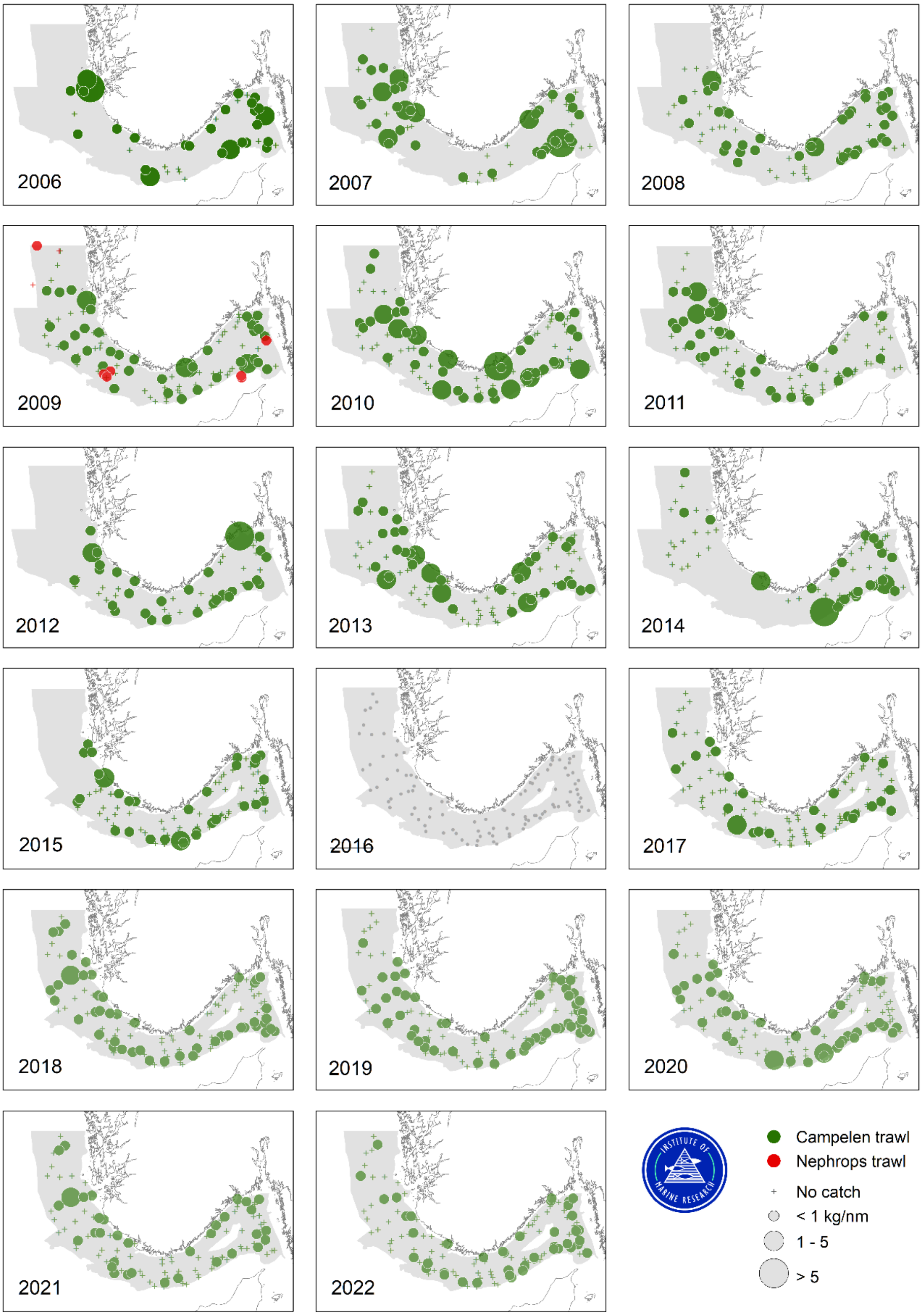


Figure 11.9.9. *Nephrops* Norwegian Deep (FU 32): Distribution of *Nephrops* in Norwegian bottom trawl shrimp survey, 2006–2022. The 2016-data are omitted from the time series due to technical problems with the trawl gear in this year's survey.

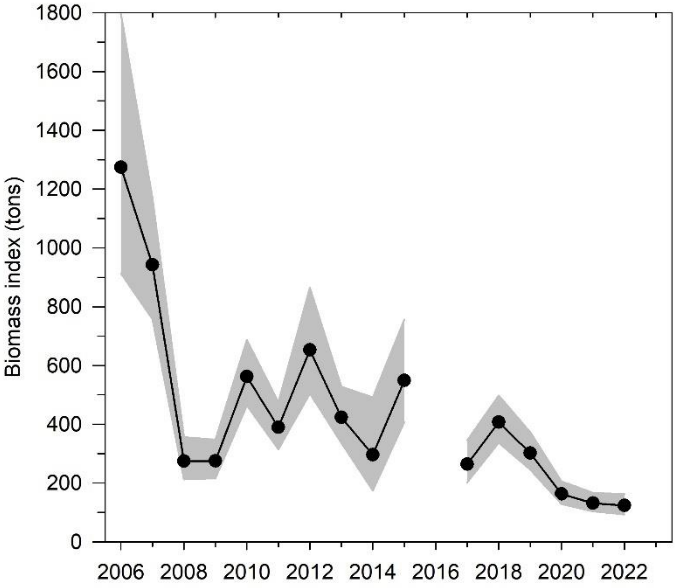


Figure 11.9.10. *Nephrops* Norwegian Deep (FU 32): Biomass index (tonnes) (2006–2022) from the Norwegian bottom trawl shrimp survey. The 2016–data are omitted from the time series due to technical problems with the trawl gear at this year's survey.

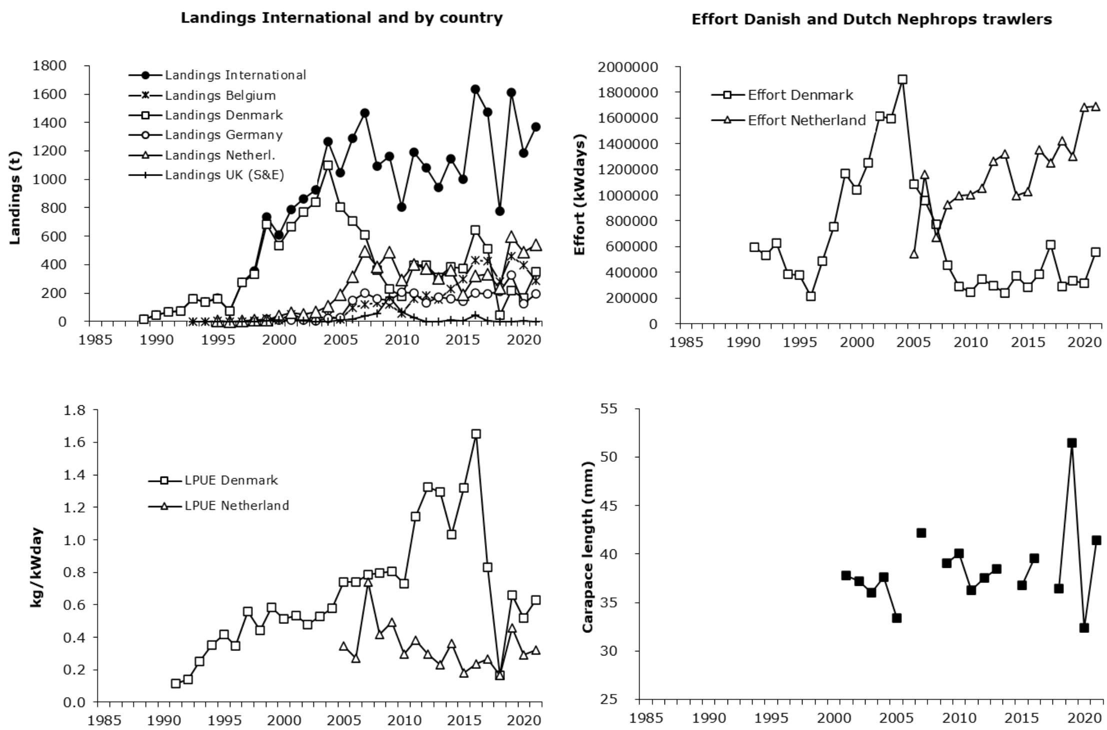


Figure 11.10.1. *Nephrops* in FU 33 (Off Horns Reef): Landings, effort, LPUE and mean size.

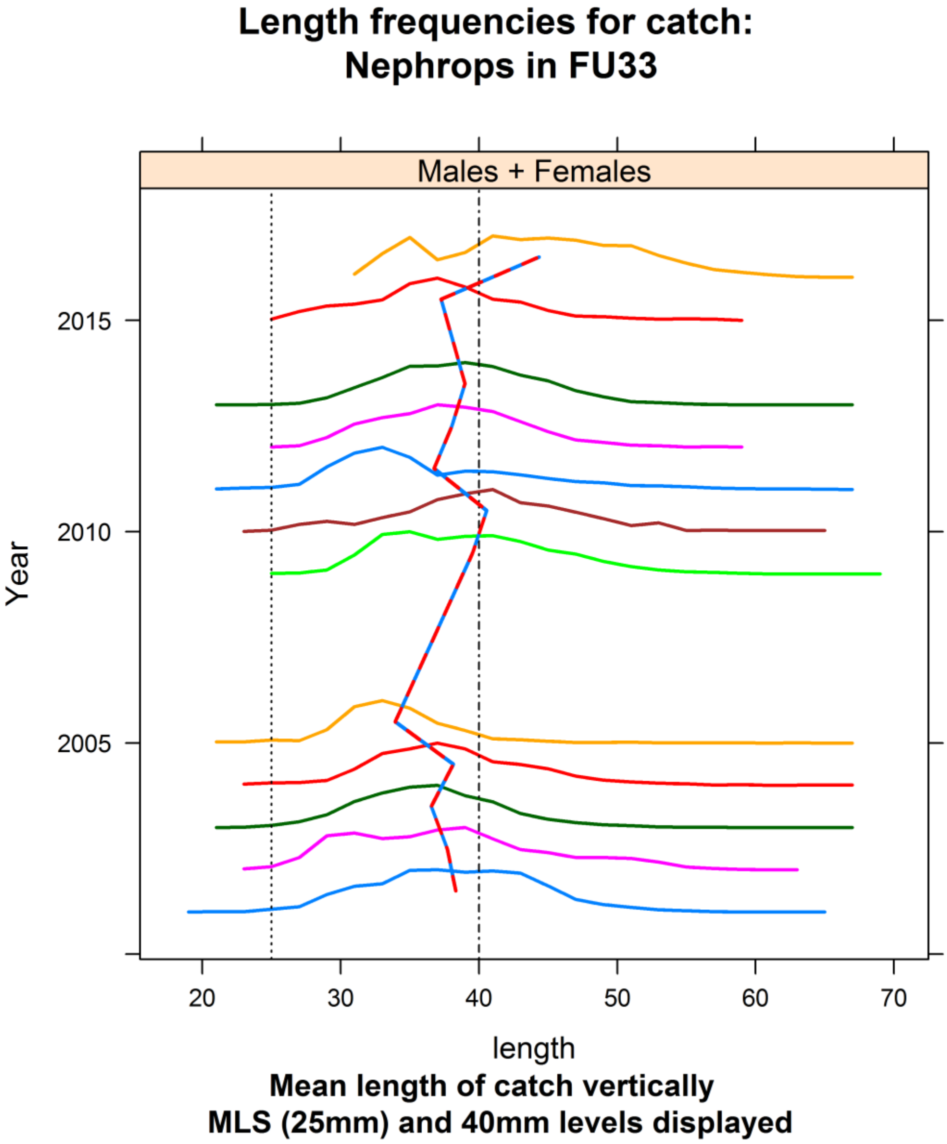


Figure 11.10.2. ***Nephrops*** **in FU 33 (Off Horn's Reef): Size distribution in Danish catches.**

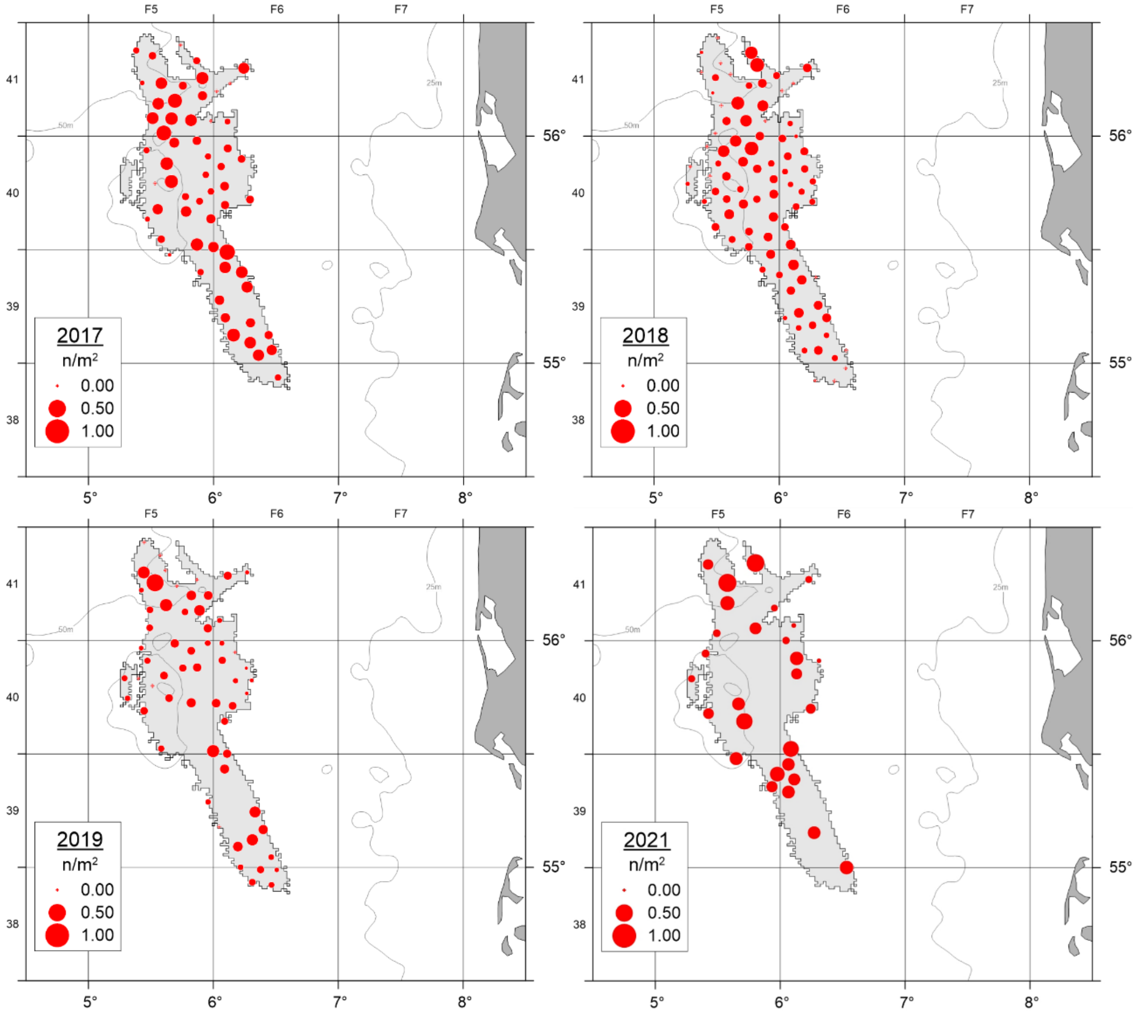


Figure 11.10.3. FU 33 (Off Horn's Reef) *Nephrops* burrow density by station for each UWTV survey year.

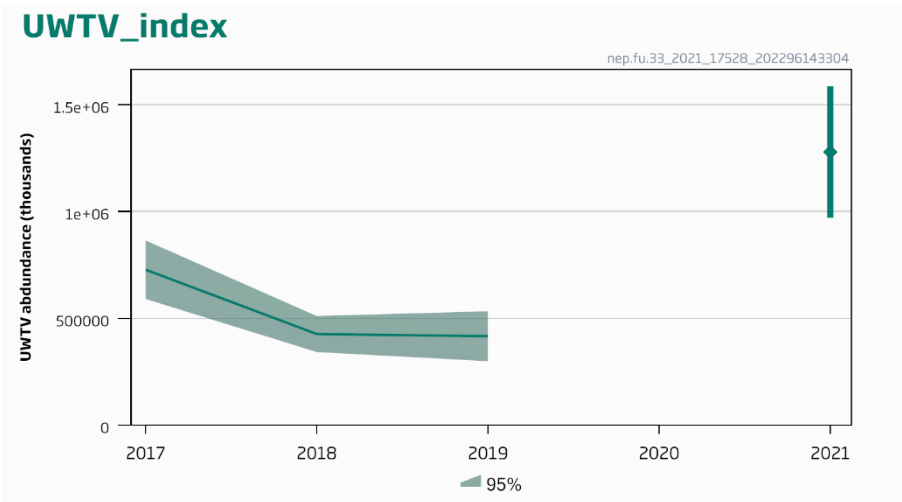


Figure 11.10.4. *Nephrops*, Off Horn's Reef (FU 33), Time series of TV survey abundance estimates (absolute conversion factor = 1.1, from FU 3 and 4), with 95% confidence intervals, from 2017 to 2021.

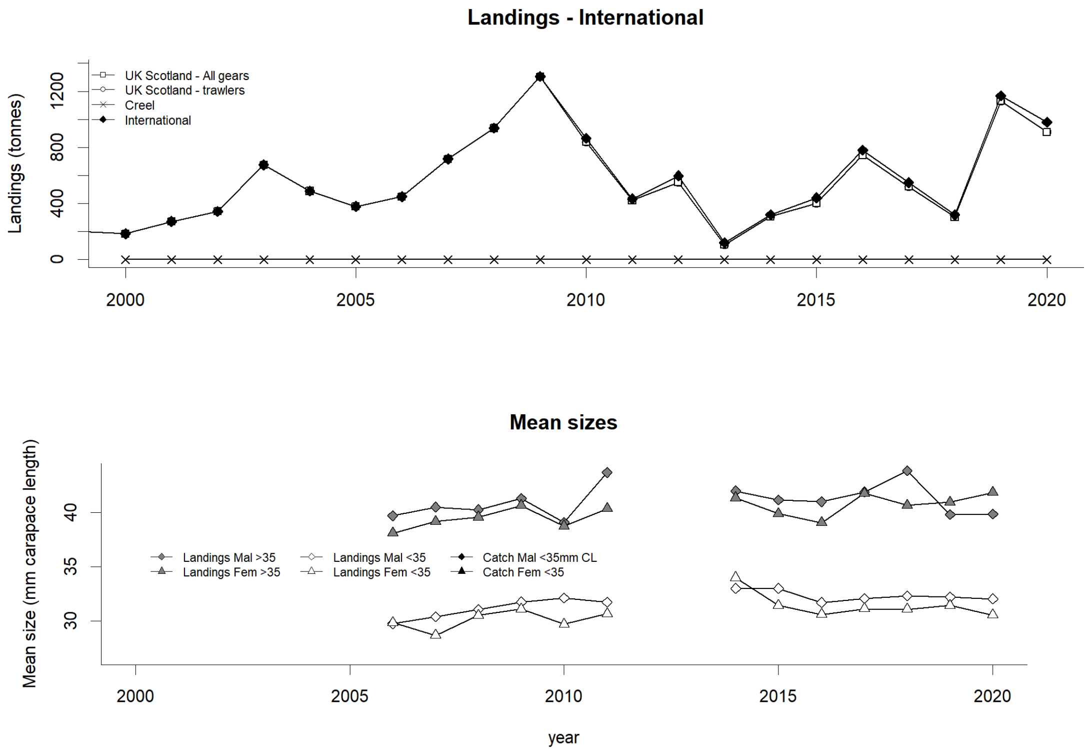


Figure 11.11.1. *Nephrops*, Devil's Hole (FU 34). Long term landings and mean sizes, data from year 2000.

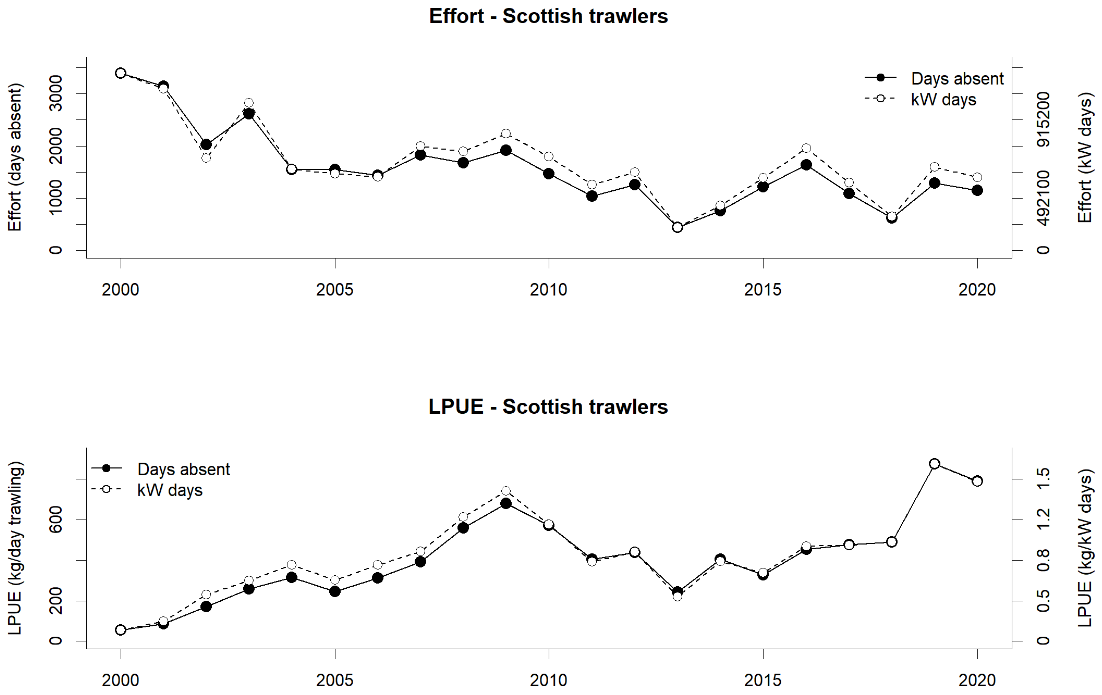


Figure 11.11.2. *Nephrops*, Devil's Hole (FU 34). Effort (days, kWday) and LPUE (kg/day, kg/kWdays), data from year 2000.

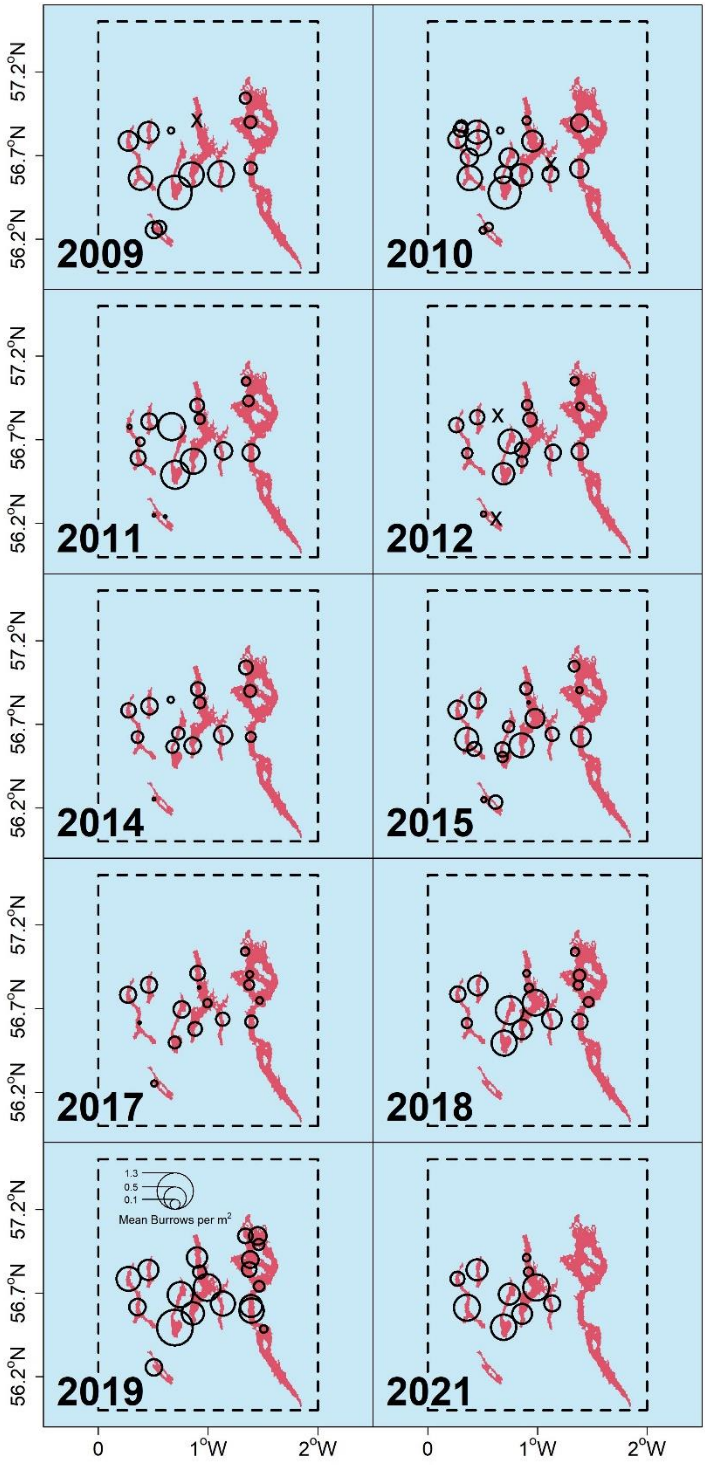


Figure 11.11.3. ***Nephrops*****, Devil's Hole (FU 34). UWTV survey distribution and relative density (2009–2021). No surveys in 2013, 2016, 2020 and 2022. Survey station locations generated from Vessel Monitoring System (VMS) data (WKNEPH, 2013). Density proportional to circle radius.**

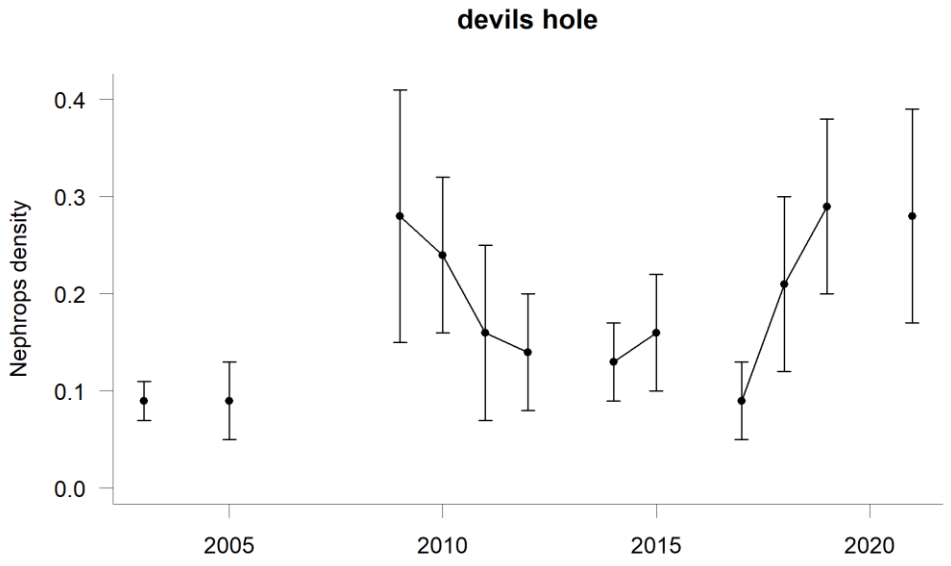


Figure 11.11.4. ***Nephrops*****, Devil's Hole (FU 34). Time series of UWTV survey density estimates with 95% confidence intervals, 2003, 2005, 2009–2021.**

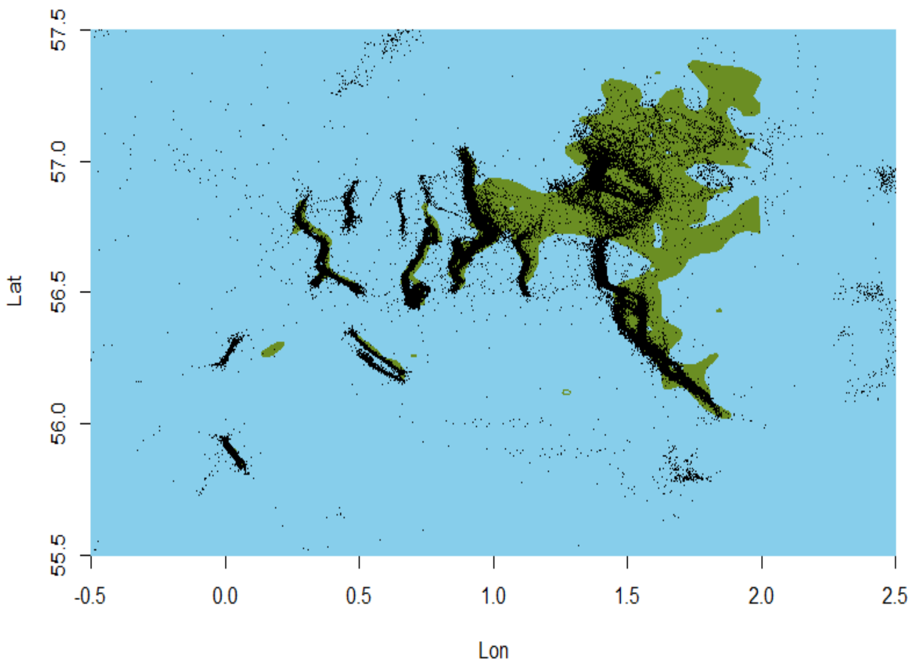


Figure 11.11.5. ***Nephrops*****, Devil's Hole (FU 34). Comparison of BGS sediment map with VMS data from Scottish trawlers (2007–2011) filtered for** ***Nephrops*** **landings > 30% of total, speeds of 0.5–3.8 knots and mesh size 70–99 mm.**

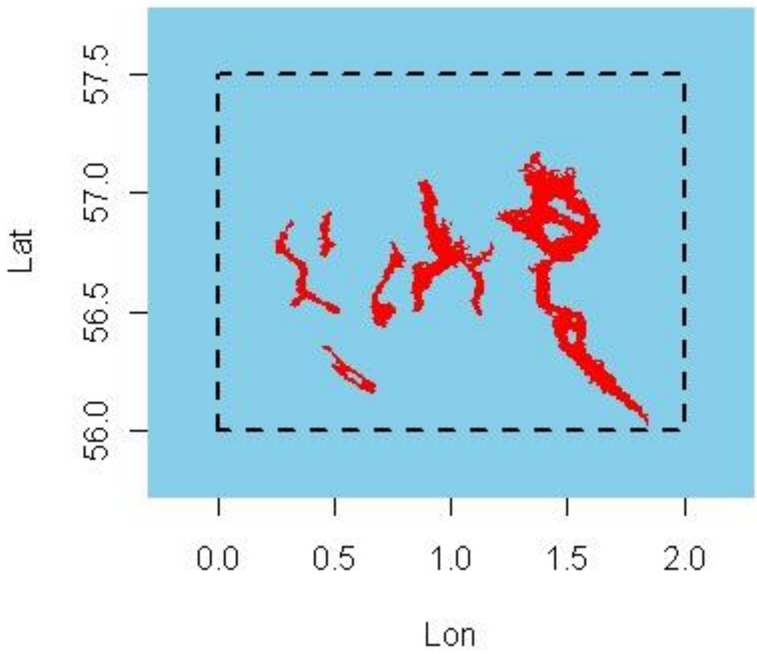


Figure 11.11.6. ***Nephrops*****, Devil's Hole (FU 34). Union of 2007–2011 annual VMS polygons (from alpha convex hull) with VMS data filtered for** ***Nephrops*** **landings > 30 % of total, speeds of 0.5–3.8 knots and mesh size 70–99 mm.**

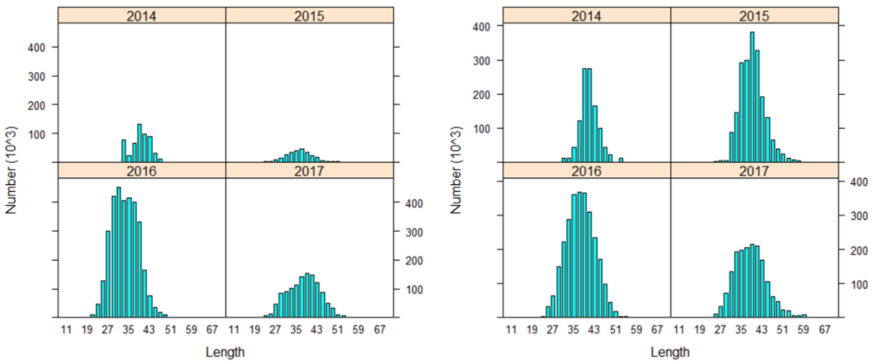


Figure 11.11.7. ***Nephrops*****, Devil's Hole (FU 34). Landings length distributions for females (left) and males (right) obtained from Intercatch and used to run the LBI screening methods (2014–2017).**

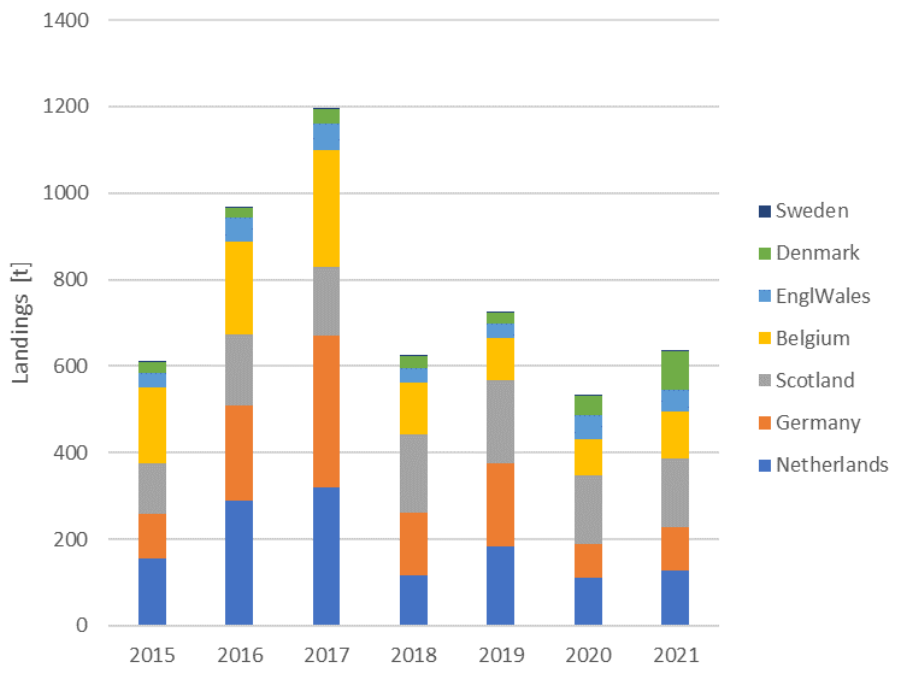


Figure 11.12.1. ***Nephrops*****, Subarea 27.4 outside FUs. Annual landings by country.**

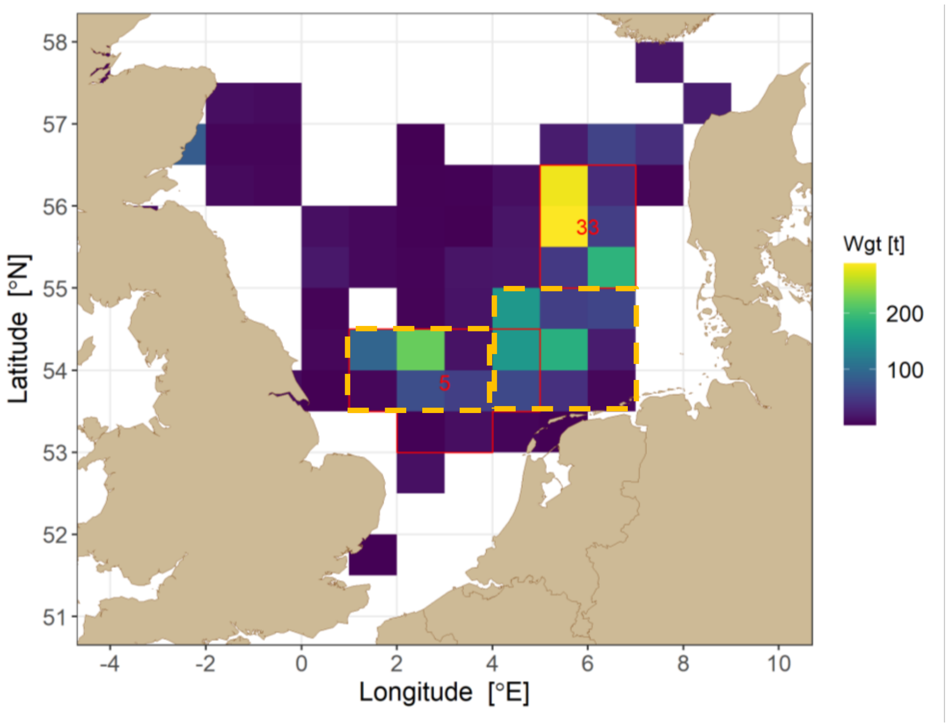


Figure 11.12.2. ***Nephrops*****, Subarea 27.4 outside FUs, and inside FUs 5 and 33. Average annual landings 2017—2021 by rectangle in tonnes. Current outlines of FUs 5 and 33 are indicated by the solid red lines. The dashed orange lines indicate the outline of a potentially redefined FU 5, together with the outline of a new functional unit towards the east, linking up with FU 33 from the south.**

12 Norway pout in ICES Subarea 4 and Division 3.a

The Section was added to the report in October 2022

Introduction: Benchmark assessment

The September 2022 assessment of Norway pout in the North Sea and Skagerrak is an update assessment based on the August 2016 ICES WKPOUT benchmark assessment (ICES WKPOUT, 2016). In the benchmark assessment, a new assessment model has been introduced (Seasonal Stochastic Assessment Model SESAM instead of the Seasonal XSA, SXSA), the assessment year has been changed (from the calendar year to 1 October to 1 October and accordingly also now including quarter 3 in the assessment year compared to quarter 2 in previous assessments), the overall assessment period has been changed (cutting off the original first assessment year 1983), the plus-group in the assessment has been changed (from 4+ to 3+), and the assessment tuning fleets have been changed (removing the quarter 1, 3, and 4 commercial tuning fleets and keeping the same survey fleets). The assessment biological parameter settings are the same according to the Inter-benchmark assessment in spring 2012 (ICES IBPNorwayPout, 2012c) with respect to the population dynamic parameter settings for natural mortality, maturity at age and mean weight at age. The previous settings in the assessment were constant natural mortality by quarter and age fixed at 0.4, 10% maturity for the 1-group and 100 % mature for the 2+ group, and constant MWA assumed in stock. The new settings according to the inter-benchmark (from May 2012 onwards) include constant quarterly and yearly natural mortality, but with varying M by age, 20% maturity for the 1-group, and slightly changed levels of constant mean weight at ages in the stock which have been calculated from long term averages of mean weight at age in the catch. These parameters have impact on the predictions and estimates of the SSB because the stock consists of very few year classes. Due to introduction of revised IBTS (International Bottom Trawl Survey) quarter 1 (Q1) and quarter 3 (Q3) indices for the full survey time series for all age groups of Norway pout by ICES in 2020 ([https://github.com/ices-tools-prod/DATRAS/tree/master/ALK substitution](https://github.com/ices-tools-prod/DATRAS/tree/master/ALK_substitution)) the sustainability of the MSY $B_{trigger} = B_{lim}$ and $F_{cap} = 0.7$ reference points were evaluated in Brooks and Nielsen (2020). Despite only a slight change in B_{lim} of less than 10% from B_{lim} = 39 447 t (Benchmark ICES WKPOUT 2016 estimate) to B_{lim} = 42 573 t by running the benchmark assessment with the new IBTS indices (Brooks and Nielsen, 2020), the WGNSSK 2020 working group decided to switch to the new B_{lim} reference point, and on this basis to calculate a new B_{pa} reference point. The sustainability of the currently implemented $F_{cap} = 0.7$ was accordingly evaluated with this new B_{lim} reference point (Brooks and Nielsen, 2020). These evaluations showed that the current F_{cap} was also sustainable with the slightly revised B_{lim} reference point (Brooks and Nielsen, 2020). See also Section 12.7 below. The assessment is a "real time" monitoring and management run up to 1 October 2022, and includes new information from 2nd half year 2021 and for the quarters 1, 2 and 3 in 2022. The assessment includes the new 3rd quarter 2022 survey information also covering the 0-group 2022-year class information, which is used real time in 3rd quarter. Consequently, the assessment does not backshift this survey information to 2nd quarter as done in the SXSA assessment run up to 1 July in the assessment year before the benchmark assessment in 2016.

Furthermore, a short-term prognosis (Forecast) up to 1 November 2022 and 1 November 2023 is given for the stock based on the assessment. The catch projection is based on a changed forecast year from 1 November to 31 October.

12.1 General

12.1.1 Ecosystem aspects

Norway pout is a short-lived species and most likely a one-time spawner. The population dynamics of Norway pout in the North Sea and Skagerrak are very dependent on changes caused by recruitment variation and variation in predation or other natural mortality, and less by the fishery (Nielsen *et al.*, 2012). Recruitment is highly variable and influences SSB and total stock biomass (TSB) rapidly because of the short life span of the species (Nielsen *et al.*, 2012; Sparholt *et al.*, 2002a, 2002b; see review in Nielsen, 2016). Furthermore, 20% of age 1 is estimated mature and is included in the SSB (Lambert *et al.*, 2009). Therefore, the recruitment in the year after the assessment year influences the SSB in the following year. Also, Norway pout is to a limited extent exploited from age 0. Only limited knowledge is available on the influence of environmental factors, such as temperature, on the recruitment (Kempf *et al.*, 2009; see review in Nielsen, 2016, Section 7). On this basis, Norway pout should be managed as a short-lived species.

Stock definition: Norway pout is a small, short-lived gadoid species, which rarely gets older than 5 years (Nielsen *et al.*, 2012, Lambert *et al.*, 2009). It is distributed from the west of Ireland to Kattegat, at the Faroe Islands, and from the North Sea to the Barents Sea. The distribution for this stock is in the northern North Sea (>57°N) and in Skagerrak at depths between 50 and 300 m (Raitt 1968; Sparholt *et al.*, 2002b; see review in Nielsen, 2016, Sections 2 and 4). Spawning in the North Sea takes place mainly in the northern part in the area between Shetland and Norway (Lambert *et al*., 2009; Nash *et al*., 2012; Huse *et al.,* 2008; See review in Nielsen, 2016, Section 4).

Previously, it has been evaluated that around 10 % of the Norway pout reach maturity already at age 1, and that most individuals reach maturity at age 2. Results in Lambert *et al.* (2009) show that the maturity rate for the 1-group is close to 20% in average (varying between years and sex) with an increasing tendency over the last 20 years. Furthermore, the average maturity rate for 2- and 3-groups in 1st quarter of the year was observed to be around 90% and 95%, respectively, as compared to 100% used in the assessment. Preliminary results from an analysis of regionalized survey data on Norway pout maturity, presented in Larsen *et al.* (2001), gave no evidence for a stock separation in the whole northern area, and this conclusion is supported by the results in Lambert *et al.* (2009) and in Nash *et al.* (2012). (See also review in Nielsen, 2016, Section 3).

Ecological role: The population dynamics of Norway pout in the North Sea and Skagerrak are very dependent on changes caused by high recruitment variation and variation in predation mortality (or other natural mortality causes) due to the short life span of the species (Nielsen *et al*., 2012; ICES WGSAM, 2011; ICES WGSAM, 2014; Sparholt *et al.,* 2002a, b; Lambert *et al.,* 2009). Norway pout natural mortality is likely influenced by spawning and maturity having implications for its age specific availability to predators in the ecosystem and the fishery (Nielsen *et al*., 2012). With present fishing mortality levels in recent years the status of the stock is more determined by natural processes and less by the fishery, and in general the fishing mortality on 0-group Norway pout is low (Nielsen *et al*., 2012; ICES WGNSSK Reports; see review in Nielsen, 2016, Section 5). There is a need to ensure that the stock remains high enough to provide food for a variety of predator species. This stock is among other an important food source for the species saithe, haddock, cod, whiting, and mackerel and predation mortality is significant (ICES-SGMSNS, 2006; ICES WGSAM, 2011; ICES WGSAM, 2014; Cormon *et al*., 2016; see review in Nielsen, 2016, Section 6). Especially the more recent high abundance of saithe predators and the more constant high stock level of northern mackerel as likely predators on smaller Norway pout are likely to significantly affect the Norway pout population dynamics. Interspecific and intraspecific density patterns in Norway pout mortality and maturity has been documented (Nielsen *et al*., 2012; Lambert *et al.,* 2009; Cormon *et al.,* 2016; see review in Nielsen, 2016). Natural mortality levels by age and season used in the stock assessment do include the predation mortality levels estimated for this stock (ICES WGSAM, 2011; ICES WGSAM, 2014), and in the 2012 Inter-benchmark assessment revised values for natural mortality have been used based on the results from Nielsen *et al.* (2012).

Biological interactions with respect to intra-specific and inter-specific relationships for Norway pout stock dynamics and important predator stock dynamics have been reviewed and further analysed in Nielsen (2016; Section 6) and there is referred to the general conclusions here.

Ecosystem impacts of fishery: In order to protect other species (cod, haddock, whiting, saithe and herring as well as mackerel, squids, flatfish, gurnards, *Nephrops*) there is a row of technical management measures in force for the small meshed fishery in the North Sea such as the closed Norway pout box, by-catch regulations, minimum mesh size, and minimum landing size. A review of regulations on the Norway pout stock and be found in Nielsen *et al.* (2016a). Benthic impacts of the Norway pout fishery has also been evaluated in Bigné et al. (2019).

12.1.2 Fisheries

The fishery is nearly exclusively performed by Danish and Norwegian vessels using small mesh trawls in the north-western North Sea, especially at the Fladen Ground and along the edge of the Norwegian Trench in the north-eastern part of the North Sea. Main fishing seasons are 3rd and 4th quarters of the year with also high catches in 1st quarter of the year especially previous to 1999. Recent catches in 1st quarter are relatively low. Some catch also originates from Norwegian fishery in the 2nd quarter. The Norway pout fishery is a mixed commercial, small meshed fishery conducted nearly exclusively by Denmark and Norway directed towards Norway pout as one of the target species together with Blue Whiting in the Norwegian fishery. The international commercial Norway pout fishery has been reviewed in Nielsen *et al.* (2016a) including a detailed analysis of the Danish commercial fishery, and a detailed description of the Norwegian fishery can be found in Johnsen *et al.* (2016). These papers include among other detailed analyses of quarterly and spatial distribution of the Norway pout fishery and catches, the by-catches and discard, the quota up-take and the fishery regulations. Furthermore, the Stock Annex also include the long-term trends in average exploitation pattern. Recently, the Danish large vessel pelagic fleet fishery has been analysed in Paoletti *et al*. (2021) which also provide yearly, seasonal and geographical fishing patterns with respect to effort allocation, catches and value of landings for the part of the Norway pout fishery conducted by this fleet for the period 2015–2020.

Landings have been relatively low since 2001 except for 2010 and recently in 2019–2020, and the 2003–2004 landings were the lowest on record (Tables 12.2.1–3). The directed fishery for Norway pout was closed in 2005, in the first half of 2006, and in 2007 as well as in the first half of 2011 and 2012. In the periods of closures there have in some years been set by-catch quotas for Norway pout in the Norwegian mixed blue whiting fishery around 5 kt, as well as in a small experimental fishery in 2007 (1 kt). In the open periods of 2008, 2009, and 2011 the fishing effort and catches have been low. Catches were above 100 kt in 2010, but have in the period 2012–2018 been well below 100 kt, while they increased again to be around or above 100 kt in 2019-2020. The landings in 2021 were 72.0 kt. The quota has not been taken in those years. The fishery has in these periods mainly been based on the 2008, 2009, 2012, 2014, 2016, 2018, 2019- and 2020-year classes being above the long-term average level. The TAC was not taken in 2008–2010 and 2012–2021, while the small TAC in 2011 was taken. The lack of full quota uptake is likely due to targeting of other industrial species like sprat for which fishing costs are lower, but also high fishing (fuel) costs and bycatch regulations (mainly in relation to herring and whiting bycatch) have an impact (see details in Nielsen *et al.*, 2016a). Late opening of the fishery at the end of quarter 3 in 2012, and individual quotas for the Danish fishery in general, as well as the recent implementation of a general herring by-catch quota in the North Sea, may also play a role in the uptake. Trends in yield are shown in Table 12.3.6 and Figure 12.3.5.

By-catch of herring, saithe, cod, haddock, whiting, and monkfish at various levels in the small meshed fishery in the North Sea and Skagerrak directed towards Norway pout has been documented (Bigné, Nielsen and Bastardie, 2019; Degel *et al*., 2006, ICES CM 2007/ACFM:35, (WD 22 and Section 16.5.2.2); see also review in Nielsen *et al.*, 2016a). By-catches of these species have been relatively low in the recent decade, and in general, the by-catch levels have decreased in the Norway pout fishery over the years. The declining tendency of by-catch of other species in the Norway pout fishery also appears from Table 12.2.1. However, here it can also be observed, that the by-catches have increased slightly in 2019, but declined again in 2020 and 2021. Trends in by-catch levels in the samples from monitoring of the Danish and Norwegian commercial Norway pout fishery should also be analysed in future benchmark assessments as the revised monitoring and sampling systems of catches may give more precise by-catch estimates. Review of scientific documentation show that gear selective devices can be used in the Norway pout fishery, significantly reducing by-catches of juvenile gadoids, larger gadoids, and other non-target species (Eigaard and Holst, 2004; Nielsen and Madsen, 2006, ICES CM 2007/ACFM:35, WD 23 and section 16.5.2.2; Eigaard and Nielsen, ICES CM2009/M:22; Eigaard, Hermann and Nielsen, 2012; see also review in Nielsen *et al*., 2016a; Johnsen *et al*., 2016). Sorting grids are at present used in the Norwegian and Danish fishery (partly implemented as management measures for the larger vessels), but modification of the selective devices and their implementation in management is still ongoing. Existing technical measures such as the closed Norway pout box, minimum mesh size in the fishery, and by-catch regulations to protect other species have been maintained. A detailed description of the regulations and their background can be found in Nielsen *et al.*, (2016a) and in the Stock Annex.

The quality of the landings statistics in Norway and Denmark is described in the ICES WKPOUT (2016) and associated Annexes (Nielsen *et al.*, 2016a; Johnsen *et al.*, 2016). The quality seems to be relatively constant during the last 20 years and of a higher quality than in the years before. From April 2020 onwards, the sampling intensity of the Danish Norway pout fishery has increased where every landing is now sampled, and the number of required samples increase with the landing weight from a minimum of 6 to a maximum of 24 per landing. This new sampling system may give more precise estimates of by-catches which should be evaluated in future benchmark assessments. The discard level of Norway pout in the North Sea fisheries is considered to be low (Nielsen *et al.*, 2016a).

12.1.3 ICES advice

In September 2021, the advice on North Sea Norway pout was updated. Based on the estimates of SSB in September 2021, ICES classified the stock to show full reproductive capacity. Norway pout is a short-lived species. Recruitment is highly variable and strongly influences the spawning stock and total biomass. The default ICES approach to MSY-based management for short-lived species is an escapement strategy, i.e. to maintain SSB, with 95% probability, above B_{lim} after the fishery has taken place. The forecast is stochastic and uncertainties in the assessment and forecast are directly taken into account to ensure the SSB stays above B_{lim} with 95% probability according to the ICES MSY and Precautionary Approach for short lived species. For the implementation of the escapement strategy, which aims to maintain the SSB above B_{lim} after the fishery has taken place, SSB is calculated for quarter 4 as a proxy for SSB at spawning time (quarter 1). The B_{lim} value was adjusted in the benchmark assessment in 2016 and again in the MSE in 2020 due to changed IBTS indices (Brooks and Nielsen, 2020). The B_{lim} estimate in the 4th quarter is lower than the previous value of B_{lim} for the 1st quarter because the 0-group and many of the 1-group fish are not yet included in the estimate of SSB. The yearly catch forecast is for the period 1 October to 30 September. ICES considered that this forecast could be used directly for management purposes for the period 1 November to 31 October. In recent years the escapement strategy has been practiced in reality in management.

The ICES advice in September 2021 was that with catches up to 118 kt in the directed Norway pout fishery in the period 1 November 2021 to 31 October 2022 corresponding to a F around 0.47 taking into account a F_{cap} of 0.70 and that the 5th percentile of the spawning-stock biomass in the 4th quarter 2020 will remain above a reference level of B_{lim} (42 573 t). The SSB was expected to remain relatively high during 2021 and 2022 due to the high 2019 and 2020 recruitment, the growth and 20% mature as 1-group, and still considering the high natural mortality as well as the short life span of the stock.

According to the escapement strategy, the fishery was closed 1 January 2012 because of the well below, nearly historical low, recruitment in 2010 and 2011. A small TAC of 6 kt was set for the second half year 2011 which was taken. Based on the high recruitment in 2012, the fishery was opened again for second half year 2012. Based on the high recruitment in 2012, 2014, 2016, 2018, 2019 and 2020, as well as a just below average recruitment in 2015 and 2017, and the low recruitment in 2021, the fishery has remained open for all of 2013–2022. The quota uptake has been low in recent years (Nielsen *et al*. 2016a). The quota uptake in 2019 was below 75%, below 80% in 2020, and below 30% in 2021.

Fishing mortality has generally been lower than the natural mortality for this stock and has decreased in recent years below the long-term average F (0.34) as estimated from the assessment in September 2022.

There is bi-annual information available to perform real time monitoring and management of the stock. This can be carried out both with fishery independent and fishery dependent information as well as a combination of those. Real time advice (forecast) and management options for 2022 (up to 31 October) is provided for the stock in autumn 2021 as well.

ICES advises that there is a need to ensure that the stock remains high enough to provide food for a variety of predator species. It is advised that by-catches of other species should also be taken into account in management of the fishery. Also, it is advised that existing measures to protect other species should be maintained.

12.1.4 Management up to 2021

There is no specific management objective set for this stock. With present fishing mortality levels, the status of the stock is more determined by natural processes and less by the fishery. The European Community has decided to apply the MSY approach for short lived species in taking measures to protect and conserve living aquatic resources, to provide for their sustainable exploitation and to minimise the impact of fishing on marine ecosystems.

ICES advised in 2005 real time management of this stock. In previous years, the advice was produced in relation to a precautionary TAC, which was set to 198 000 t in the EC zone and 50 000 t in the Norwegian zone. On basis of the real time management advice from ICES, EU and Norway agreed to close the directed Norway pout fishery in 2005, first part of 2006, all of 2007 and in first part of 2011 and 2012. In 2005 and 2007, the TAC was 0 in the EC zone and 5000 t in the Norwegian zone – the latter to allow for by-catches of Norway pout in the directed Norwegian blue whiting fishery. The final TAC set for 2008 was 115 kt (EU), 116 kt (EU) for 2009, 163 kt (EU) for 2010, 8 kt for 2011, 96 kt for 2012, 323 kt for 2013, 251 kt for 2014, 328 kt for 2015, 360 kt for 2016, 346 kt for 2017, 173 kt for 2018, 137 kt for 2019, 171 kt for 2020 and 255 kt for 2021, however, the TACs were not taken during this period except for the small TAC in 2011. For 2021, the TAC include a TAC of 12 kt for UK, and this has not been exploited. The TAC advice for 2022 up to now has been 118.3 kt. Fishery was closed in first half year 2011 and 2012. By-catch regulations have sometimes been restrictive (e.g. in 2009 and 2010 mainly in relation to whiting bycatch).

In managing this fishery, by-catches of other species have been taken into account. Existing technical measures such as the closed Norway pout box, minimum mesh size in the fishery, and by-catch regulations to protect other species have been maintained.

Long term management strategies have been evaluated for this stock based on joint EU-Norway requests (see Section 12.10). ICES has evaluated and commented on three management strategies in 2007, although these have not been decided on. Long term management strategies have been evaluated again in September 2012 and June 2013 based on new joint EU-Norway requests (ICES, 2012b) in spring 2012 and spring 2013 to be available for the September 2012 and September 2013 ICES advice, respectively. These MSEs have been presented in a special ICES reports (Vinther and Nielsen, 2012; 2013). No long-term management strategies have been decided upon.

With the changes introduced by the August 2016 Norway pout benchmark assessment (ICES WKPOUT, 2016 and Annexes) involving change of assessment model, change of assessment year, change of assessment period, removal of the commercial fishery tuning fleet in the assessment, change of the plus-group in the assessment from 4+ to 3+ and change of the stock MSY reference level these previous MSEs could not be used anymore for long term management plans of the stock (including the F_{cap} estimates made there).

Long term management strategy evaluation according to the new assessment and the revised reference levels as established from the benchmark assessment in August 2016, have been requested in a joint EU-Norway request from November 2017. Based on this EU / Norway request ICES on 29 May 2018 released its advice evaluating long-term management strategies for Norway pout in area 4 and 3.a (http://ices.dk/sites/pub/Publication%20Reports/Advice/2018/Special_requests/eu-no.2018.07.pdf) which is based on the work from the ICES WKNPOUT (2018) (Report of the Workshop for Management Strategy Evaluation for Norway Pout, ICES, Copenhagen 26–28 February 2018, ICES CM2018/ACOM:38 Ref WGNSSK, 96 pp) as presented to the ICES WGNSSK and approved by ICES ACOM in May 2018. This is summarized below.

ICES has evaluated sustainability of a range of harvest control rules (HCRs) within the escapement strategy presently used for Norway pout, with additional lower (TAC_{min}) and upper (TAC_{max}) bounds on TAC and optional use of upper fishing mortality values (F_{cap}) (ICES WKNPOUT, 2018). Several HCRs were identified that combined TAC_{min} in the range of 20 000–40 000 t and TAC_{max} less than or equal to 200 000 t (150 000 t or 200 000 t) and F_{cap} values of 0.3 and 0.4, resulting in no more than a 5% probability of the spawning-stock biomass falling below B_{lim}.

ICES has evaluated harvest control rules (HCRs) within the escapement strategy presently practiced (aimed at retaining a minimum stock size in the sea every year after fishing) that are furthermore simulated to be restricted by a combination of TAC lower bounds (TAC_{min}) and upper bounds (TAC_{max}). For some HCRs, an upper limit on F (F_{cap}) is also used for setting the TAC.

Because of uncertainties in the estimate of the incoming year class, escapement strategies for short-lived species, where catch opportunities are very dependent on the strength of the incoming year class, may lead to a TAC where a too high portion of the stock is caught. ICES evaluations were conditioned by a maximum realized level of fishing mortality the fishery can exert (assumed at 0.89; $F_{historical}$), which means that the full TAC will not be taken if the required F to catch the TAC exceeds this value.

The identified combinations of lower TAC_{min} bound, upper TAC_{max} bound, and F_{cap} give a less variable TAC and F from one year to the next, but also a lower long-term yield than the default escapement strategy. ICES is not in position to advice on this trade-off between higher yield and stability.

The results are sensitive to the assumption that the fishery stops catching Norway pout when F exceeds $F_{historical}$. Therefore, the HCR should be re-evaluated if future F exceeds $F_{historical}$ (0.89).

The evaluation showed that the current procedure for providing TAC advice for Norway pout, based on an escapement strategy is only precautionary with the addition of an F_{cap} at 0.7.

In consultations between EU and Norway held 5–6 September 2018, the advice was presented by ICES and in the following discussions, certain limited additional elements, to be reviewed by ICES, came up. This resulted in an additional EU / Norway request from September 2018 on evaluation of additional elements concerning the ICES advice evaluating long-term management strategies for Norway pout in area 4 and 3.a. Here ICES was requested to assess, following MSY $B_{escapement}$:

→ *which scenarios of TAC_{min} and TAC_{max} would be precautionary, if the F_{cap} is set at 0.7 (building on request part 2 and 3, pages 3 and 4 of the advice).*

→ *which scenarios of TAC_{min} and TAC_{max} would be precautionary, if an inter-annual flexibility of +/-10% (both banking and borrowing) was introduced for Norway pout (building on request part 2 and 3, pages 3 and 4 of the advice, plus including precautionary scenarios with an F_{cap} of 0.7 – following from paragraph 1 of this request).*

On this basis, ICES has evaluated additional harvest control rules (HCRs) within the escapement strategy presently used for Norway pout, with additional lower (TAC_{min}) and upper (TAC_{max}) bounds on TAC and use of an upper fishing mortality (F_{cap}) at 0.7. As for the scenario made for ICES May 2018 advice (ICES WKNPOUT, 2018), ICES evaluations were conditioned by a maximum realized level of fishing mortality the fishery can exert (assumed at 0.89; $F_{historical}$), which means that the full TAC will not be taken if the required F to catch the TAC exceeds this value.

This is presented in the ICES advice:
http://ices.dk/sites/pub/Publication%20Reports/Advice/2018/Special_requests/eu.2018.19.pdf.

Several HCRs were identified that combined TAC_{min} in the range of 20 000–40 000 t and TAC_{max} less than or equal to 200 000 t, resulting in no more than a 5% probability of the spawning-stock biomass falling below B_{lim}. Increasing the F_{cap} from 0.4 (which was previously evaluated) to 0.7 results in a higher median and mean TAC, but also in a higher long-term probability of SSB falling below B_{lim}. It also results in a higher probability of being constrained by the TAC_{max}.

The evaluations and ACOM approval of this led to identification of an expanded set of sustainable scenarios with a F_{cap} of 0.7. Tables 1 and 2 in http://ices.dk/sites/pub/Publication%20Reports/Advice/2018/Special_requests/eu.2018.19.pdf summarize the long-term (2023–2037) performance metrics for the (precautionary) combinations that result in no more than 5% probability of SSB falling below B_{lim} in the period 2023–2037. More detailed statistics for both precautionary and non-precautionary HCRs are shown in the Table 3 of this advice.

Given that Norway pout is short-lived and that the HCR scenarios are based on the escapement strategy, the application of an additional inter-annual quota flexibility of ±10% is not considered precautionary.

ICES has changed the historical IBTS Q1 and IBTS Q3 DATRAS indices for demersal species in the North Sea including the Norway pout indices based on introduction of a new calculation method for the indices. Brooks and Nielsen (2020) evaluate potential change in the MSY and PA sustainability reference points of using the revised IBTS survey indices in DATRAS compared to the previously used indices, and presents output from exploratory Management Strategy Evaluation (MSE) with consequences for the precautionary Fcap of changed biomass reference points. That is, whether the F_{cap} of 0.7 is still sustainable with the changed biomass reference points for the stock resulting from this revision of survey data. The conclusions in Brooks and Nielsen (2020) is that with no limits on TAC, then the assumption of a maximum implementable F has a stronger effect on the simulated stock dynamics. When the maximum implementable F is near F_{cap}, then F_{cap} has very little effect on the stock dynamics. If we assume that the maximum implementable F is extremely large (2.0 which is more than double the maximum estimated value), then the effect of F_{cap} can be seen again. With maximum implementable F at either its maximum historical estimate or at 1.0, then all risk statistics still show F_{cap} = 0.7 to be precautionary. Furthermore, even with the unrealistically high maximum implementable F, then the only risk that goes above 0.05 (when rounded to the nearest 0.01 units) is risk3.long.Q4 for a F_{cap} = 0.7. The type 3 risk statistics may require more replicates to converge to the true value expected from infinite replicates; if needed, this could be investigated in a benchmark. However, the overall result is that risk 1 statistics all indicate precautionarity even under extreme assumptions for high fishing effort.

No decision on long-term management plans are currently available for the Norway pout in area 4 and 3.a based on the identified sustainable scenarios. The stock is still managed according to the escapement strategy with a F_{cap} of 0.7 and with no lower TAC_{min} bound or upper TAC_{max} bound set. See also Section 12.7 below.

An overview of recent relevant management measures and regulations for the Norway pout fishery and the stock can be found in Nielsen *et al.* (2016a) and in the Stock Annex.

12.2 Data available

12.2.1 Landings / catches

Data for annual nominal landings of Norway pout as officially reported to ICES are shown in Table 12.2.1. The landings equal the catches of Norway pout as discard in this small meshed fishery is negligible (see also Nielsen *et al.*, 2016a). Historical data for annual landings (catches) as provided by ICES (Working Group members) are presented in Table 12.2.2, and data for national landings (catches) by quarter of year and by geographical area are given in Table 12.2.3. Total observed and predicted (by the SESAM stochastic assessment model) catches by quarter is given in Table 12.2.3a. Both the Danish and Norwegian landings (catches) of Norway pout were low in 2007 and 2011. The landings were moderate in 2008–09, 2012, 2014 and 2017–2018, higher in 2013 and 2015–2016, and high in 2010 (126 kt), 2019 (98 kt) and 2020 (129 kt). The landings in 2021 were moderate on 72 kt. The TAC was not reached in any of those recent years. The most recent catches have been included in the assessment. Catches for 3rd quarter 2022 include Danish and Norwegian catches up to 15th September 2022. Catches in the last 15 days of 3rd quarter 2022 are assumed to be relatively low and no guesses on that have been included in the assessment.

12.2.2 Age compositions in Landings

Age compositions were available from Norway and Denmark (except for Norway in 2007 and 2008). Catch in numbers at age by quarter of year is shown in Table 12.2.4. Only very few biological samples were taken from the low Norway pout catches in 2005 and 2011, as well as in first half year 2006, 2007, and 2012. The data are in the InterCatch database.

As no age composition data for Norwegian landings have been provided for 2007 and 2008 because of small catches, the catch at age numbers from Norwegian fishery are calculated from Norwegian total catch weight divided by mean weight at age from the Danish fishery for those years. As no age composition data for the Danish landings in first half year 2010 have been sampled because of very small catches the catch at age numbers from Danish fishery is calculated from Danish total catch weight divided by mean weight at age from the Norwegian fishery in 2010.

A full-scale Norway pout age reading check and otolith exchange program was made in 2018 with participation of 14 readers from seven countries (Denmark, Norway, Scotland, UK, France, Netherlands and Germany) (ICES WGBIOP, 2018). Different methods were applied for age determination of this species; whole, broken and sectioned otoliths and images were provided of samples prepared using each method. Samples were collected during the 2016 Q3 IBTS and 2014 Q4 commercial fishing trips from ICES area 27.4.a covering the length range of the fish and considered adequately representative of the stock. Results based on sectioned otoliths were exceptional with an overall percentage agreement based on modal age of 99% and an average CV of 3% (ICES WGBIOP, 2018). For the whole and broken otoliths the average percentage agreement based on modal age is 82%, with an average CV of 20%. There is a slight tendency for some readers to overestimate the age at modal age 0 and 1 and underestimate in comparison to modal age 2. The bias that existed between the primary readers from Norway and Denmark in 2016 is still apparent. These results are based only on those readers who provide age data for assessment purposes. In conclusion, there is an overall high level of agreement between readers of the Norway pout - nop.27.3a4 stock. The agreement is higher between the countries who read sectioned otoliths (Germany and UK-England) compared to those who read whole (Denmark) and broken otoliths (Denmark, Norway and UK-Scotland) (ICES WGBIOP, 2018). Further details on the age reading checks and analyses can be found in Section 12.11 below.

12.2.3 Weight at age

Mean weight at age in the catch is estimated as a weighted average of Danish and Norwegian data. Mean weight at age in the catch is shown in Table 12.2.5 and the historical levels, trends and seasonal variation in this is shown in Figure 12.2.1. Mean landings weight at age from Danish and Norwegian fishery from 2005–2008 as well as for 2011 are uncertain because of the few observations. Missing values have been filled in using a combination of sources, values from 2004, from adjacent quarters and areas, and from other countries within the same year, for the period 2005–2008, and in first half year 2010, and for 2011 there has also been used information from other quarters. Also, mean weight at age information from Norway has in 2011 involved survey estimates. The assumptions of no changes in weight at age in catch in these years do not affect assessment output significantly because the catches in the same period were low. Mean weight at age data is available from both Danish and Norwegian fishery in 2009, second half 2010, second half 2011, second half 2012, and all of 2013–2021 as well as for quarter 1 to quarter 3 2022. Relative low mean weights at age have been observed for age groups 1–2 in quarter 1 in 2019–2020. Danish data and age readings have been checked according this. Very small fish were observed in this period in the Danish catches, so this is not an artefact.

Mean weight at age in the stock is given in Table 12.2.6. The Inter-benchmark assessment in spring 2012 (ICES IBPNorwayPout, 2012c) introduced revised estimates of mean weight at age in the stock used in the Norway pout assessment. The background and rationale behind the revision of mean weight at age in the stock is described in the IBPNorwayPout report (ICES, 2012c) and primary literature (e.g. Lambert *et al.*, 2009). On this basis, the same mean weight at age by quarter in the stock is used for all years, and mean weight at age in the catch is partly used as estimator of weight in the stock. Based on the 2016 benchmark assessment (ICES WKPOUT 2016), slightly revised constant mean weight-at-age estimates in the stock were used both in the benchmark assessment and in the following update assessments for the 1-, 2- and 3- groups by quarter taken as the long-term averages from the commercial mean weight at age data. Data for mean weight at age by quarter for age 0 were kept constant as estimated in the 2012 Inter-benchmark. The revised mean weight at age in the stock was applied in the assessment runs as obtained from long-term averages measured from the commercial fishery catch. This has resulted in slightly changed levels of constant mean weight at ages in the stock compared to the 2012 Inter-Benchmark which have been calculated partly from long term averages of mean weight at age in the catch. In the Stock Annex and in Nielsen (2016), a summary is given of the Inter-benchmark revisions in 2012 of the population dynamic parameters in the assessment. No major revision of mean weight at age in the stock has been performed in 2016 (ICES WKPOUT 2016) compared to the values used in previous assessments. The estimation of mean weights at age in the catches and the used mean weights in the stock in the assessment is described in Nielsen (2016) and in the Stock Annex. The data are in the InterCatch database.

12.2.4 Maturity and natural mortality

The Inter-benchmark assessment in spring 2012 (ICES IBPNorwayPout, 2012c) introduced revised estimates of maturity and natural mortality at age used in the Norway pout stock assessment. The background and rationale behind the revision of the natural mortality and maturity parameters is described in the IBPNorwayPout report (ICES, 2012c) and primary literature (e.g. Nielsen *et al.*, 2012; Lambert *et al.*, 2009; ICES WGSAM, 2011; ICES WGSAM, 2014). In Nielsen (2016) and in the Stock Annex a summary is given of the Inter-benchmark revisions of the population dynamic parameters used in the assessment where maturity and natural mortality used in the assessment is described. Proportion mature and natural mortality by age and quarter used in the assessment is given in Table 12.2.6.

The same proportion mature and natural mortality are used for all years in the assessment. The proportion mature used is 0% for the 0-group, 20% of the 1-group and 100% of the 2+-group independent of sex. The revisions of the maturity ogive which have been implemented in the 2012 inter-benchmark assessment as well as in the present assessment is based on results from a paper by Lambert *et al.* (2009) indicating that the maturity rate for the 1-group is close to 20% in average (varying between years and sex) with an increasing tendency over the last 20 years. Furthermore, the average maturity rate for 2- and 3-groups in 1st quarter of the year was observed to be only around 95% as compared to 100% used in the assessment.

Instead of using a constant natural mortality set to 0.4 for all age groups in all seasons as used in the previous assessments, then variable natural mortality between ages have been introduced in the 2012 ICES IBPNorwayPout inter-benchmark assessment (ICES, 2012c) and the present assessment. The revision of the natural mortality parameters is based on results in Nielsen *et al*. (2012) and the ICES WGSAM (2011) and ICES WGSAM (2014) multi-species assessment reports. The revised values are shown in Table 12.2.6.

12.2.5 Summary of Inter-benchmark assessment on population dynamic parameters

A summary of the ICES Spring 2012 inter-benchmark assessment with revised weight, maturity and natural mortality parameters at age included in the assessment is given in Nielsen (2016) and in the Stock Annex as well as in the ICES IBPNorwayPout inter-benchmark assessment report (ICES, 2012c).

12.2.6 Catch, Effort and Research Vessel Data

Description of catch, effort and research vessel data used in the assessment is given in the ICES WKPOUT 2016 Benchmark Report (ICES, 2016) and its Annexes, in Section 5.3 below, as well as in the Stock Annex (see also Table 12.3.1).

12.2.6.1 Commercial fishery data

Catch information for 1984–2022 is included in this assessment as presented in tables 12.2.1–12.2.5 and Figure 12.2.1. Catches in all of 2005, 1st quarter 2009, first half year 2011 and 2012, and first quarter 2013 were nearly 0 and only very limited information exists about this catch. Consequently, there has been assumed and used low catches of 0.1 million individuals per age (for age groups 1–3) per quarter in the assessment for 2005 and 2011. The fishing effort and catch efficiency (catch per unit of effort) and of the Danish and Norwegian commercial fishery according to year and quarter of year are shown in tables 12.2.7 and 12.2.8, respectively, and according to year and fishing vessel engine horse power category in Tables 12.2.9 and 12.2.10, respectively. Furthermore, trends herein are shown in Nielsen *et al.* (2016a), in Johnsen *et al.* (2016) and in Paoletti *et al*. (2021).

No commercial fishery tuning fleet is included in the assessment from 2006 onwards based on the decisions made in the Norway pout benchmark assessment in September 2016 (ICES WKPOUT, 2016).

12.2.6.2 Research vessel data

Fishery independent survey data used as tuning fleets in the present assessment is given in Table 12.2.11 and Figure 12.2.2 (see also Table 12.3.1).

Survey indices series of abundance of Norway pout by age and quarter are for the assessment period available from the IBTS (International Bottom Trawl Survey 1st and 3rd quarter) and the EGFS (English Ground Fish Survey, 3rd quarter) and SGFS (Scottish Ground Fish Survey, 3rd quarter), Table 12.2.11. The new survey data from the 1st quarter 2022 IBTS and the 3rd quarter 2021 IBTS research surveys have been included in this September 2022 assessment as well as the 3rd quarter 2022 EGFS and SGFS research survey information. The survey data time series including the new information is presented in Table 12.2.11, as well as trends in survey indices in Figure 12.2.2. Surveys covering the Norway pout stock are described in detail in ICES WKPOUT (2016), Nielsen (2016) and in Johnsen and Søvik (2016) as well as in the Stock Annex. Survey data time series used in tuning of the Norway pout stock assessment are described below.

From 2009 and onwards, the SGFS changed its survey area slightly with a few more hauls in the northern North Sea and a few less hauls in the German Bight. This is not evaluated to influence the indices significantly as the indices are based on weighted sub-area averages.

In 3rd quarter 2015–2016 test trials were conducted in the international third quarter IBTS with 15 min duration hauls compared to 30 min duration hauls. The new 15 min test hauls have been included in the index calculation for 3rd quarter 2015–2016, and will potentially affect the Norway pout indices for the SGFS and the combined IBTS Q3 index. It has been necessary to include the 15 min hauls in the SGFS 2015–2016 data as extensive areas (of the total SGFS survey area) are only covered with this type of hauls. Only one 15 min test haul was included in the EGFS 2015 and none in 2016. There has been no continuation of the tow duration experiment in the Q3 surveys in 2017–2022 and, accordingly, no new 15 min hauls have been conducted and included in the Q3 2017–2022 SGFS and EGFS survey indices (and consequently in the combined Q3 IBTS survey index). Analyses of this are still on-going and nothing conclusive is available at present concerning potential significant impacts of this on the indices. Preliminary analyses indicate no significant differences in catch rates of Norway pout between the 15 min hauls and the 30 min hauls in the SGFS, however, the variability is very high and there are only very few observations available. Long time series and many observations are necessary to make statistically robust evaluations of and conclusions on potential differences.

In September 2015, the EGFS survey indices were revised as to incorporate the relevant primes within the Norway pout area following the IBTS Manual (2015), i.e. in the selection of the prime stations to be included in the Norway pout index calculation. The revision is described in detail in an ICES working document to ICES WGNSSK 2015 (Silva, 2015). This has changed the EGFS indices for Norway pout for all years and ages since 1992. Especially, the indices for the 0-group have changed significantly without any obvious trends over time. However, the perception of the dynamics in the stocks (e.g. strong year classes as 0-group and also as older ages in the cohorts) seems not to have changed in relative terms for this survey. Consequently, there is consistency in this to the previous EGFS indices and in relation to the other survey indices also for Norway pout. In the EGFS Q3 2017–2022, an additional haul has been taken (prime 77 – DATRAS haul number 147) fished on behalf of the Scottish (SGFS) that falls inside ICES rectangle 40E8 and, therefore, inside the Norway pout index area according to the IBTS manual. This prime is expected to be fished from now on by the English (EGFS) so it will fall inside the English survey index instead of the Scottish survey index. In order to make the EGFS time series consistent over time it has been decided to exclude the Prime 77 haul in the 2017–2022 indices used in the assessment. By comparison it appears that the survey trends seem similar with or without prime 77 in the EGFS for 2017–2022. In the 2020 and 2021, EGFS survey, all 77 prime stations were successfully fished aimed at 30 minute tows, though with some reduced to at least 20 minute tows for operational reasons. Due to technical issues with the research vessel in the 2022 EGFS survey, not all the tows were completed as intended, completing 66 or the 77 planned tows with an additional 5 tows completed on behalf of our Scottish colleagues (SGFS survey). Of the 45 planned tows that contribute to the Norway Pout indices, 5 rectangles were missed (44F4, 45F3, 51F0, 51F1 and 51F2) without significant geographical trends. However, these tows may have been fished by other nations on the EGFS behalf, with 51F0-51F2 likely to have been picked up by UK(Scotland). The five tows completed on behalf of UK(Scotland) were fished in 40E8, 43F4, 46E9, 46E8 and 46E7. None of these have been included in the EGFS Norway pout indices calculation in order to be consistent. Additionally, of note, the station in 45E8 was shot in the incorrect rectangle (44E8) but was hauled in the correct rectangle. This too has been set as 45E8 in the data so is correctly accounted for within these indices. All 66 Prime stations and the additional 5 fished for Scotland were successfully fished, were aimed at being 30 minute tows, though some were reduced to be either 15 or 20 minute tows for operational reasons. The above modifications in the EGFS is not expected to change the perception of the trends in this survey index and not expected to have significant effect on the assessment results.

With respect to the SGFS 2017 Q3 index, around 5 survey days was lost in 2017 due to vessel issues. Hence, there were only 76 hauls in 2017 compared to 99 hauls in 2016. In 2016, there was almost a 50/50 split by ICES Subarea with 50 hauls undertaken in 4A and 49 in 4B in the SGFS. In 2017, this was slightly more unbalanced with 43 hauls taking place in 4A and 33 in 4B. In 2019, there has been a slight revision of the SGFS indices from 2013–2018 because of additional data check and removal of invalid hauls. This have resulted in very slight changes. As expected, the divergence was very small and typically around 1–3% increase and obviously were dependent on how many invalid hauls were recorded during each survey year. This does not at all change the perception of the trends in this survey index and does not have significant effect on the assessment results. Also, a few invalid hauls during the 2019 survey was encountered with the result that in order to ensure that there would be no loss to the overall survey Norway covered 6 of the stations normally completed by Scotland within the most North-Easterly 2 legs of the SGFS survey. These were stations 50F0, 50F1, 50F2, 48F1, 48F2 and 48F3. In 2018, these stations accounted for around 2% of the overall Norway Pout abundance for the survey so it is expected that although not an ideal situation from the perspective of providing consistent coverage the impact of this change will be minimal. In the SGFS 2020 survey, there was only one invalid haul, and the SGFS 2021 survey was conducted as planned. For the 2022 SGFS survey there was a delay in MS Scotia commencing this survey (2 weeks late). Accordingly, the area covered by Scotland was not quite as originally intended with some stations being covered by other nations whilst MS Scotia was out of action. In addition, MS Scotia were not able to secure access to Norwegian or Danish waters thereby restricting the eastern extent of the survey. Despite this, the

SGFS survey coverage overall in 2022 was broadly in line with previous years with regard to effort with the number of stations completed within each of the old SGFS demersal areas being broadly in line (as a proportion of total) with 2021 aside from the numbers of stations completed around the Shetland area where there was an increase in effort largely due to other nations prioritising other stations to complete at the point when the SGFS survey was under threat of cancellation due to vessel breakdown. However, based on the SGFS survey specialists have made comparative plots of the two SGFS survey years 2021 and 2022 with respect to geographical coverage, catch rates and abundance indices and compared the two plots for both years, they conclude that the index provided in 2022 is robust despite the necessary changes effected during 2022 quarter 3 SGFS survey programme.

Additionally, it should be noted that in the 2014 IBTS Q1 survey, less hauls were conducted in the northern part of the North Sea than usual. This did not result in change in the perception of the stock dynamics.

From 3rd quarter 2018, the depth range of the IBTS survey has been extended to 250 m (previously 200 m). The tows deeper than 200 m are extra stations. These stations have not been included in the NP survey indices. Obviously, those additional hauls cannot be included into the standard indices before the effects are statistically robustly evaluated and before reasonable time series and adequate number of observations are available to analyse the potential effects of inclusion of the deeper tows in the indices.

In 2020, the IBTS quarter 1 (Q1) and quarter 3 (Q3) indices have been substantially revised (https://github.com/ices-tools-prod/DATRAS/tree/master/ALK_substitution) also covering the full Norway pout index time series for all age groups. The changes in the survey indices and their influence on assessment results as well as sustainability reference points are shown, described and evaluated in Brooks and Nielsen (2020). See also further details in Section 12.1.4 above and section 12.7 below. Again in 2022, there seem to have been extensive updates of the IBTS Q1 and Q3 survey indices for Norway pout on DATRAS, and a few have changed substantially. However, for the most recent years this is not extensive. For the above reasons, it was in the in 2020 assessment decided to keep the survey indices calculated with the new method constant in the period 1984-2019 as estimated in 2020 for future assessments, and only update the indices from 2020 onwards from the DATRAS IBTS Q1 and IBTS Q3 data and indices.

The survey data time series including the new information are presented in Table 12.2.11.

12.2.6.3 Revision of assessment tuning fleets

The revision of the tuning fleets used in the benchmark 2004 assessment - as used in the 2005–2006 and 2007–2015 assessments – and the additional revisions of the tuning fleets in the benchmark 2016 assessment – as used in the September 2016 and future assessments - is summarised in **Table 12.3.1. Details of the revision are described in the Stock Annex** and in the ICES WKPOUT 2016 Report (ICES, 2016) and its Annexes**.**

The overall assessment period has been changed by cutting off the first assessment year (1983), so the assessment period is from 1984–2022, and the assessment tuning fleets have been changed by removing the quarter 1, 3, and 4 commercial tuning fleets and keeping the same survey fleets. The assessment biological parameter settings are the same according to the Inter-benchmark assessment in spring 2012 (ICES IBPNorwayPout, 2012c) with respect to the population dynamic parameter settings in the assessment for natural mortality, maturity at age and mean weight at age in the stock (see also Table 12.3.1).

12.3 Catch at Age Data Analyses

12.3.1 Review of assessment

The September 2021 assessment was accepted and no overall or specific recommendations and comments were given here. Potential retrospective patterns in SSB and R were discussed at the ICES WGNSSK meeting in May 2018 as well in the following meetings, but no major issues and problems were pointed at, and it was concluded that the assessment has been performed correctly and performs relatively well. In the 2014 assessment review, it was only noted that potential area specific assessment should be considered in relation to a benchmark assessment.

12.3.2 Final Assessment

A seasonal extension to the State-space Assessment Model (SAM) was used during this September 2022 assessment (SESAM), and in the benchmark 2016 Norway pout assessments reported in ICES WKPOUT (2016). In the latter, the SESAM assessment model was evaluated and compared with the assessment model previously used (Seasonal extended survivors analysis SXSA). It was found that this new model (SESAM) estimates very similar trends in SSB and fishing mortality compared to SXSA. The SESAM model was preferred by the ICES WKPOUT (2016) benchmark assessment group due to its ability to incorporate process and observation error and estimate uncertainties in all quantities, including the forecast.

The method is described in detail in Nielsen and Berg (2016; WD6 of the ICES WKPOUT (2016)), and the source code, input data and output is available online at www.stockassessment.org under "NorPoutBench2016", and for the current September 2022 assessment under "NP_Sep2022_v2" at the same website.

In brief, the model is the same as the SAM model, except that the time step used is one quarter of a year rather than a full year. Recruitment is assumed to occur in quarter 3 only. The logarithm of the fishing mortality at age and quarter is assumed to follow a multivariate random walk with lag 4 and correlated increments, i.e. the log F-at-age in a given quarter is given by the log F-vector in the same quarter one year earlier plus a correlated noise term with mean zero.

The observation equations in SESAM are also extended to deal with zero observations (both surveys and catches), which are usually treated as missing values in SAM. This is done by introducing a detection limit for each fleet, and defining the likelihood of a zero observation to be the probability of obtaining a value less than the detection limit. The detection limit is set to 0.5 times the smallest positive observation by fleet.

A special option is included to down-weight the influence of large jumps in log F on the estimated random walk variance due to periods where the fishery was closed. This option reduces the estimated log F process variance considerably.

In the ICES WKPOUT (2016) benchmark, a number of variants of the SESAM model were investigated and compared to the previous assessment model, SXSA. These variants included the use (or not) of commercial CPUE data, omission of the earliest years of data from the assessment, alternative settings for the detection threshold used to handle zero-valued data, and omitting the years of fishery closure when estimating the random walk variance on fishing mortality.

The final SESAM model also used in this September 2022 assessment excludes commercial CPUE data, omits 1983 data from the assessment, use age 3+-group, and omits the years of fishery closure from the random walk variance calculation. In relation to evaluation of stock sustainability and forecast, B_{lim} is set equal to B_{loss} based on quarter 4 SSB values to align with the new fishing season (1 November to 31 October). The short-term forecast is stochastic, which allows the probability of SSB being below B_{lim} to be evaluated immediately following the fishing season.

Stock indices and assessment settings used in the assessment are presented in Tables 12.3.1–12.3.2.

Results of the SESAM analysis are presented in Tables 12.3.1–12.3.2 (assessment model parameters, settings, and options), Table 12.3.3 (population numbers at age (recruitment)), Table 12.3.4 (fishing mortalities by year and quarter), Table 12.3.5 (diagnostics), and Table 12.3.6 (stock summary). The summary of the results of the assessment are shown in Table 12.3.6 and Figures 12.3.1 (spawning stock biomass, SSB), 12.3.2 (total stock biomass, TSB), 12.3.3 (fishing mortality, F_{bar}), 12.3.4 (recruitment), 12.3.5 (yield, catches on yearly and quarterly basis), and 12.3.6–12.3.7 (stock-recruitment plots for quarter 1 and quarter 3, respectively). The retrospective patterns and the residuals from the SESAM September 2022 assessment are given in Figure 12.3.8 and Figures 12.3.9–12.3.11, respectively.

Fishing mortality has generally been lower than natural mortality and has decreased in the recent 20 years below the long term yearly average (0.34, Tables 12.3.4 and 12.3.6). Fishing mortality for the 1st and 2nd quarter has in general decreased in recent years, while fishing mortality for 3rd and especially 4th quarter, that historically constitutes the main part of the annual F, has also decreased moderately during the last 20 years. Fishing mortality in 2005, first part of 2006, 2007, 2008, 2011, and in first part of 2012 was close to zero due to the closure of the Norway pout fishery in those periods. Fishing mortality was moderate in 2009 and 2010 and on a higher level in second half 2012 and in 2013–2021, and the TACs have not been fished up in any of these recent years. In recent years the quota uptake has been below 30% (see Nielsen *et al.*, 2016a), and in 2019 the quota uptake was below 75%, below 80% in 2020, and below 30% in 2021. The low TAC of 6 kt in 2011 was taken in second half year resulting in a very low F in 2011.

Spawning stock biomass (SSB) has since 2001 decreased continuously until 2005 but has in recent years increased again due to the strong 2008, 2009, 2012, 2014, 2016, 2018, 2019, 2020 and 2022 year classes, and the lowered fishing mortality. The stock biomass fell to a level well below B_{lim} in 2005 which is the lowest level ever recorded. By 1 January 2007 and 2008 the stock was at B_{pa} (= MSY $B_{escapement}$) (i.e. at increased risk of suffering reduced reproductive capacity), while the stock by 1 January 2009, 2010, 2011, 2012, 2014, 2015, 2016, 2017, 2018, 2019, 2020, 2021 and 2022 has been above B_{pa} (i.e. the stock show full reproductive capacity).

The recruitment in 2010 was very low and at the same level as the low 2003- and 2004-year classes where these three-year classes are the lowest on record since the mid-1980s. The recruitment in 2008, 2009, 2012, 2014, 2016, 2018, 2019, 2020 and 2022 was high. Recruitment in 2011 and 2013 was also very low, and the recruitment in 2015 and 2017 was slightly below long-term average (46 billion), but because of the strong 2012, 2014, 2016, 2018, 2019- and 2020-year classes the SSB has been well above B_{pa} (= MSY $B_{escapement}$) by 1 January 2014, 2015, 2016, 2017, 2018, 2019, 2020, 2021 and 2022 even with a high yearly TAC in 2014–2021 (up to 3rd quarter) considering growth, high natural mortality, and 20% maturation at age 1. The 2021 recruitment is about half (26 billion) of the long-term average (48 billion) and will reduce the stock biomass, but because of the strong 2019, 2020 and 2022 recruitment the stock is expected to remain above B_{pa} by the end of 2022.

12.3.3 Comparison with 2015–2021 assessments

The final, accepted September 2015 SXSA assessment run was compared to the Inter-benchmark May 2012 and the update September 2014 and May 2014 Scenario 2 SXSA assessments. The results of the comparative runs between the September 2015 and the September 2014 and May 2014 assessments are shown in the ICES WGNSSK 2015 Report. The resulting outputs of these assessments showed to be identical giving similar perception of stock status and dynamics.

The WKPOUT 2016 benchmarking comparison of the SESAM and SXSA May 2014 assessments are presented in the ICES WKPOUT 2016 Report (ICES, 2016). The overall conclusions were that the two assessments give the same perception of stock dynamics with respect to abundance (SSB) and recruitment over time. There was some variability in the estimates of fishing mortality especially in the middle of the assessment period, however, the SXSA estimates lies within the confidence intervals of the SESAM estimates of fishing mortality.

In Figures 12.3.1, 12.3.3 and 12.3.4 the SESAM September 2022 assessment estimates of spawning stock biomass, fishing mortality, and recruitment are shown, respectively, in comparison to the corresponding SXSA May 2014 assessment estimates. It also appears from this comparison that the conclusions are the same as above for the comparison of the two 2014 assessments, i.e. that the two assessments give the same perception of stock dynamics.

The retrospective analysis based on the SESAM September 2022 assessment is shown in Figure 12.3.8. There is a tendency towards the retrospective analyses do not fully converge even though being at the same level and showing the same perceptions of the stock dynamics. For the latest years it converges for SSB, but for a few previous years to this the convergence is not as high. No strong retrospective patterns are observed for SSB, however, the Mohns rho values are relatively high for SSB (23%), but below the threshold of 0.3 for short lived species. For the most recent years the convergence is high for SSB and for all years the retrospective patterns are within the confidence limits of the estimates for both SSB, F and R (Figure 12.3.8). There is a strong positive retrospective pattern for recruitment with a tendency to overestimate recruitment in the terminal assessment year. This is due to not full consistency between in-year-0-group indices and 1-group-indices the following year for the EGFS and SGFS Q3 surveys. It should be noted that there is some difference between estimates of the B_{loss} level in the start of Q4 in 2005 between assessments.

12.4 Historical stock trends

The assessment and historical stock performance is consistent with previous years' assessments, i.e. the perception of stock dynamics of the SSB and recruitment over time are consistent, while there is some variability between models in the estimates of the average fishing mortality of ages 1 and 2 over time especially in the middle of the assessment period. However, there is a tendency to overestimate recruitment in the terminal assessment year. According to the benchmark assessments, the SXSA estimates of fishing mortality is within the confidence limits of the SESAM estimates of fishing mortality. Based on the Inter-Benchmark in spring 2012 with revised estimates of natural mortality, maturity at age and mean weight at age for the stock in the assessment there was observed a consistent (over time) slight increase in SSB (because 20% of the age group 1 is considered mature compared to 10 % in the previous assessments), and a consistent slight decrease in recruitment and total stock biomass compared to previous years mainly because of the revised natural mortality by age and quarter. This is shown in the ICES IBPNorwayPout Report (ICES, 2012c) and the Stock Annex.

There has been a smaller consistent decrease in $F_{bar(1–2)}$, because of the introduction of the revised IBTS Q1 and Q3 index time series for Norway pout of all age groups in 2020 (Brooks and Nielsen, 2020). The changes are not affecting TSB (Total Stock Biomass) and recruitment very much. This is because the changes have been relatively higher for the indices of the older mature age groups in the population.

Recruitment Estimates

The long-term average recruitment (age 0, 2nd quarter) is 48 billion (arithmetic mean) for the period 1984–2022 (Table 12.3.6). Recruitment is highly variable and influences SSB and TSB rapidly due to the short life span of the species and because 20% reach maturity as 1-group. The recruitment reached historical minima in 2003–2004 as well as in 2010. The recruitment in 2008, 2009, 2012, 2014, 2016, 2018, 2019, 2020 and 2022 was high. Recruitment in 2011 and 2013 was very low, and the recruitment in 2015 and 2017 and 2021 has been below long-term average (48 billion).

12.5 Short-term prognoses

The short-term forecast is stochastic based on the SESAM September 2022 assessment, which allows the probability of SSB being below B_{lim} to be evaluated immediately following the fishing season. The SESAM is, like the SXSA, a quarterly based model estimating biomass at the start of each quarter of the year.

Short-term projections are carried out as follows.

1. Assume values for M, weight-at-age in the catches and in the stock, and maturity-at-age for the projection period. Since all of those quantities except weight-at-age in the catches are assumed constant over time, only weight-at-age requires special treatment. A procedure for forecasting catch weights is described in ICES WKPOUT (2016, WD6, Nielsen and Berg, 2016), but see also below.
2. Draw K samples from the joint posterior distribution of the states (log N and log F) in the last year with data, and the recruitment in all years.
3. Assume that log Ft = log Ft-4 + log Gt, for all future values of t where Gt is some chosen vector of multipliers of the F-process. If Gt = 1 for all t this corresponds to assuming the same level and quarterly pattern in F for all future time-steps as in the last data year.
4. Create K forecasting trajectories starting from the samples of joint posterior distribution of the states. This is done by sampling K recruitments from the vector of historic recruitments obtained in step 2, and then projecting the states forward in time using the stock equation with randomly sampled process errors from their estimated distribution.

It should be noted that the short term forecast only uses the observed 2022 recruitment (Q3 2022) in the SSB estimate by 4th quarter 2022. The recruits in 2023 do not become a part of SSB by 4th quarter (1 October) 2023 because they have not reached maturity yet by 4th quarter 2023, but will do that by 1 January 2024 (20% mature as 1-group here). However, the forecast is just run up to 4th quarter 2023, and the recruits in 2023 is accordingly not used (and shall not be that) in the forecast SSB estimate in Q4 2023.

5. Find Gt such that the 5th (or any other) percentile of the catches (total mass) in the projections equal some desired level such as B_{lim} (optional).

Forecasting weight-at-age in the catches

There is substantial variation in weight-at-age in the commercial catches from year to year, which means that usual methods of using running averages will be quite sensitive to the bandwidth of the running average. This is important, since TAC estimates calculated in step 5 above depend directly on the catch weight-at-age.

The following model is used:

$$E(\sqrt{CW_{a,q,t}}) = \mu_{a,q} + s(cohort, a) + U_t$$

where $\mu_{a,q}$ is a mean for each combination of quarter and age, s( ) is tensor product smoothing spline, and U_t are normal distributed random effects. The square root transform is used to achieve variance homogeneity in the residuals. See Figure 1 in ICES WKPOUT (2016, WD6, Nielsen and Berg, 2016).

The projected mean weight at ages in the catch used in the forecast are shown in Table 12.6.1.

Forecasts

The first forecast provides a TAC advice according to a calculated yield in the forecast year where the probability of SSB being below B_{lim} by 1 October in the forecast year is less than 5%, i.e. the forecast estimates the yield according to SSB that meets the 5% criterion at the B_{lim} date which is 1 October as explained below in Section 12.7. The purpose of the first forecast is to calculate the catch of Norway pout from 1 October 2022 to 31 October 2023 with F scaled such that the fifth percentile of the SSB distribution one year a head (1 October 2023) equals B_{lim}, i.e. where the probability of SSB being below B_{lim} by 1 October in the forecast year is less than 5%. The results of the forecast are presented in Table 12.6.2 and Figure 12.6.1, and this results in a catch up to 117 kt (116 823 t) in the directed Norway pout fishery in the period 1 October 2022 to 31 October 2023 which corresponds to a $F_{bar(1–2)}$ of 0.635 and a SSB at 133 kt (133 480 t) by 1 October 2023.

The purpose of the second forecast is to calculate the catch of Norway pout from 1 October 2022 to 31 October 2023 with F scaled to zero. The results of the forecast are presented in Table 12.6.3 and Figure 12.6.2 resulting in no catch in the directed Norway pout fishery in the period 1 October 2022 to 31 October 2023 which corresponds to a $F_{bar(1–2)}$ of 0.00 and a SSB at 191 kt (190 620 t) by 1 October 2023.

The purpose of the third forecast is to calculate the catch of Norway pout from 1 October 2022 to 31 October 2023 with F scaled to F status quo for previous year up to 1 October 2022. The results of the forecast are presented in Table 12.6.4 and Figure 12.6.3 where catches up to 46 kt (45 564 t) can be taken in the directed Norway pout fishery in the period 1 October 2022 to 31 October 2023 which corresponds to a $F_{bar(1–2)}$ of 0.220 and a SSB at 166 kt (165 940 t) by 1 October 2023.

The purpose of the fourth forecast is to calculate the catch of Norway pout from 1 October 2022 to 31 October 2023 with F scaled such that the median of the SSB distribution one year a head (1 October 2023) equals B_{lim}. The results of the forecast are presented in Table 12.6.5 and Figure 12.6.4 where catches up to 369 kt (369 402 t) can be taken in the directed Norway pout fishery in the period 1 October 2022 to 31 October 2023 which corresponds to a $F_{bar(1–2)}$ of 4.060 and a SSB of 43 kt (42 573 t) by 1 October 2023.

The purpose of the fifth forecast is to calculate the catch of Norway pout from 1 October 2022 to 31 October 2023 with F scaled such that SSB one year a head (1 October 2023) equals B_{pa}. The results of the forecast are presented in Table 12.6.6 and Figure 12.6.5 where catches up to 282 kt (281 510 t) can be taken in the directed Norway pout fishery in the period 1 October 2022 to 31 October 2023 which corresponds to a $F_{bar(1–2)}$ of 2.295 and a SSB of 70 kt (70 000 t = B_{pa}) by 1 October 2023.

The purpose of the sixth forecast is to calculate the catch of Norway pout from 1 October 2022 to 31 October 2023 with F scaled to 0.3, i.e. with a F_{cap} = 0.3. The results of the forecast are presented in Table 12.6.7 and Figure 12.6.6 where catches up to 61 kt (61 133 t) can be taken in the directed Norway pout fishery in the period 1 October 2022 to 31 October 2023 which corresponds to a $F_{bar(1–2)}$ of 0.303 and a SSB of 159 kt (158 540 t) by 1 October 2023.

The purpose of the seventh forecast is to calculate the catch of Norway pout from 1 October 2022 to 31 October 2023 with F scaled to 0.4, i.e. with a F_{cap} = 0.4. The results of the forecast are presented in Table 12.6.8 and Figure 12.6.7 where catches up to 79 kt (79 162 t) can be taken in the directed Norway pout fishery in the period 1 October 2022 to 31 October 2023 which corresponds to a $F_{bar(1–2)}$ of 0.405 and a SSB of 150 kt (149 820 t) by 1 October 2023.

The purpose of the eight forecast is to calculate the catch of Norway pout from 1 October 2022 to 31 October 2023 with F scaled to 0.5, i.e. with a F_{cap} = 0.5. The results of the forecast are presented in Table 12.6.9 and Figure 12.6.8 where catches up to 96 kt (95 769 t) can be taken in the directed Norway pout fishery in the period 1 October 2022 to 31 October 2023 which corresponds to a $F_{bar(1–2)}$ of 0.503 and a SSB of 142 kt (142 220 t) by 1 October 2022.

The purpose of the ninth forecast is to calculate the catch of Norway pout from 1 October 2022 to 31 October 2023 with F scaled to 0.6, i.e. with a F_{cap} = 0.6. The results of the forecast are presented in Table 12.6.10 and Figure 12.6.9 where catches up to 112 kt (111 636 t) can be taken in the directed Norway pout fishery in the period 1 October 2022 to 31 October 2023 which corresponds to a $F_{bar(1–2)}$ of 0.603 and a SSB of 136 kt (135 600 t) by 1 October 2023.

The purpose of the tenth forecast is to calculate the catch of Norway pout from 1 October 2022 to 31 October 2023 with F scaled to 0.7, i.e. with a F_{cap} = 0.7. The results of the forecast are presented in Table 12.6.11 and Figure 12.6.10 where catches up to 126 kt (126 284 t) can be taken in the directed Norway pout fishery in the period 1 October 2022 to 31 October 2023 which corresponds to a $F_{bar(1–2)}$ of 0.705 and a SSB of 129 kt (129 060 t) by 1 October 2023.

According to the long-term management strategy evaluation based on the joint EU-Norway request from November 2017 and the resulting released advice by ICES in May 2018 evaluating long-term management strategies for Norway pout in area 4 and 3.a (http://ices.dk/sites/pub/Publication%20Reports/Advice/2018/Special_requests/eu-no.2018.07.pdf) it was shown that the current procedure for providing TAC advice for Norway pout, based on an escapement strategy where the probability of SSB being below B_{lim} by 1 October in the forecast year is less than 5% is only precautionary with the addition of an F_{cap} at 0.7. See also Section 12.1.4 above and Section 12.7 below.

12.6 Medium-term projections

No medium-term projections are performed for this stock. The stock contains only a few age groups and is highly influenced by recruitment.

12.7 Biological reference points

As explained in the ICES WKPOUT 2016 Report (ICES, 2016), Section 3.8, the benchmark has recommended that the B_{lim} = B_{loss} should be the lowest SSB estimated in quarter 4, because this is closest to the beginning of the fishing season (1 November), and would be the most appropriate to use as a B_{lim} reference point, because the probability of SSB being below B_{lim} can then be evaluated immediately after the fishing season for which a TAC is being calculated. It was argued that the quarter 4 SSB (an existing output of the SESAM model) was adequate for this purpose because any attempt to calculate an SSB corresponding to 1 November would require further assumptions and would effectively only be an interpolation between the quarter 4 and subsequent quarter 1 SSBs, thus unnecessarily complicating the calculation of the SSB. The forecast provides a TAC advice according to a calculated yield in the forecast year where the probability of SSB being below B_{lim} by 1 October in the forecast year is less than 5%, i.e. the forecast estimates the yield according to SSB that meets the 5% criterion at the B_{lim} date which is 1 October. Accordingly, it is recommended that this TAC is used for the management year 1 November–31 October. This is an approximation and will be sustainable unless radical changes occur in the seasonal fishing pattern used in the forecast. In the period between 1 October and 1 November in the forecast year there will be provided a new assessment.

In Table 12.6.12, quarterly minima of the estimated SSB time series (1984–2016) are shown from the SESAM Benchmark Assessment Baseline Run from the Norway pout benchmark assessment in ICES WKPOUT (2016). The estimates are quarterly minima estimated at the beginning of the season. The lowest observed biomasses in the assessment period are in 2005. The estimates are B_{loss} estimates which equals B_{lim} according to the ICES WKPOUT 2016 benchmark assessment which by 1 October is B_{lim} = 39 450 t (ICES, 2016). In Table 12.6.13, the same minima for the same period is shown using the new IBTS Q1 and Q3 survey indices introduced in the assessment from 2020 onwards. See also Section 12.1.4 above and Section 12.7 below.

The B_{lim} SSB estimate in Q4 is low because of the 0-group and many of the 1-group fish are not in the SSB yet at that time. However, in the forecast there is a change in maturity and an age class shift by 1 January, i.e. the 0-group becomes 1-group and 20% of those become mature, and the 1-group becomes 2-group and 100% of those become mature. This is in the forecast calculated into the SSB available for spawning in 1 quarter of the forecast year.

The fishing pattern has not changed in the most recent years. Accordingly, the use of B_{lim} by Q4 should be sustainable.

It should be noted that there is a tendency towards the retrospective analyses for SSB do not fully converge even though being at the same level (see also Section 12.3 above). It should also be noted that there is quite some difference between estimates of the B_{loss} level in the start of Q4 in 2005 between assessments.

Framework	Reference point	Value	Technical basis	Source
MSY approach	MSY $B_{escapement}$	Not defined*		
	F_{MSY}	Not defined		
	F_{cap}	0.70	A long-term management strategy evaluation, indicating that an escapement strategy for Norway pout is only precautionary with the addition of an upper limit on fishing mortality = F_{cap} ($F_{bar[1-2]}$) at 0.7	ICES (2020)
Precautionary approach	B_{lim}	42 573 tonnes (4th quarter)	$B_{lim} = B_{loss}$, the lowest observed biomass in 2005 (as estimated in the updated benchmark assessment)	ICES (2020)
	B_{pa}	69 736 tonnes (4th quarter)	$B_{pa} = B_{lim}\ e^{0.3 \times 1.645}$	ICES (2020)
	F_{lim}	Not defined		
	F_{pa}	Not defined		
Management plan	SSB_{MGT}	Not applicable		
	F_{MGT}	Not applicable		

*** MSY $B_{escapement}$ has not been defined, as the escapement strategy uses directly the 95% probability of SSB being above B_{lim}.**

No F-based reference points are advised for this stock except for an F_{cap} (see below and sections 12.1.4, 12.5 and 12.10).

Norway pout is a short-lived species and most likely a one-time spawner. The population dynamics of Norway pout in the North Sea and Skagerrak are very dependent on changes caused by recruitment variation and variation in predation (or other natural) mortality, and less by the fishery. Recruitment is highly variable and influences SSB and TSB rapidly due to the short life span of the species. (Basis: Nielsen *et al.*, 2012; Sparholt *et al.*, 2002a,b; Lambert *et al.*, 2009). Furthermore, 20 % of age 1 is considered mature and is included in SSB (Lambert *et al.*, 2009). Therefore, the recruitment in the year after the assessment year does influence the SSB in the following year. Also, Norway pout is to limited extent exploited already from age 0. All in all, the stock is very dependent of yearly dynamics and should be managed as a short-lived species.

On this basis, advice on yield in the forecast year where the probability of SSB being below B_{lim} by 1 October in the forecast year is less than 5% is considered sustainable. That is where F is scaled such that the fifth percentile of the SSB distribution one year a head (1 October in forecast year) equals B_{lim}. According to the long term management strategy evaluation based on the joint EU-Norway request from November 2017 and the resulting released advice by ICES in May 2018 evaluating long-term management strategies for Norway pout in area 4 and 3.a (http://ices.dk/sites/pub/Publication%20Reports/Advice/2018/Special_requests/eu-no.2018.07.pdf) it was shown that the current procedure for providing TAC advice for Norway pout, based on an escapement strategy where the probability of SSB being below B_{lim} by 1 October in the forecast year is less than 5% is only precautionary with the addition of an F_{cap} at 0.7 (see also Section 12.1.4 above).

B_{pa} has been calculated from

$$B_{pa} = B_{lim}\ e^{0.3*1.645}\ (SD).$$

A SD estimate around 0.3–0.4 is considered to reflect the real uncertainty in the assessment. This SD-level also corresponds to the level for SD around 0.2–0.3 recommended to use in the manual for the Lowestoft PA Software (CEFAS, 1999). The relationship between the B_{lim} and B_{pa} (42 573 and 69 736 t) is 0.6.

It is obvious that the Norway pout, being a short-lived species, has no well-defined break point (inflection) in the SSB-R relationship (ICES IBPNorwayPout 2012c; ICES WKPOUT, 2016) and therefore there is no clear point at which impaired recruitment can be considered to commence (i.e. SSB does not impact R negatively, and that there is a relatively high recruitment observed at B_{loss} as well as more observations above than below the inflection point).

The $B_{lim} = B_{loss}$ = 42 573 t (quarter 4) is based on the lowest observed SSBs in 2005.

Revision of Reference points in 2020

Due to introduction of revised IBTS (International Bottom Trawl Survey) quarter 1 (Q1) and quarter 3 (Q3) indices for the full survey time series for all age groups of Norway pout by ICES in 2020 (https://github.com/ices-tools-prod/DATRAS/tree/master/ALK_substitution) the long term sustainability of the B_{lim} and F_{cap} = 0.7 reference points were during summer 2020 evaluated and presented in Brooks and Nielsen (2020).

The analyses showed a slight change in B_{lim} of less than 10% from B_{lim} = 39 447 t (Benchmark ICES WKPOUT, 2016 estimate) to B_{lim} = 42 573 t by running the benchmark assessment with the new IBTS indices (Brooks and Nielsen, 2020).

Furthermore, Brooks and Nielsen (2020) evaluated harvest control rules (HCRs) within the escapement strategy presently practiced (aimed at retaining a minimum stock size in the sea every year after fishing) that are based on the new B_{lim} value and simulated to be restricted by a combination of an upper limit on F values (F_{cap}), different F_{max} values (between the historical observed F_{max} of 0.67, i.e. the $F_{historical}$ for the assessment using the revised IBTS data, and up to a F_{max} value of 2) as well as different TAC upper bounds (TAC_{max}) for setting the TAC. The TAC_{max} values evaluated was from 200 kt up to infinite (i.e. with no upper TAC bound). The sustainability of the current F_{cap} = 0.7 was evaluated through long term management strategy evaluation simulations with the new B_{lim} reference point and according to the different F_{max} and TAC_{max} values applied as described above and detailed in Brooks and Nielsen (2020)

These evaluations showed that the currently implemented F_{cap} of 0.7 is also precautionary and sustainable with the slightly revised B_{lim} reference point (Brooks and Nielsen, 2020).

This is the case also in extremely unrealistic scenarios of an infinite TAC_{max} and with F_{max} values between 0.67 and up to 2 (Brooks and Nielsen, 2020). All scenarios for F_{max} = 0.67 and for a very unrealistic high F_{max} = 1 with infinite TAC_{max} are sustainable. Even with the totally unrealistically high maximum implementable F of 2 then the risk only goes above 0.05 with an F_{cap} = 0.7 (when rounded to the nearest 0.01 units) for the risk3.long.Q4. All other scenarios for F_{max} = 2 values are sustainable (Brooks and Nielsen, 2020). This means that if there were a totally unrealistic high F_{max} of around 1.6 which is similar to the natural mortality level for the stock then all scenarios of F_{cap} = 0.7 would obviously be sustainable.

The WGNSSK working group has on this basis decided to switch to the new B_{lim} reference point, and on this basis to calculate a new B_{pa} reference point, and continue with the currently implemented F_{cap} of 0.7. It should again be noted that no lower bound TAC_{min} or upper bound TAC_{max} boundaries have been implemented in the management (see also Section 12.1.4).

In Table 12.6.13 quarterly minima of the estimated SSB time series (1984–2016) are shown from the SESAM updated Benchmark Assessment Run (Run: NP_Sep17_fixC_Benchmark2016Data_NewIBTS, www.stockassessment.org) with new IBTS Q1 and Q3 survey indices for Norway pout made available in 2020 (Brooks and Nielsen, 2020). The estimates are quarterly minima estimated at the beginning of the season. The lowest observed biomasses in the assessment period are still in 2005. The estimates are B_{loss} estimates which equals B_{lim} which by 1 October is B_{lim} = 42 573 t, i.e. based on the lowest observed SSBs in 2005.

12.8 Quality of the assessment

The estimates of the SSB, recruitment and the average fishing mortality of the 1- and 2-group are consistent with the estimates of previous year’s assessment, except that SSB has consistently increased and F_{bar} has consistently decreased because of introduction of the new IBTS Q1 and Q3 indices in 2020 (see Section 12.7 above). The overall perception of stock dynamics with respect to abundance (SSB) and recruitment over time is the same. There is some variability in the estimates of fishing mortality especially in the middle of the assessment period, however, the previous year estimates of fishing mortality lies within the confidence intervals of the SESAM estimates of fishing mortality. The estimates of Mohn’s Rho in the retrospective analyses are of the baseline SESAM assessment September 2022, with terminal assessment year ranging from 2017–2022, is 23% for SSB, -7% for F_{bar}, and 67% for R shown in Figure 12.3.8. Despite these tendencies of overestimating spawning stock biomass, underestimating fishing mortality, and overestimating recruitment, then the terminal year estimates lie within the confidence limits of the model estimates which appear from Figure 12.3.8 (see also Sections 12.3.3 and 12.4 above).

The assessment is considered appropriate to indicate trends in the stock and immediate changes in the stock because of the assessment taking into account the seasonality in fishery, use of seasonal based fishery independent information, and using most recent information about recruitment. The assessment provides stock status and year class strengths of all year classes in the stock up to the end of third quarter of the assessment year. The assessment method gives a good indication of the stock status the 1 October the following year based on projection of existing recruitment information in 3rd quarter of the assessment year.

12.9 Status of the stock

Based on the estimates of SSB in September 2022, ICES classifies the stock at full reproductive capacity.

With F scaled such that the fifth percentile of the SSB distribution one year a head (1 October 2023) equals B_{lim}, i.e. where the probability of SSB being below B_{lim} by 1 October in the forecast year is less than 5% catches up to 117 kt (116 823 t) can be taken in the directed Norway pout fishery in the period 1 October 2022 to 31 October 2023 which corresponds to a $F_{bar(1–2)}$ of 0.635 and a SSB at 113 kt (113 480 t) by 1 October 2023. This is due to the strong 2018, 2019, 2020 and 2022 recruitment being above the long-term average recruitment (48 billion) and a 2021 recruitment around half (26 billion) of the long-term average, growth of the stock and still taking into consideration the high natural mortality as well as the short life span of the stock.

Fishing mortality has generally been lower than the natural mortality for this stock and has decreased in recent years below the long-term average F (0.34). However, if the advised catch is taken, the F is expected increase to above this average for the period 1 October 2022 to 31 October 2023. Targeted fishery for Norway pout was closed in 2005, first half year 2006, in all of 2007, as well as in first half of 2011 and 2012 and fishing mortality and effort has accordingly reached historical minima in these periods (Table 12.3.6). The fishery was open for the second half 2006, 2011 and 2012 as well as in all of the years 2008–2010 and 2013–2021. Here, the fishing mortality was low in 2008 and 2011, moderate in 2009 and 2010, and on a higher level in 2013–2021, but still well below the long-term average. The TACs have not been fished up in any of these recent years. Less than 75% of the quota was taken in 2019, less than 80% in 2020, and less than 30% in 2021.

The recruitment reached historical minima in 2003–2004, and the 1987, 2002, 2006, and 2010 year classes were weak. The recruitment in 2008, 2009, 2012, 2014, 2016, 2018, 2019, 2020 and 2022 was high well above the long-term average (48 billion). Recruitment in 2011 and 2013 was also very low, and the recruitment in 2015, 2017 and 2021 has been below the long-term average (Table 12.3.6).

12.10 Management considerations

There are no management objectives for this stock.

From the results of the forecast presented here with a F scaled such that the fifth percentile of the SSB distribution one year a head (1 October 2023) equals B_{lim}, i.e. where the probability of SSB being below B_{lim} by 1 October in the forecast year is less than 5% catches up to 117 kt (116 823 t) can be taken in the directed Norway pout fishery in the period 1 October 2022 to 31 October 2023 which corresponds to a $F_{bar(1–2)}$ of 0.635 and a SSB at 113 kt (113 480 t) by 1 October 2023. This is due to the strong 2018, 2019, 2020 and 2022 recruitment being above the long-term average recruitment (48 billion) and a 2021 recruitment around half (26 billion) of the long-term average, growth of the stock and still taking into consideration the high natural mortality as well as the short life span of the stock.

Norway pout is a short-lived species and most likely a one-time spawner. The population dynamics of Norway pout in the North Sea and Skagerrak are very dependent on changes caused by recruitment variation and variation in predation (or other natural) mortality, and less by the fishery. Recruitment is highly variable and influences SSB and TSB rapidly due to the short life span of the species. (Basis: Nielsen *et al.*, 2012; Sparholt et al., 2002a,b; Lambert *et al.*, 2009). Furthermore, 20% of age 1 is considered mature and is included in SSB (Lambert *et al.*, 2009). Therefore, the recruitment in the year after the assessment year does influence the SSB in the following year. Also, Norway pout is to limited extent exploited already from age 0. All in all, the stock is very dependent of yearly dynamics and should be managed as a short-lived species.

There is a need to ensure that the stock remains high enough to provide food for a variety of predator species. Natural mortality levels by age and season used in the stock assessment reflect the predation mortality levels estimated for this stock from the recent multi-species stock assessment performed by ICES (ICES WGSAM, 2014; 2011; ICES-SGMSNS, 2006). Biological interactions with respect to intra-specific and inter-specific relationships for Norway pout stock dynamics and important predator stock dynamics have been reviewed and further analysed in Nielsen (2016; Section 6) and there is referred to the general conclusions here.

Existing technical measures such as the closed Norway pout box, minimum mesh size in the fishery, and by-catch regulations to protect other species have been maintained. An overview of recent relevant management measures and regulations for the Norway pout fishery and the stock can be found in Nielsen *et al.* (2016a) and in the Stock Annex.

Historically, the fishery includes by-catches especially of haddock, whiting, saithe, and herring. Existing technical measures to protect these by-catch species should be maintained or improved. By-catches of these species have been relatively low in the recent decade, and in general, the by-catch levels of these gadoids have decreased in the Norway pout fishery over the years. The declining tendency of by-catch of other species in the Norway pout fishery also appears from Table 12.2.1. However, here it can also be observed, that the by-catches have increased slightly in 2019 compared to previous years and to 2020–2021. From April 2020 onwards, the sampling intensity of the Danish Norway pout fishery has increased where every landing is now sampled, and the number of required samples increase with the landing weight from a minimum of 6 to a maximum of 24 per landing. This new sampling system may give more precise estimates of by-catches which should be evaluated in future benchmark assessments.

Sorting grids in combination with square mesh panels have been shown to reduce by-catches of whiting and haddock by 57% and 37%, respectively (Eigaard and Holst, 2004; Nielsen and Madsen, 2006; Eigaard and Nielsen, 2009; Eigaard *et al.*, 2012). Sorting grids are at present used in the Norwegian and Danish fishery (partly implemented as management measures for the larger vessels), but modification of the selective devices and their implementation in management is still ongoing. In Eigaard *et al.* (2021) a new bycatch reduction device, termed "Excluder", is presented as an alternative to a traditional rigid sorting grid, mandatory in the small-meshed Norway Pout trawl fishery in the North Sea. For all bycatch species analysed in Eigaard *et al.* (2021), the Excluder had significantly lower catches relative to the grid: herring (21%), whiting (6%), mackerel (5%), American plaice (70%), witch flounder (15%), and lesser silver smelt (71%). For Norway Pout there was a significant increase in the overall catch efficiency of 32%. These results are explained by a 10 cm smaller L50 (the length of fish with 50% probability of being rejected by the sorting system) of the Excluder and a 15 times larger sorting area, which reduces the risk of clogging and loss of function. The excluder has been implemented in the EU fishing zone from January 2022 so it is optional to choose between sorting grid or excluder. ICES suggests, that these devices (or modified forms of those) are fully implemented and brought into use in the fishery. The implementation of these technical measures shall be followed up by adequate control measures of landings or catches at sea to ensure effective implementation of the existing by-catch measures. An overview of recent relevant management measures and regulations for the Norway pout fishery and the stock can be found in Nielsen *et al.* (2016a) and in the Stock Annex.

12.2.1 Long term management strategies

ICES has evaluated and commented on three management strategies in 2007, following requests from managers – fixed fishing mortality (F = 0.35), Fixed TAC (50 000 t), and a variable TAC escapement strategy. The 2007 evaluation showed that all three management strategies are capable of generating stock trends that stay at or above B_{pa} = MSY $B_{escapement}$, i.e. away from B_{lim} with a high probability in the long term and are, therefore, considered to be in accordance with the MSY and precautionary approach. ICES does not recommend any particular one of the strategies.

The choice between different strategies depends on the requirements that fisheries managers and stakeholders have regarding stability in catches or the overall level of the catches. The variable TAC escapement strategy as evaluated in 2007 has higher long-term yield compared to the fixed fishing mortality strategy (and the fixed TAC strategy), but at the cost of a substantially higher probability of having closures in the fishery. If the continuity of the fishery is an important property, the fixed F (equivalent to fixed effort) strategy will perform better.

There should be no shift in management strategies between years. In recent years the escapement strategy has been practiced.

A detailed description of these long-term management strategies and management plan evaluations can be found in the Stock Annex and in the ICES AGNOP 2007 (ICES CM 2007/ACFM:39), ICES WGNSSK 2007 (ICES CM 2007/ACFM:30, Section 5.3) and the ICES AGSANNOP (ICES CM 2007/ACFM:40) reports as well as in Vinther and Nielsen (2012, 2013).

ICES has again in September–October 2012 and April–May 2013 (Vinther and Nielsen, 2012; 2013) evaluated and commented on long term management strategies for the stock using updated stock information. In September 2012, ICES evaluated 3 additional management strategies within the escapement strategy (Vinther and Nielsen, 2012): 1) A long term minimum TAC > 0 together with a maximum TAC (only with one yearly assessment in September) with the result that a minimum TAC up to 27 kt (revised to 20 kt in the 2013 evaluation) and a maximum TAC of 100–250 kt will be long term sustainable; 2) A long term fixed initial TAC the first 6 months of the year followed by an date where the TAC for the whole year is set based on a fixed F (only with one yearly September assessment) with the result that an initial TAC between 25–50 kt and a fixed F = 0.35 (corresponding to median catch of 60 kt) is long term sustainable; 3) Similar to 2, but here with a within year update assessment and advice based on the escapement strategy, and the result here is that an initial TAC of up to 50 kt is sustainable when having a within year up-date assessment. The difference between the MSE 1 and 2–3 is that the initial fixed TAC is assumed to be taken (or possibly lost) within the first six months of the year (MSE 2–3), while the minimum TAC in MSE 1 can be applied all year. As a follow up on this, ICES evaluated in April 2013 one additional management strategy within the escapement strategy (Vinther and Nielsen, 2013): 4) A long term minimum TAC > 0 and a maximum TAC, but where the TAC year is from 1 November–31 October rather than from 1 January to 31 December, and one annual advice from the September assessment, with the result that a minimum TAC up to 20 kt with maximum TAC of 100 kt ($F_{max/cap}$ = 0.8) or with maximum TAC of 200 kt ($F_{max/cap}$ = 0.6) will be long term sustainable with some level of F control according to those F_{cap} levels.

With the changes introduced by the August 2016 Norway pout benchmark assessment (ICES WKPOUT, 2016 and Annexes) involving change of assessment model, change of assessment year, change of assessment period, removal of the commercial fishery tuning fleet in the assessment, change of the plus-group in the assessment from 4+ to 3+ and change of stock MSY reference level these above previous MSEs cannot be used anymore for long term management plans of the stock (including the F_{cap} estimates made there).

Long term management strategy evaluation according to the new assessment and the revised reference levels as established from the benchmark assessment in August 2016, have been requested in a joint EU-Norway request from November 2017. Based on this EU / Norway request ICES on 29 May 2018 released its advice evaluating long-term management strategies for Norway pout in area 4 and 3.a (http://ices.dk/sites/pub/Publication%20Reports/Advice/2018/Special_requests/eu-no.2018.07.pdf) which is based on the work from the ICES WKNPOUT (Report of the Workshop for Management Strategy Evaluation for Norway Pout, ICES, Copenhagen 26-28 February 2018, ICES CM2018/ACOM:38 Ref WGNSSK, 96 pp) as presented to the ICES WGNSSK and approved by ICES ACOM in May 2018.

ICES has evaluated sustainability of a range of harvest control rules (HCRs) within the escapement strategy presently used for Norway pout, with additional lower (TAC_{min}) and upper (TAC_{max}) bounds on TAC and optional use of upper fishing mortality values (F_{cap}). Several HCRs were identified that combined TAC_{min} in the range of 20 000–40 000 t and TAC_{max} less than or equal to 200 000 t (150 000 t or 200 000 t) and F_{cap} values of 0.3 and 0.4, resulting in no more than a 5% probability of the spawning-stock biomass falling below B_{lim}.

ICES has evaluated harvest control rules (HCRs) within the escapement strategy presently used (aimed at retaining a minimum stock size in the sea every year after fishing) that are restricted by a combination of TAC lower bounds (TAC_{min}) and upper bounds (TAC_{max}). For some HCRs, an upper limit on F (F_{cap}) is also used for setting the TAC.

Because of uncertainties in the estimate of the incoming year class, escapement strategies for short-lived species, where catch opportunities are very dependent on the strength of the incoming year class, may lead to a TAC where a too high portion is caught. ICES evaluations were conditioned by a maximum realized level of fishing mortality the fishery can exert (assumed at 0.89; $F_{historical}$), which means that the full TAC will not be taken if the required F to catch the TAC exceeds this value.

The identified combinations of TAC_{min} lower bound, TAC_{max} upper bound and F_{cap} give a less variable TAC and F from one year to the next, but also a lower long-term yield than the default escapement strategy. ICES is not in position to advise on this trade-off between higher yield and stability.

The results are sensitive to the assumption that the fishery stops catching Norway pout when F exceeds $F_{historical}$. Therefore, the HCR should be re-evaluated if future F exceeds $F_{historical}$ (0.89).

The evaluation showed that the current procedure for providing TAC advice for Norway pout, based on an escapement strategy is only precautionary with the addition of an F_{cap} at 0.7.

In consultations between EU and Norway, held on 5 and 6 September 2018, the advice was presented by ICES and in the following discussions, certain limited additional elements, to be reviewed by ICES, came up. This resulted in an additional EU / Norway request from September 2018 on evaluation of additional elements concerning the ICES advice evaluating long-term management strategies for Norway pout in area 4 and 3.a. Here ICES is requested to assess, following MSY $B_{escapement}$:

→ *- which scenarios of TAC_{min} and TAC_{max} would be precautionary, if the F_{cap} is set at 0.7 (building on request part 2 and 3, pages 3 and 4 of the advice).*

→ *-which scenarios of TAC_{min} and TAC_{max} would be precautionary, if an inter-annual flexibility of +/-10% (both banking and borrowing) was introduced for Norway pout (building on request part 2 and 3, pages 3 and 4 of the advice, plus including precautionary scenarios with an F_{cap} of 0.7 – following from paragraph 1 of this request).*

On this basis, ICES has evaluated additional harvest control rules (HCRs) within the escapement strategy presently used for Norway pout, with additional lower (TAC_{min}) and upper (TAC_{max}) bounds on TAC and use of an upper fishing mortality (F_{cap}) at 0.7. As for the scenario made for ICES May 2018 advice (ICES WKNPOUT, 2018), ICES evaluations were conditioned by a maximum realized level of fishing mortality the fishery can exert (assumed at 0.89; $F_{historical}$), which means that the full TAC will not be taken if the required F to catch the TAC exceeds this value.

This is presented in the ICES advice: http://ices.dk/sites/pub/Publication%20Reports/Advice/2018/Special_requests/eu.2018.19.pdf.

Several HCRs were identified that combined TAC_{min} in the range of 20 000–40 000 t and TAC_{max} less than or equal to 200 000 t, resulting in no more than a 5% probability of the spawning-stock biomass falling below B_{lim}. Increasing the F_{cap} from 0.4 (which was previously evaluated) to 0.7 results in a higher median and mean TAC, but also in a higher long-term probability of SSB falling below B_{lim}. It also results in a higher probability of being constrained by the TAC_{max}.

The evaluations and ACOM approval of this led to identification of an expanded set of sustainable scenarios with a F_{cap} of 0.7. Tables 1 and 2 in http://ices.dk/sites/pub/Publication%20Reports/Advice/2018/Special_requests/eu.2018.19.pdf summarize the long-term (2023–2037) performance metrics for the (precautionary) combinations that result in no more than 5% probability of SSB falling below B_{lim} in the period 2023–2037. More detailed statistics for both precautionary and non-precautionary HCRs are shown in the Table 3 of this advice.

Given that Norway pout is short-lived and that the HCR scenarios are based on the escapement strategy, the application of an additional interannual quota flexibility of ±10% is not considered precautionary.

No decision on long-term management plans are currently available for the Norway pout in area 4 and 3.a based on the identified sustainable scenarios.

Due to introduction of revised IBTS (International Bottom Trawl Survey) quarter 1 (Q1) and quarter 3 (Q3) indices for the full survey time series for all age groups of Norway pout by ICES in 2020 (https://github.com/ices-tools-prod/DATRAS/tree/master/ALK_substitution) the long term sustainability of the B_{lim} and F_{cap} = 0.7 reference points were during summer 2020 evaluated and presented in Brooks and Nielsen (2020).

The analyses showed a slight change in B_{lim} of less than 10% from B_{lim} = 39 447 t (Benchmark ICES WKPOUT, 2016 estimate) to B_{lim} = 42 573 t by running the benchmark assessment with the new IBTS indices (Brooks and Nielsen, 2020).

Furthermore, the working document evaluated harvest control rules (HCRs) within the escapement strategy presently practiced (aimed at retaining a minimum stock size in the sea every year after fishing) that are based on the new B_{lim} value and simulated to be restricted by a combination of an upper limit on F values (F_{cap}), different F_{max} values (between the historical observed F_{max} of 0.67, i.e. the $F_{historical}$ for the assessment using the revised IBTS data, and up to a F_{max} value of 2) as well as different TAC upper bounds (TAC_{max}) for setting the TAC. The TAC_{max} values evaluated was from 200 kt up to infinite (i.e. with no upper TAC bound). The sustainability of the current F_{cap} = 0.7 was through long term management strategy evaluation simulations evaluated with the new B_{lim} reference point and according to the different F_{max} and TAC_{max} values applied as described above and detailed in Brooks and Nielsen (2020).

These evaluations showed that the currently implemented F_{cap} of 0.7 is also precautionary and sustainable with the slightly revised B_{lim} reference point (Brooks and Nielsen, 2020).

This is the case also in extremely unrealistic scenarios of an infinite TAC_{max} and with F_{max} values between 0.67 and up to 2 (Brooks and Nielsen, 2020). All scenarios for F_{max} = 0.67 and for a very unrealistic high F_{max} = 1 with infinite TAC_{max} are sustainable. Even with the totally unrealistically high maximum implementable F of 2 then the risk only goes above 0.05 with an F_{cap} = 0.7 (when rounded to the nearest 0.01 units) for the risk3.long.Q4. All other scenarios for F_{max} = 2 values are sustainable (Brooks and Nielsen, 2020). This means that if there were a totally unrealistic high F_{max} of around 1.6 which is similar to the natural mortality level for the stock then all scenarios of F_{cap} = 0.7 would obviously be sustainable.

The WGNSSK working group has on this basis decided to switch to the new B_{lim} reference point, and on this basis to calculate a new B_{pa} reference point, and continue with the currently implemented F_{cap} of 0.7. It should again be noted that no lower bound TAC_{min} or upper bound TAC_{max} boundaries have been implemented in the management (see also Section 12.1.4).

12.11 Other issues

Recommendations for future assessments

Age reading check and otolith exchange program

In July 2018, a report of the 2018 Norway Pout exchange was sent out by ICES WGBIOP, the first official SmartDots exchange (ICES WGBIOP, 2018). As decided upon by ICES WGBIOP each of the official exchanges will now have a full report, "Norway Pout Exchange 2018 Report" and a summary report, "Norway Pout Exchange 2018 Summary Report" for the stock assessment working group, in this case WGNSSK. This has been made available on the ICES SmartDots page late 2018 (see below) along with a link to download the data (ICES WGBIOP, 2018).

The reports have been produced by an R-script which uses output from the SmartDots database to run a standardized analysis based on the traditional Guus Eltink sheet, so all the tables and plots should look familiar. Not all of the plots produced have been commented upon in the text but have been included so they can be discussed in the relevant labs according to the routines there. (ICES WGBIOP, 2018).

The summary of the age reading check and otolith exchange program is given below. In 2015, a preliminary age reading exchange took place between the primary age readers of Norway pout from DTU Aqua (Denmark) and IMR (Norway) to identify if any age reading issues exist. The samples included in the exchange were from the commercial Norway pout fishery in the North Sea and Skagerrak-Kattegat areas (nop.27.3a4 stock) as age readings from this fishery are used directly in the Norway pout stock assessment to estimate catch, mean weight, maturity and mortality at age. Here, 227 samples were selected from quarter 4, 2014 and quarter 3, 2015 covering the fish length range of Norway pout in the North Sea. Results showed an overall percentage agreement of 72%, with 100% agreement at age 0 and a decrease in agreement with an increase in age. Results showed a tendency for the Norwegian reader to estimate the ages of the fish to be one year older in comparison to the Danish reader. As Norway pout grow very quickly in the first year, the centre of the otoliths are highly opaque and this can cause problems when identifying the first winter ring. In addition, subsequent growth zones are much narrower in comparison and the interpretation of growth zones towards the edge may also contribute to difficulties in age determination, especially for older fish. The exchange was carried out without the inclusion of otolith images and, thus, no record of which growth structures the readers identify when determining the age of the fish. These results indicated the need for a full-scale exchange to be carried out based on otoliths images and including all age reading laboratories who routinely read Norway pout.

The full-scale exchange was initially planned for 2016 and a timetable proposed which would allow for the results to be considered in relation to the 2017 stock assessment and potential InterBenchmark Assessment if required. Due to difficulties with sample collection and the WebGR age reading platform delays were encountered. A revised timetable was proposed in line with the launch of the BETA version of the new age reading tool – SmartDots, making the results available for the Norway pout stock assessment in Spring 2018. The exchange took place from

January to March 2018 and 14 readers from seven countries participated (Scotland, UK, France, Norway, Denmark, Netherlands and Germany). Different methods were applied for age determination of this species; whole, broken and sectioned otoliths and images were provided of samples prepared using each method. Samples were collected during the 2016 Q3 IBTS and 2014 Q4 commercial fishing trips from ICES area 27.4.a. covering the length range of the fish and considered adequately representative of the stock (ICES WGBIOP, 2018).

Results based on sectioned otoliths were exceptional with an overall percentage agreement based on modal age of 99% and an average CV of 3% (ICES WGBIOP, 2018). For the whole and broken otoliths the average percentage agreement based on modal age is 82%, with an average CV of 20%. There is a slight tendency for some readers to overestimate the age at modal age 0 and 1 and underestimate in comparison to modal age 2. The bias that existed between the primary readers from Norway and Denmark in 2016 is still apparent. These results are based only on those readers who provide age data for assessment purposes (ICES WGBIOP, 2018).

In conclusion, there is an overall high level of agreement between readers of the Norway pout - nop.27.3a4 stock (ICES WGBIOP, 2018). The agreement is higher between the countries who read sectioned otoliths (Germany and UK-England) compared to those who read whole (Denmark) and broken otoliths (Denmark, Norway and UK-Scotland). This can be partly attributed to one Norwegian and one Danish reader who occasionally overestimate in comparison to modal age 0 and 1 with the identification of the first winter ring being problematic. At modal age 2, there is a stronger tendency for readers to underestimate in comparison to modal age with the exception of the Norwegian reader who continues to overestimate. Most variability is seen in the annotations of the broken otoliths which is the preferred method. It should be noted that the image quality of the sectioned otoliths is much higher. The AEM’s show that there is a difference of just one year when comparing the readers estimates to modal age. (ICES WGBIOP, 2018).

Data needs

There are no major data deficiencies identified for this stock, whose assessment is usually of high quality.

The consumption amount of Norway pout by its main predators should be evaluated in relation to production amount in the Norway pout stock under consideration of consumption and production of other prey species for those predators in the ecosystem. This also implies need for information on prey switching dynamics of North Sea fish predators which also are foraging on Norway pout. Biological interactions with respect to intra-specific and inter-specific relationships for Norway pout stock dynamics and important predator stock dynamics have been reviewed and further analysed in Nielsen (2016; Section 6) and there is referred to the general conclusions here.

Trends in by-catch levels in the samples from monitoring of the Danish and Norwegian commercial Norway pout fishery should also be analysed in future benchmark assessments.

It will be relevant to investigate retrospective patterns in the SESAM assessment among other in relation to the Mohn´s Rho values for recruitment, SSB and F, as well as to conduct further analyses of the uncertainty and residuals in the assessment.

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Table 12.2.1 NORWAY POUT IV & IIIa. Nominal landings (tonnes) from the North Sea and Skagerrak / Kattegat, ICES areas IV and IIIa in the period 2011-2021, as officially reported to ICES, EU and FAO. By-catches of Norway pout in other (small meshed) fishery included.

Norway pout ICES area IIIa

Country	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Denmark	2	118	6.945	538	2.220	918	110	159	1.125 *	5.585 *	1.942 *
Faroe Islands	-	-	-	-	-	-	-	-	-	-	-
Norway	-	-	147	9	41	82	72	6	6 *	16 *	1 *
Sweden	-	-	1	1	1	1	4	1	181 *	13 *	2 *
Germany	-	-	-	-	-	-	2	-	-	-	-
Total	2	118	7.093	548	2.262	1.001	188	166	1.312	5.614	1.945

*Preliminary.

Norway pout ICES area IVa

Country	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Denmark	4.038	25.431	31.375	27.894	10.760	21.125	12.312	10.367	35.647 *	59.402 *	39.871 *
Faroe Islands	-	-	-	-	5.270	3.156	-	-	3034 *	- *	- *
Netherlands	-	-	-	-	17	8	1	2	- *	88 *	23 *
Germany	-	-	-	-	22	27	1	-	- *	4 *	486 *
Norway	3.189	4.528	45.839	18.647	43.742	35.959	21.275	25.498	59.546 *	63.726 *	29.863 *
Sweden	1	3	4	1	12	-	-	4	32 *	35 *	2 *
UK(Scotland)	-	-	-	8	3	12	-	-	- *	82 *	10 *
Latvia	-	-	-	-	-	-	-	-	-	23 *	- *
Total	7.228	29.962	77.218	46.550	59.826	60.287	33.589	35.871	98.259	123.337	70.255

*Preliminary.

Norway pout ICES area IVb

Country	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Denmark	32	9	43	16	53	1463	45	20	573 *	620 *	189 *
Faroe Islands	-	-	-	-	-	-	-	-	-	-	-
Germany	-	-	-	-	-	-	13	3	- *	- *	- *
Netherlands	-	-	-	-	1	-	-	-	1 *	- *	- *
Norway	21	59	615	8	577	11	10	-	109 *	35 *	88 *
Sweden	-	-	0	0	714	1	2	-	25 *	- *	2 *
UK (E/W/NI)	-	-	-	-	-	-	-	-	-	3 *	- *
UK (Scotland)	-	-	-	6	-	18	-	-	- *	- *	- *
Total	53	68	658	30	1.345	1.493	70	23	708	658	279

*Preliminary.

Norway pout ICES area IVc

Country	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Denmark	-	-	-	-	-	1	-	-	-	-	-
France	-	-	-	-	-	-	-	-	-	-	-
Netherlands	-	-	-	-	-	-	-	-	-	-	-
UK (E/W/NI)	-	-	-	-	-	-	-	-	-	-	-
Total	0	0	0	0	0	1	0	0	0	0	0

*Preliminary.

Norway pout Sub-area IV and IIIa (Skagerrak) combined

Country	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Denmark	4.072	25.558	38.363	28.448	13.033	23.507	12.467	10.546	37.345	65.607	42.002
Faroe Islands	0	0	0	0	5.270	3.156	0	0	3.034	0	0
Norway	3.210	4.587	46.601	18.664	44.360	36.052	21.357	25.504	59.661	63.777	29.952
Sweden	1	3	5	2	727	2	6	5	238	48	6
Netherlands	0	0	0	0	18	8	1	2	1	88	23
Germany	0	0	0	0	22	27	16	3	0	4	486
UK	0	0	0	14	3	30	0	0	0	85	10
Total nominal landings	7.283	30.148	84.969	47.128	63.433	62.782	33.847	36.060	100.279	129.609	72.479
By-catch of other species and other	-759	-3.075	-2.869	-2.958	-33	618	86	87	-2.625	-112	-525
ICES estimate of total landings (IV+IIIaN)	6.524	27.073	82.100	44.170	63.400	63.400	33.933	36.147	97.654	129.497	71.954
Agreed TAC (EU)	4.500 x	70.683 x	165.700 x	128.250 x	150.000 x	150.000 x	141.950 x	85.265 x	55.000 x	72.500 x	116.555 x
TAC (Norway)	3.000	25.000	157.000	108.000	178.000	210.000	204.235	90.978	82.230	98.053	127.019
TAC (UK)											11.745

* provisional / preliminary
** provisional / preliminary
*** 781 ton from trial fishery (directed fishery); 160 ton from by-catches in other fisheries
**** A by-catch qouta of 5000 t has been set.
***** 681 t taken in trial fishery; 1300 t in by-catches in other (small meshed) fisheries.
+ Landings less than 1
n/a not available
x EU Agreed TAC

Table 12.2.2 NORWAY POUT IV & IIIa. Annual landings ('000 t) in the North Sea and Skagerrak (not incl. Kattegat, IIIaS) by country, for 1961-2021 (Data provided by ICES WGNSSK Working Group members). (Norwegian landing data include landings of by-catch of other species). Includes by-catch of Norway pout in other (small meshed) fisheries).

Year	Denmark		Faroes	Norway	Sweden	UK (Scotland)	Others	Total
	North Sea	Skagerrak						
1961	20,5	-	-	8,1	-	-	-	28,6
1962	121,8	-	-	27,9	-	-	-	149,7
1963	67,4	-	-	70,4	-	-	-	137,8
1964	10,4	-	-	51	-	-	-	61,4
1965	8,2	-	-	35	-	-	-	43,2
1966	35,2	-	-	17,8	-	-	+	53,0
1967	169,6	-	-	12,9	-	-	+	182,5
1968	410,8	-	-	40,9	-	-	+	451,7
1969	52,5	-	19,6	41,4	-	-	+	113,5
1970	142,1	-	32	63,5	-	0,2	0,2	238,0
1971	178,5	-	47,2	79,3	-	0,1	0,2	305,3
1972	259,6	-	56,8	120,5	6,8	0,9	0,2	444,8
1973	215,2	-	51,2	63	2,9	13	0,6	345,9
1974	464,5	-	85,0	154,2	2,1	26,7	3,3	735,8
1975	251,2	-	63,6	218,9	2,3	22,7	1	559,7
1976	244,9	-	64,6	108,9	+	17,3	1,7	437,4
1977	232,2	-	48,8	98,3	2,9	4,6	1	387,8
1978	163,4	-	18,5	80,8	0,7	5,5	-	268,9
1979	219,9	9	21,9	75,4	-	3	-	329,2
1980	366,2	11,6	34,1	70,2	-	0,6	-	482,7
1981	167,5	2,8	16,4	51,6	-	+	-	238,3
1982	256,3	35,6	12,3	88	-	-	-	392,2
1983	301,1	28,5	30,7	97,3	-	+	-	457,6
1984	251,9	38,1	19,11	83,8	-	0,1	-	393,01
1985	163,7	8,6	9,9	22,8	-	0,1	-	205,1
1986	146,3	4	2,5	21,5	-	-	-	174,3
1987	108,3	2,1	4,8	34,1	-	-	-	149,3
1988	79	7,9	1,3	21,1	-	-	-	109,3
1989	95,7	4,2	0,8	65,3	+	0,1	0,3	166,4
1990	61,5	23,8	0,9	77,1	+	-	-	163,3
1991	85	32	1,3	68,3	+	-	+	186,6
1992	146,9	41,7	2,6	105,5	+	-	0,1	296,8
1993	97,3	6,7	2,4	76,7	-	-	+	183,1
1994	97,9	6,3	3,6	74,2	-	-	+	182
1995	138,1	46,4	8,9	43,1	0,1	+	0,2	236,8
1996	74,3	33,8	7,6	47,8	0,2	0,1	+	163,8
1997	94,2	29,3	7,0	39,1	+	+	0,1	169,7
1998	39,8	13,2	4,7	22,1	-	-	+	79,8
1999	41	6,8	2,5	44,2	+	-	-	94,5
2000	127	9,3	-	48	0,1	-	+	184,4
2001	40,6	7,5	-	16,8	0,7	+	+	65,6
2002	50,2	2,8	3,4	23,6	-	-	-	80,0
2003	9,9	3,4	2,4	11,4	-	-	-	27,1
2004	8,1	0,3	-	5	-	-	0,1	13,5
2005	0.9*	-	-	1	-	-	-	1,9
2006	35,1	0,1	-	11,4	-	-	-	46,6
2007	2.0**	-	-	3,7	-	-	-	5,7
2008	30,4	-	-	5,7	+	-	+	36,1
2009	17,5	-	-	37,0	+	-	+	54,5
2010	64,9	0,2	-	60,9	+	+	+	126,0
2011	3,3	-	-	3,2	+	+	+	6,5
2012	22,3	0,1	-	4,6	+	+	+	27,0
2013	29,0	6,2	-	46,9	+	+	+	82,1
2014	25,0	0,5	-	18,7	+	+	+	44,2
2015	10,8	2,2	5,3	44,4	0,7	+	+	63,4
2016	23,2	0,9	3,2	36,1	+	+	+	63,4
2017	12,4	0,1	+	21,4	+	+	+	33,9
2018	10,5	0,2	+	25,5	+	+	+	36,2
2019	36,8	1,1	+	59,8	+	+	+	97,7
2020	60,1	5,6	+	63,8	+	+	+	129,5
2021	40,1	1,9	+	30,0	+	+	+	72,0

* 781 t taken in a trial fishery; 160 t in by-catches in other (small meshed) fisheries.
** 681 t taken in trial fishery; 1300 t in by-catches in other (small meshed) fisheries.

Table 12.2.3 NORWAY POUT IV & IIIa. National landings (tonnes) by quarter of year 2005-2022 and by area and country. (Data provided by Working Group members. Norwegian landing data include landings of by-catch of other species). (By-catch of Norway pout in other (small meshed) fisheries included).

Year	Quarter	Denmark									Norway		Total
	Area	IIIaN	IIIaS	Div. IIIa	IVaE	IVaW	IVb	IVc	Div. IV	Div. IV + IIIaN	IVaE	Div. IV	Div. IV + IIIaN
2005	1	-	-	-	9	0	-	-	9	9	12	12	21
	2	-	-	-	151	-	0	-	151	151	352	352	503
	3	-	-	-	781	0	0	-	781	781	387	387	1.168
	4	0	-	-	0	0	0	-	-	-	211	211	211
	Total	-	-	-	941	-	-	-	941	941	962	962	1.903
2006	1	-	-	-	75	83	-	-	158	158	2.205	2205	2.363
	2	-	-	-	-	-	15	-	15	15	2.846	2846	2.861
	3	114	-	114	-	649	20	-	669	783	5.749	5749	6.532
	4	3	-	3	-	34.262	-	-	34.262	34.265	605	605	34.870
	Total	117	-	117	75	34.994	35	-	35.104	35.221		11.405	46.626
2007	1	-	-	-	561	789	-	-	1.350	1.350	74	74	1.424
	2	-	-	-	4	-	-	-	4	4	1.097	1097	1.101
	3	1	2	3	-	-	-	-	-	1	2.429	2429	2.430
	4	-	-	-	-	682	-	-	682	682	155	155	837
	Total	1	2	3	565	1.471	-	-	2.036	2.037		3.755	5.792
2008	1	125	-	125	19	86	123	-	228	353	7	7	360
	2	-	-	-	-	-	30	-	30	30	1.803	1803	1.833
	3	-	-	-	-	6.102	-	-	6.102	6.102	3.582	3582	9.684
	4	-	-	-	-	22.686	1.239	-	23.925	23.925	336	336	24.261
	Total	125	-	125	19	28.874	1.392	-	30.285	30.410		5.728	36.138
2009	1	1	-	1	22	515	-	-	537	538	2	2	540
	2	-	-	-	-	-	-	-	-	-	4.026	4026	4.026
	3	2	-	2	-	11.567	-	-	11.567	11.569	31.251	31251	42.820
	4	-	-	-	-	5.399	4	-	5.403	5.403	1.736	1736	7.139
	Total	3	-	3	22	17.481	4	-	17.507	17.510	37.015	37.015	54.525
2010	1	-	-	-	-	194	-	-	194	194	104	104	298
	2	157	-	157	-	478	59	-	537	694	17.906	17906	18.600
	3	37	-	37	-	33.618	213	-	33.831	33.868	41.883	41883	75.751
	4	8	-	8	-	30.276	38	-	30.314	30.322	984	984	31.306
	Total	202	-	202	-	64.566	310	-	64.876	65.078	60.877	60.877	125.955
2011	1	-	-	-	-	-	-	-	-	-	-	0	-
	2	-	-	-	-	-	-	-	-	-	188	188	188
	3	-	-	-	-	456	5	-	461	461	3.004	3004	3.465
	4	-	-	-	-	2.853	-	-	2.853	2.853	18	18	2.871
	Total	-	-	-	-	3.309	5	-	3.314	3.314	3.210	3.210	6.524
2012	1	-	-	-	-	15	-	-	15	15	12	12	27
	2	-	-	-	-	-	-	-	-	-	280	280	280
	3	2	-	2	-	62	8	-	70	72	395	395	467
	4	125	-	125	-	22.204	-	-	22.204	22.329	3.900	3.900	26.229
	Total	127	-	127	-	22.281	8	-	22.289	22.416	4.587	4.587	27.003
2013	1	-	-	-	-	59	-	-	59	59	18	18	77
	2	6	-	6	-	409	-	-	409	415	10.045	10.045	10.460
	3	4.791	-	4.791	5	3.260	43	-	3.308	8.099	16.350	16.350	24.449
	4	1.366	-	1.366	-	25.211	-	-	25.211	26.577	20.537	20.537	47.114
	Total	6.163	-	6.163	5	28.939	43	-	28.987	35.150	46.950	46.950	82.100
2014	1	-	-	-	-	1.318	-	-	1.318	1.318	6	6	1.324
	2	62	-	62	-	-	2	-	2	64	3.146	3.146	3.210
	3	492	-	492	-	5.606	20	-	5.626	6.118	7.252	7.252	13.370
	4	-	-	-	-	18.006	-	-	18.006	18.006	8.260	8.260	26.266
	Total	554	-	554	-	24.930	22	-	24.952	25.506	18.664	18.664	44.170
2015	1	-	-	-	21	305	-	-	326	326	268	268	594
	2	2	-	2	-	549	-	-	549	551	6.812	6.812	7.363
	3	2.217	1	2.218	10	3.221	19	-	3.250	5.467	21.335	21.335	26.802
	4	-	-	-	-	6.689	-	-	6.689	6.689	15.945	15.945	22.634
	Total	2.219	1	2.220	31	10.764	19	-	10.814	13.033	44.360	44.360	57.393
2016	1	-	-	-	-	514	-	-	514	514	575	575	1.089
	2	244	1	245	-	267	-	-	267	511	8.296	8.296	8.807
	3	673	1	674	5	2.222	51	-	2.278	2.951	20.897	20.897	23.848
	4	-	-	-	3	20.135	-	-	20.138	20.138	6.286	6.286	26.424
	Total	917	2	919	8	23.138	51	-	23.197	24.114	36.054	36.054	60.168
2017	1	-	-	-	-	703	-	-	703	703	30	30	733
	2	5	-	5	-	-	-	-	-	5	3.470	3.470	3.475
	3	104	-	104	6	1.969	-	-	1.975	2.079	11.546	11.546	13.625
	4	-	-	-	68	9.597	2	-	9.667	9.667	6.433	6.433	16.100
	Total	109	-	109	74	12.269	3	-	12.345	12.454	21.479	21.479	33.933
2018	1	-	-	-	-	371	-	-	371	371	9	9	380
	2	2	-	2	-	3	-	-	3	5	4.138	4.138	4.143
	3	157	-	157	-	190	1	-	191	348	8.969	8.969	9.317
	4	-	-	-	-	9.921	-	-	9.921	9.921	12.386	12.386	22.307
	Total	159	-	159	-	10.485	1	-	10.486	10.645	25.502	25.502	36.147
2019	1	-	-	-	-	483	-	-	483	483	13	13	496
	2	178	-	178	-	2.166	-	-	2.166	2.344	8.832	8.832	11.176
	3	947	-	947	-	5.347	1	-	5.348	6.295	32.326	32.326	38.621
	4	-	-	-	-	28.208	567	-	28.775	28.775	18.586	18.586	47.361
	Total	1.125	-	1.125	-	36.204	568	-	36.772	37.897	59.757	59.757	97.654
2020	1	-	-	-	111	3.432	-	-	3.543	3.543	282	282	3.825
	2	2.343	-	2.343	-	1.288	-	-	1.288	3.631	7.333	7.333	10.964
	3	3.018	-	3.018	-	3.574	2	-	3.576	6.594	40.868	40.868	47.462
	4	225	-	225	129	51.570	33	-	51.732	51.957	15.289	15.289	67.246
	Total	5.586	-	5.586	240	59.864	35	-	60.139	65.725	63.772	63.772	129.497
2021	1	-	-	-	-	6.650	-	-	6.650	6.650	64	64	6.714
	2	1.036	-	1.036	-	606	-	-	606	1.642	12.787	12.787	14.429
	3	864	-	864	-	3.376	1	-	3.377	4.241	15.825	15.825	20.066
	4	42	-	42	44	29.382	1	-	29.427	29.469	1.276	1.276	30.745
	Total	1.942	-	1.942	44	40.014	2	-	40.060	42.002	29.952	29.952	71.954
2022	1	-	-	-	-	747	-	-	747	747	-	0	747
	2	218	-	218	-	-	-	-	-	218	3.432	3.432	3.650
	3	512	-	512	-	8	2	-	10	522	8.019	8.019	8.541

Table 12.2.3a NORWAY POUT in IV and IIIaN (Skagerrak). Observed and SESAM model predicted total catches in tonnes by quarter.

	year	observed	predicted
1	1984	56790	65971
2	1984.25	56532	33047
3	1984.5	152291	112121
4	1984.75	110942	95045
5	1985	57467	45789
6	1985.25	15509	15977
7	1985.5	62489	64063
8	1985.75	92017	61332
9	1986	37773	25643
10	1986.25	7657	9404
11	1986.5	45085	37557
12	1986.75	89993	41072
13	1987	33883	28219
14	1987.25	15435	8768
15	1987.5	38729	36431
16	1987.75	60847	62858
17	1988	22181	22482
18	1988.25	3559	6457
19	1988.5	21793	18292
20	1988.75	61762	31643
21	1989	15379	13138
22	1989.25	13234	11117
23	1989.5	55066	37471
24	1989.75	82880	46659
25	1990	27984	25131
26	1990.25	39713	20366
27	1990.5	26156	30597
28	1990.75	45242	46829
29	1991	42722	30238
30	1991.25	20786	20691
31	1991.5	62518	57482
32	1991.75	64380	61025
33	1992	64218	50647
34	1992.25	27973	27883
35	1992.5	114122	88040
36	1992.75	96177	84451
37	1993	36214	47716
38	1993.25	29291	26836
39	1993.5	62290	58553

	year	observed	predicted
40	1993.75	53470	47092
41	1994	34575	25579
42	1994.25	15373	14556
43	1994.5	53799	43132
44	1994.75	79838	40748
45	1995	36942	27508
46	1995.25	28019	19741
47	1995.5	69763	68693
48	1995.75	97048	61174
49	1996	21888	26555
50	1996.25	13366	15422
51	1996.5	74631	63671
52	1996.75	46194	40697
53	1997	15320	16645
54	1997.25	8708	10528
55	1997.5	78809	61786
56	1997.75	54100	51034
57	1998	19502	18732
58	1998.25	11836	12082
59	1998.5	20866	30733
60	1998.75	22830	25202
61	1999	7827	7347
62	1999.25	12533	7386
63	1999.5	41445	24617
64	1999.75	30497	31757
65	2000	10207	11737
66	2000.25	11589	13300
67	2000.5	44173	43075
68	2000.75	119001	66064
69	2001	21400	15236
70	2001.25	11778	8991
71	2001.5	4630	16383
72	2001.75	26565	31945
73	2002	8553	6370
74	2002.25	6686	4217
75	2002.5	32922	17009
76	2002.75	28947	21798
77	2003	3190	3349
78	2003.25	3106	1946
79	2003.5	10833	10914

	year	observed	predicted
80	2003.75	7518	7714
81	2004	2040	1777
82	2004.25	667	705
83	2004.5	4018	5437
84	2004.75	6762	7511
85	2005	8	5
86	2005.25	8	5
87	2005.5	13	10
88	2005.75	13	12
89	2006	2205	1847
90	2006.25	2848	2508
91	2006.5	6551	8450
92	2006.75	34949	25574
93	2007	1428	514
94	2007.25	1100	1159
95	2007.5	2430	4197
96	2007.75	838	2201
97	2008	361	290
98	2008.25	1840	1567
99	2008.5	8532	5622
100	2008.75	24111	4457
101	2009	538	214
102	2009.25	2105	2982
103	2009.5	36661	17428
104	2009.75	6509	8920
105	2010	198	314
106	2010.25	40322	6390
107	2010.5	57487	25228
108	2010.75	33071	17175
109	2011	0	0
110	2011.25	222	1525
111	2011.5	3749	6378
112	2011.75	2872	6658
113	2012	29	52
114	2012.25	281	666
115	2012.5	469	1886
116	2012.75	26168	12388
117	2013	79	125
118	2013.25	10460	2803
119	2013.5	24444	12961

	year	observed	predicted
120	2013.75	47126	39932
121	2014	1324	390
122	2014.25	3212	3880
123	2014.5	13384	14348
124	2014.75	26244	20166
125	2015	594	459
126	2015.25	7364	6347
127	2015.5	26804	26802
128	2015.75	22655	30941
129	2016	1089	668
130	2016.25	8846	6458
131	2016.5	23849	24496
132	2016.75	26457	23888
133	2017	735	481
134	2017.25	3475	5192
135	2017.5	13623	19204
136	2017.75	16107	24129
137	2018	379	255
138	2018.25	4143	4729
139	2018.5	9316	13057
140	2018.75	22292	15185
141	2019	495	386
142	2019.25	11179	7245
143	2019.5	38621	24009
144	2019.75	47373	33691
145	2020	3808	1268
146	2020.25	10958	13261
147	2020.5	47467	36481
148	2020.75	67100	57982
149	2021	6724	2159
150	2021.25	14428	11808
151	2021.5	20060	20650
152	2021.75	30767	40208
153	2022	743	452
154	2022.25	3650	5169
155	2022.5	8541	8173

Table 12.2.4 NORWAY POUT in IV and IIIaN (Skagerrak). Catch in numbers at age by quarter (millions). SOP is given in tonnes. Data for 1990 were estimated within the SXSA program used in the 1996 assessment.

Age	Year	1984				1985				1986			
	Quarter	1	2	3	4	1	2	3	4	1	2	3	4
0		0	0	1	2231	0	0	6	678	0	0	0	5572
1		2.759	2252	5290	3492	2.264	857	1400	2991	396	260	1186	1791
2		1.375	1165	1683	734	1.364	145	793	174	1069	87	245	39
3		143	269	8	0	192	13	19	0	72	3	6	0
4+		0	0	0	0	1	0	0	0	3	0	0	0
SOP		56790	56532	152291	110942	57464	15509	62489	92017	37889	7657	45085	89993
Age	Year	1987				1988				1989			
	Quarter	1	2	3	4	1	2	3	4	1	2	3	4
0		0	0	8	227	0	0	741	3146	0	0	159	4854
1		2687	1075	1627	2151	249	95	183	632	1736	678	1672	1741
2		401	60	171	233	700	74	250	405	48	133	266	93
3		12	0	0	5	20	0	0	0	6	6	5	13
4+		1	0	0	0	0	0	0	0	0	0	0	0
SOP		33894	15435	38729	60847	22181	3559	21793	61762	15379	13234	55066	82880
Age	Year	1990				1991				1992			
	Quarter	1	2	3	4	1	2	3	4	1	2	3	4
0		0	0	20	993	0	0	734	3486	0	0	879	954
1		1840	1780	971	1181	1501	636	1519	1048	3556	1522	3457	2784
2		584	572	185	116	1336	404	215	187	1086	293	389	267
3		20	19	6	4	93	19	22	18	118	20	1	2
4+		10	0	0	0	6	0	0	0	3	0	0	0
SOP		28287	39713	26156	45242	42776	20786	62518	64380	64224	27973	114122	96177
Age	Year	1993				1994				1995			
	Quarter	1	2	3	4	1	2	3	4	1	2	3	4
0		0	0	96	1175	0	0	647	4238	0	0	700	1692
1		1942	813	1147	1050	1975	372	1029	1148	3992	1905	2545	3348
2		699	473	912	445	591	285	421	134	240	256	47	59
3		15	58	19	2	56	29	71	0	6	32	3	3
4+		0	0	0	0	0	0	0	0	0	0	0	0
SOP		36206	29291	62290	53470	34575	15373	53799	79838	36942	28019	69763	97048
Age	Year	1996				1997				1998			
	Quarter	1	2	3	4	1	2	3	4	1	2	3	4
0		0	0	724	2517	0	0	109	343	0	0	94	339
1		535	560	1043	650	672	99	3090	1922	261	210	411	531
2		772	201	1002	333	325	131	372	207	690	310	332	215
3		14	38	37	0	79	119	105	35	47	18	2	13
4+		0	0	0	0	0	0	0	0	8	24	0	0
SOP		21888	13366	74631	46194	15320	8708	78809	54100	19562	12026	20866	22830
Age	Year	1999				2000				2001			
	Quarter	1	2	3	4	1	2	3	4	1	2	3	4
0		0	0	41	1127	0	0	73	302	0	0	32	368
1		202	318	1298	576	653	280	1368	4616	220	133	122	267
2		128	220	338	160	185	207	266	245	845	246	27	439
3		73	93	35	23	3	48	20	6	35	100	1	1
4+		1	0	0	0	0	0	0	0	0	0	0	0
SOP		7833	12535	41445	30497	10207	11589	44173	119001	21400	11778	4630	26565
Age	Year	2002				2003				2004			
	Quarter	1	2	3	4	1	2	3	4	1	2	3	4
0		0	0	340	290	0	0	7	1	0	0	14	57
1		485	351	621	473	59	64	191	54	13	4	51	100
2		148	24	284	347	76	49	121	161	55	16	51	78
3		17	5	24	26	22	25	16	32	9	6	7	2
4+		0	0	0	0	0	0	0	1	0	0	0	0
SOP		8553	6686	32922	28947	3190	3106	10842	7549	2040	667	4018	6762
Age	Year	2005				2006				2007			
	Quarter	1	2	3	4	1	2	3	4	1	2	3	4
0		*	*	*	*			10	368	0	0	0	0
1		*	*	*	*	30	56	130	1086	20	41	32	10
2		*	*	*	*	52	45	65	50	43	26	16	6
3		*	*	*	*	9	24	7	1	0	0	2	1
4+		*	*	*	*	0	0	0	0	0	0	0	0
SOP		8	8	13	13	2205	2848	6551	34949	1428	1100	2430	838
Age	Year	2008				2009				2010			
	Quarter	1	2	3	4	1	2	3	4	1	2	3	4
0		0	0	0	1179	0	0	58	12	0	0	0	0
1		5	54	166	438	50	36	621	169	6	799	1118	716
2		10	41	115	31	1	47	613	27	1	905	738	331
3		0	0	0	0	0	5	9	1	0	17	15	0
4+		0	0	0	0	0	0	0	0	0	0	0	0
SOP		361	1840	8532	24111	538	2105	36661	6509	198	40322	57487	33071
Age	Year	2011				2012				2013			
	Quarter	1	2	3	4	1	2	3	4	1	2	3	4
0		0	0	0	1	0	0	1	135	0	0	8	76
1		0	1	44	23	1	5	8	404	5	631	805	1287
2		0	5	69	61	0	2	4	185	0	39	131	199
3		0	0	4	0	0	2	1	10	0	4	18	27
4+		0	0	0	0	0	0	0	0	0	0	0	0
SOP		0	222	3749	2872	29	281	469	26168	79	10460	24444	47126
Age	Year	2014				2015				2016			
	Quarter	1	2	3	4	1	2	3	4	1	2	3	4
0		0	0	141	884	0	0	14	33	0	0	13	480
1		10	33	197	522	46	365	1064	934	19	260	492	406
2		51	60	167	115	6	23	164	33	40	160	291	339
3		1	2	3	0	1	2	2	5	2	10	7	0
4+		0	0	0	0	0	0	0	0	0	0	0	0
SOP		1324	3212	13384	26244	594	7364	26804	22655	1089	8846	23849	26457
Age	Year	2017				2018				2019			
	Quarter	1	2	3	4	1	2	3	4	1	2	3	4
0		0	0	7	11	0	0	24	638	0	0	97	1007
1		39	159	319	515	1	114	111	261	47	519	1629	1767
2		1	25	127	87	21	84	140	385	10	284	97	64
3		0	4	40	7	1	8	17	0	4	29	4	0
4+		0	0	0	0	0	0	0	0	0	0	0	0
SOP		735	3474	13623	16107	379	4143	9316	22291	495	11179	38627	47372
Age	Year	2020				2021				2022			
	Quarter	1	2	3	4	1	2	3	4	1	2	3	
0		0	0	29	127			3	105			0	
1		288	353	1774	2439	31	330	526	699	1	129	310	
2		270	266	247	183	311	311	260	359	33	27	39	
3		2	20	9	3	11	19	8	8	2	8	29	
4+		0	0	0	0	0	0	0	0	0	0	0	
SOP		3807	10959	47471	67211	6724	14426	20063	30764	743	3650	8542	

In 2007-08: Catch numbers from Norwegian fishery calculated from Norwegian total catch weight divided by mean weight at age from Danish Fishery.

Table 12.2.5 NORWAY POUT in IV and IIIaN (Skagerrak). Mean weights (grams) at age in catch, by quarter 1984-2022, from Danish and Norwegian catches combined. See footnote concerning data from 2005-2008 and 2010-2013. The mean weights at age weighted with catch number by area, quarter and country (DK, N).

Year	1984				1985				1986			
Quarter of year	1	2	3	4	1	2	3	4	1	2	3	4
Age 0			6,54	6,54			8,37	6,23				7,20
1	6,55	8,97	17,83	20,22	7,86	12,56	23,10	26,97	6,69	14,49	28,81	26,90
2	24,04	22,66	34,28	35,07	22,7	28,81	36,52	40,90	29,74	42,92	43,39	44,00
3	39,54	37,00	34,10	46,23	45,26	43,38	58,99		44,08	55,39	47,60	
4					41,80				82,51			
Year	1987				1988				1989			
Quarter of year	1	2	3	4	1	2	3	4	1	2	3	4
Age 0			5,80	7,40			9,42	7,91			7,48	6,69
1	8,13	12,59	20,16	23,36	9,23	11,61	26,54	30,60	7,98	13,49	26,58	26,76
2	28,26	31,51	34,53	37,32	27,31	33,26	39,82	43,31	26,74	28,70	35,44	34,70
3	52,93			46,60	38,38				39,95	44,39		46,50
4	63,09				69,48							
Year	1990				1991				1992			
Quarter of year	1	2	3	4	1	2	3	4	1	2	3	4
Age 0			6,40	6,67			6,06	6,64		8,00	6,70	8,14
1	6,51	13,75	20,29	28,70	7,85	12,95	30,95	30,65	8,78	11,71	26,52	27,49
2	25,47	25,30	32,92	38,90	20,54	28,75	44,28	43,10	25,73	31,25	42,42	44,14
3	37,72	40,35	39,40	52,94	35,43	49,87	67,25	59,37	41,80	49,49	50,00	50,30
4	68,00				44,30				43,90			
Year	1993				1994				1995			
Quarter of year	1	2	3	4	1	2	3	4	1	2	3	4
Age 0			4,40	8,14			5,40	8,81			5,01	7,19
1	9,32	14,76	25,03	26,24	8,56	15,22	29,26	31,23	7,70	10,99	25,37	24,6
2	24,94	30,58	35,19	36,44	25,91	29,27	38,91	49,59	24,69	22,95	33,40	39,57
3	46,50	48,73	55,40	70,80	42,09	46,88	53,95		50,78	37,69	45,56	57,00
4												
Year	1996				1997				1998			
Quarter of year	1	2	3	4	1	2	3	4	1	2	3	4
Age 0			3,88	5,95			3,61	10,18			4,82	8,32
1	8,95	12,06	27,81	28,09	7,01	11,69	20,14	22,11	8,76	12,55	23,82	24,33
2	21,47	25,72	40,90	38,81	23,11	26,40	31,13	32,69	22,16	25,27	31,73	30,93
3	37,58	37,94	50,44	56,00	39,11	34,47	44,03	38,62	34,84	32,18	44,92	33,24
4									42,40	40,00		
Year	1999				2000				2001			
Quarter of year	1	2	3	4	1	2	3	4	1	2	3	4
Age 0			2,84	7,56			7,21	13,86			6,34	7,90
1	8,98	12,40	22,16	25,60	10,05	15,65	23,76	22,98	8,34	16,79	27,00	30,01
2	25,84	24,15	32,66	37,74	19,21	25,14	38,90	34,48	21,50	23,57	39,54	35,51
3	36,66	35,24	43,98	51,63	32,10	41,30	39,61	50,04	39,84	37,63	54,20	55,70
4	46,57	46,57										
Year	2002				2003				2004			
Quarter of year	1	2	3	4	1	2	3	4	1	2	3	4
Age 0			7,28	7,20			9,12	9,79			9,80	7,89
1	8,59	16,40	27,13	27,47	11,58	13,13	28,33	15,98	11,54	14,63	31,02	31,75
2	25,98	30,39	43,37	36,87	22,85	26,19	38,01	31,87	27,41	26,22	38,44	39,31
3	32,30	40,10	54,11	41,28	34,96	39,89	46,24	45,79	41,52	34,80	49,50	49,80
4							70,00	70,00				
Year	2005				2006				2007			
Quarter of year	1	2	3	4	1	2	3	4	1	2	3	4
Age 0			9,8	7,89			8,90	8,90			8,9	8,9
1	11,97	14,65	31,02	31,75	14,80	14,70	27,42	26,92	7,8	7,8	45,00	45,00
2	27,90	26,24	38,44	39,31	27,20	26,24	39,16	47,80	29,86	29,86	57,07	57,07
3	41,36	34,80	49,50	49,80	40,60	34,80	49,80	48,50	41,52	34,80	56,22	56,22
4												
Year	2008				2009				2010			
Quarter of year	1	2	3	4	1	2	3	4	1	2	3	4
Age 0				9,9			6,6	8,5				
1	11,0	11,0	26,8	24,40	10,2	19,3	28,0	32,7	25,60	15,51	25,37	27,75
2	29,8	29,8	35,6	56,0	24,0	25,8	30,1	32,0	37,20	29,99	38,55	39,88
3	56,0	56,0				39,8	51,5	55,7		47,00	45,50	62,20
4												
Year	2011				2012				2013			
Quarter of year	1	2	3	4	1	2	3	4	1	2	3	4
Age 0				8,90			6,58	6,66			4,30	9,56
1		20,33	22,14	30,50	27,24	22,81	28,86	38,52	12,44	14,48	22,97	27,68
2		37,75	37,50	35,61	36,24	40,54	40,30	49,59	32,87	30,21	38,87	46,38
3		52,00	52,00	52,00	37,22	46,77	48,33	59,15	42,40	40,71	45,24	57,93
4												
Year	2014				2015				2016			
Quarter of year	1	2	3	4	1	2	3	4	1	2	3	4
Age 0			5,31	6,46			8,22	5,69			15,00	12,53
1	8,69	26,06	30,12	30,00	7,53	17,82	21,14	22,61	14,90	16,54	26,91	32,26
2	23,51	36,53	39,44	42,37	29,30	32,97	25,04	34,80	19,08	26,21	34,99	34,1
3	50,63	42,77	39,30		46,20	46,61	47,97	41,68	30,76	35,91	34,05	
4												
Year	2017				2018				2019			
Quarter of year	1	2	3	4	1	2	3	4	1	2	3	4
Age 0			4,70	6,25			4,82					
1	18,17	17,11	23,69	24,11	6,05	15,56	25,62		4,57	10,44	5,28	6,70
2	30,95	25,85	34,38	37,59	15,78	25,21	39,50		13,58	17,67	21,12	21,54
3	23,69	27,21	41,52	49,92	28,59	30,13	48,75		33,40	25,40	36,12	40,29
4											50,79	
Year	2020				2021				2022			
Quarter of year	1	2	3	4	1	2	3	4	1	2	3	
Age 0			5,18	5,85			3,55	6,16			3,30	
1	5,88	14,68	21,87	24,70	14,40	16,69	21,90	24,55	5,89	18,66	19,26	
2	7,64	19,64	33,05	33,33	19,15	26,72	31,70	35,35	20,80	32,84	35,64	
3	20,10	28,78	36,99		30,03	31,63	38,46	39,08	27,30	40,77	40,18	
4												

Mean weights at age from Danish and Norwegian landings from 2005-2008 uncertain because of few observations and use of values from 2004 and from adjacent quarters in the same year where observations have been missing. No mean weight at age data delivered by Norway in 2007-2008.
In general, mean weights at age are uncertain for quarters and countries where only very few fish have been caught. This problem is met by always calculating and using weighted mean weights at age, i.e. weighted by the catch number by country (Denmark and Norway) and quarter of year.

Table 12.2.6 NORWAY POUT IV & IIIaN (Skagerrak). Mean weight at age in the stock, proportion mature and natural mortality used in the assessment. (From 2012 InterBenchmark & 2016 Benchmark Assessments).

Age	Weight (g)				Proportion mature	M
	Q1	Q2	Q3	Q4		Quarterly
0	-	-	4	6	0	0,29
1	9	12	25	25	0,2	0,29
2	25	25	40	40	1	0,39
3	40	50	60	58	1	0,44

Table 12.2.7 NORWAY POUT IV & IIIaN (Skagerrak). Danish fishing effort (number of fishing days) and catch per unit of effort (CPUE in tonnes / fishing day) per year and quarter of year (1987-2022) for main Danish fishery (metiér) catching Norway pout. (Data for fishing trips where the catch has consisted of at least 70% Norway pout).

Year	Metier	Effort (no fishing days) per quarter					CPUE (ton per fishing day) per quarter				
		1	2	3	4	Yearly	1	2	3	4	Yearly
1987	OTB_DEF_16-31_0_0	84		1240	2057	3381	12		53	136	71
1988		38		164	1773	1975	27		101	132	107
1989		28		664	940	1632	99		98	54	73
1990		49		134	914	1097	33		30	84	51
1991		18		395	972	1385	5		140	103	99
1992		136		1123	1645	2904	17		130	152	112
1993		153	6	1864	1718	3741	33	2	62	107	64
1994		35		543	1645	2223	2		91	131	89
1995		26		529	1591	2146	6		139	176	127
1996		6		520	521	1047	1		73	107	73
1997				733	1363	2096			137	99	115
1998		10		116	286	412	17		30	30	28
1999				192	869	1061			40	68	56
2000				140	2377	2517			107	168	142
2001		121			527	648	142			122	132
2002				488	790	1278			78	94	89
2003				72	252	324			19	52	36
2004		44		52	196	292	23		26	111	76
2006				39	1056	1095			57	137	117
2008		6		309	292	607	5		139	162	121
2009		20		176	35	231	46		165	181	148
2010			14	749	361	1124		74	169	295	210
2011				24	73	97			54	123	88
2012	OTB_DEF_16-31_2_35				549	549				123	123
2013			21	157	805	983		41	30	99	62
2014		33		263	681	977	28		66	47	50
2015		6	27	86	130	249	19	3	58	57	38
2016		6	10	27	263	306	43	5	44	46	34
2017		20		40	165	225	43		38	67	51
2018		11	1	6	136	154	34		28	45	45
2019		20	18	46	325	409	17	24	52	60	58
2020		72	35	25	346	477	50	30	41	69	73
2021		33	3	11	101	147	34	5	25	66	54
2022*											

* Only pelagic trawlers that have fished in 2022 up to 15th September 2022.

Table 12.2.8 NORWAY POUT IV & IIIaN (Skagerrak). Fishing effort (number of fishing days) and catch per unit of effort (CPUE in ton / fishing day) per year (2011-2022) and quarter of year for main Norwegian fishery (metiérs) catching Norway pout.

		Fishing days					CPUE (ton/fishing day)				
Year	Metier	Q1	Q2	Q3	Q4	Yearly	Q1	Q2	Q3	Q4	Yearly
2011	OTB_DEF_16-31_0_0		1	23		24		10,0	24,1		23,5
2011	OTB_DEF_16-31_2_40		5	75		80		20,2	29,2		28,6
2012	OTB_DEF_16-31_0_0			3	24	27			15,7	35,4	33,2
2012	OTB_DEF_16-31_2_40				74	74				38,9	38,9
2013	OTB_DEF_16-31_0_0		101	163	99	363		31,3	29,9	47,2	35,0
2013	OTB_DEF_16-31_2_40		224	341	227	792		30,7	31,1	60,8	39,5
2014	OTB_DEF_16-31_0_0		62	64	57	183		18,2	35,1	33,9	29,0
2014	OTB_DEF_16-31_2_40		41	123	143	307		26,0	34,7	38,2	35,2
2015	OTB_DEF_16-31_0_0		130	308	71	509		38,3	37,8	38,7	38,0
2015	OTB_DEF_16-31_2_40	5	38	235	192	470	28,7	41,0	42,5	55,6	47,6
2016	OTB_DEF_16-31_0_0		269	269	51	589		24,1	23,0	22,6	23,4
2016	OTB_DEF_16-31_2_40	23	37	357	80	497	24,9	23,5	38,6	45,8	38,0
2017	OTB_DEF_16-31_0_0		125	198	15	338		28,7	22,5	25,6	24,9
2017	OTB_DEF_16-31_2_40		1	105	87	193		8,8	37,8	51,2	43,7
2018	OTB_DEF_16-31_0_0		128	163	43	334		23,5	22,4	19,1	22,4
2018	OTB_DEF_16-31_2_40		17	112	233	362		27,8	35,3	45,0	41,2
2019	OTB_DEF_16-31_0_0		243	526	112	881		31,6	37,9	34,1	35,7
2019	OTB_DEF_16-31_2_40		44	272	220	536		36,1	40,5	54,0	45,7
2020	OTB_DEF_16-31_0_0	2	172	445	67	686	25,0	38,5	38,6	24,7	37,2
2020	OTB_DEF_16-31_2_40	6	24	474	131	635	24,3	40,5	37,9	79,3	46,4
2021	OTB_DEF_16-31_0_0		272	303	25	600		28,3	28,5	14,5	27,8
2021	OTB_DEF_16-31_2_40	4	171	182	8	365	16,3	30,3	25,1	12,5	27,2
2022	OTB_DEF_16-31_0_0		62	134		196		28,2	24,7		25,8
2022	OTB_DEF_16-31_2_40		15	26		41		26,7	21,6		23,5

Table 12.2.9 NORWAY POUT IV and IIIaN (Skagerak). Fishing effort (number of fishing days) and catch per unit of effort (CPUE in ton per fishing day) per year and vessel horse power (HP) class (1987-2022) for main Danish fishery (metiér) catching Norway pout.

Year	Metier	Effort (no fishing days) per Vessel HP Class					CPUE (ton per fishing day) per vessel hp class				
		500-1000	1000-1500	1500-2000	>=2000	Yearly	500-1000	1000-1500	1500-2000	>=2000	Yearly
1987	OTB_DEF_16-31_0_0	2625	706	32	18	3381	117	129	82	4	83
1988		913	1000	53	9	1975	128	178	279	72	164
1989		897	707	14	14	1632	111	126	5	6	62
1990		615	448	24	10	1097	105	100	27	1	58
1991		671	688	26		1385	148	172	73		131
1992		1965	845	73	21	2904	195	239	73	18	131
1993		1773	1862	93	13	3741	117	122	63	12	78
1994		1009	1114	66	34	2223	165	221	94	14	123
1995		1068	884	167	27	2146	294	259	159	58	192
1996		452	544	32	19	1047	109	122	125	15	93
1997		1229	778	47	42	2096	192	206	58	55	128
1998		163	232		17	412	61	46		10	39
1999		619	357	51	34	1061	106	89	36	80	78
2000		1449	802	138	128	2517	205	188	110	202	177
2001		322	266		60	648	185	301		71	186
2002		738	393	135	12	1278	131	144	77	30	96
2003		172	115	24	13	324	64	45	43	48	50
2004		165	109		18	292	71	116		111	100
2006		465	464	166		1095	132	183	93		136
2008		320	287			607	189	213			201
2009		111	120			231	199	324			262
2010		279	606	239		1124	349	299	206		285
2011			97			97		121			121
2012	OTB_DEF_16-31_2_35	122	314	89	24	549	123	155	119	94	123
2013		331	504	108	40	983	81	144	84	64	93
2014		425	474	78		977	55	53	53		54
2015		21	228			249	66	52			59
2016		81	139	77	9	306	45	39	37	55	44
2017		72	124	14	15	225	42	41	91	93	67
2018		35	86	12	21	154	38	40	30	81	45
2019		102	227	34	47	410	68	36	59	70	58
2020		156	182	34	106	477	44	43	89	109	73
2021		8	63	2	75	147	24	19	72	90	54
2022*											

* Only pelagic trawlers that have fished in 2022 up to 15th September 2022.

Table 12.2.10 NORWAY POUT IV & IIIaN (Skagerrak). Fishing effort (number of fishing days) and catch per unit of effort (CPUE in ton / fishing day) per year (2011-2022) and quarter of year for main Norwegian fishery (metiérs) catching Norway pout.

		Fishing days					CPUE (ton/fishing day)				
Year	Metier	500-1000	1000-1500	1500-2000	> 2000	Yearly	500-1000	1000-1500	1500-2000	> 2000	Yearly
2011	OTB_DEF_16-31_0_0		24			24		23,5			23,5
2011	OTB_DEF_16-31_2_40		20		60	80		18,3		32,1	28,6
2012	OTB_DEF_16-31_0_0		17	4	6	27		34,8	13,75	41,7	33,2
2012	OTB_DEF_16-31_2_40	19	28		27	74	21,2	26,9		63,8	38,9
2013	OTB_DEF_16-31_0_0		273	75	15	363		34,4	30,9	65,3	35,0
2013	OTB_DEF_16-31_2_40		162	130	500	792		23,2	34,10332	46,2	39,5
2014	OTB_DEF_16-31_0_0		142	16	25	183		25,5	16,6	56,4	29,0
2014	OTB_DEF_16-31_2_40	80	58	67	102	307	42,9	14,6	36,6	39,8	35,2
2015	OTB_DEF_16-31_0_0		228	106	175	509		33,7	42,7	40,8	38,0
2015	OTB_DEF_16-31_2_40			103	367	470			49,7	47,0	47,6
2016	OTB_DEF_16-31_0_0		207	136	246	589		25,5	21,0	23,0	23,4
2016	OTB_DEF_16-31_2_40		18	72	407	497		28,3	42,8	37,6	38,0
2017	OTB_DEF_16-31_0_0		123	107	108	338		24,7	21,4	28,6	24,9
2017	OTB_DEF_16-31_2_40		9	86	98	193		51,9	41,1	45,2	43,7
2018	OTB_DEF_16-31_0_0	40	121	107	66	334	20,9	20,2	22,1	27,8	22,4
2018	OTB_DEF_16-31_2_40	14	26	63	259	362	36,2	46,6	34,4	42,5	41,2
2019	OTB_DEF_16-31_0_0	144	232	171	334	881	27,3	29,5	32,4	45,3	35,7
2019	OTB_DEF_16-31_2_40	7	8	118	403	536	57,7	56,4	45,5	45,3	45,7
2020	OTB_DEF_16-31_0_0	146	133	118	289	686	28,1	33,9	31,8	45,5	37,2
2020	OTB_DEF_16-31_2_40	4	3	94	534	635	37,5	60,5	36,0	48,3	46,4
2021	OTB_DEF_16-31_0_0	128	122	141	209	600	25,9	26,2	23,6	32,7	27,8
2021	OTB_DEF_16-31_2_40			78	287	365			29,2	26,6	27,2
2022	OTB_DEF_16-31_0_0	69		37	90	196			16,8	30,6	25,8
2022	OTB_DEF_16-31_2_40			41		41			23,5		23,5

Table 12.2.11 NORWAY POUT IV & IIIaN (Skagerrak). Research vessel indices (CPUE in catch in number per trawl hour) of abundance for Norway pout.

Year	IBTS/IYFS[1] February (1st Q)			EGFS[2,3] August				SGFS[4] August				IBTS 3rd Quarter[1]			
	1-group	2-group	3-group	0-group	1-group	2-group	3-group	0-group	1-group	2-group	3-group	0-group	1-group	2-group	3-group
1971	1,556	22	-	-	-	-	-	-	-	-	-	-	-	-	-
1972	2,589	856	8	-	-	-	-	-	-	-	-	-	-	-	-
1973	4,207	438	-	-	-	-	-	-	-	-	-	-	-	-	-
1974	25,559	388	24	-	-	-	-	-	-	-	-	-	-	-	-
1975	5,067	1,850	36	-	-	-	-	-	-	-	-	-	-	-	-
1976	4,422	328	35	-	-	-	-	-	-	-	-	-	-	-	-
1977	6,122	238	44	-	-	-	-	-	-	-	-	-	-	-	-
1978	1,480	565	56	-	-	-	-	-	-	-	-	-	-	-	-
1979	2,737	316	76	-	-	-	-	-	-	-	-	-	-	-	-
1980	3,274	552	30	-	-	-	-	-	1,928	346	12	-	-	-	-
1981	1,092	377	14	-	-	-	-	-	185	127	9	-	-	-	-
1982	4,511	266	81	-	-	-	-	8	991	44	22	-	-	-	-
1983	2,252	592	13	-	-	-	-	13	490	91	1	-	-	-	-
1984	5,000	956	89	-	-	-	-	2	615	69	8	-	-	-	-
1985	2,342	1,401	98	-	-	-	-	5	636	173	5	-	-	-	-
1986	2,066	386	19	-	-	-	-	38	389	54	9	-	-	-	-
1987	3,171	475	63	-	-	-	-	7	338	23	1	-	-	-	-
1988	123	710	25	-	-	-	-	14	38	209	4	-	-	-	-
1989	2,017	254	170	-	-	-	-	2	382	21	14	-	-	-	-
1990	1,295	712	70	-	-	-	-	58	206	51	2	-	-	-	-
1991	2,428	693	157	-	-	-	-	10	732	42	6	7,523	515	486	6
1992	5,060	860	33	2,975	6,116	1,710	303	12	1,715	221	24	2,560	4,106	740	151
1993	2,574	2,643	346	3,706	3,582	1,706	108	2	580	329	20	4,080	1,506	921	92
1994	1,532	374	99	9,487	1,148	147	25	136	387	106	6	3,196	685	114	21
1995	5,951	757	85	5,478	8,374	282	62	37	2,438	234	21	2,864	4,106	860	134
1996	915	2,626	233	8,241	1,326	378	9	127	412	321	8	4,559	672	419	41
1997	9,633	1,557	674	441	6,295	372	102	1	2,154	130	32	490	3,308	345	76
1998	1,009	5,332	268	1,391	377	340	3	2,628	938	127	5	2,931	791	745	23
1999	3,522	601	668	10,985	1,175	40	29	3,603	1,784	179	37	7,854	2,316	230	106
2000	8,034	1,563	98	2,267	9,730	264	2	2,094	6,656	207	23	1,644	7,556	590	14
2001	1,306	2,805	288	2,243	1,434	1,344	31	759	727	710	26	2,089	1,164	938	57
2002	1,784	812	864	4,939	1,137	58	18	2,559	1,192	151	123	1,974	749	76	52
2003	1,241	573	94	323	572	75	5	1,767	779	126	1	1,812	1,015	193	8
2004	903	364	37	278	557	109	6	731	719	175	19	773	590	209	14
2005	698	123	38	3,395	414	67	15	3,073	343	132	18	2,679	395	104	18
2006	3,400	113	23	1,813	1,996	124	20	1,127	1,285	69	9	1,391	1,800	197	14
2007	1,287	769	31	1,610	1,181	720	43	5,003	1,023	395	8	4,151	1,186	430	40
2008	2,438	461	154	628	1,340	411	104	3,456	1,263	263	57	3,035	1,610	267	98
2009	5,553	1,582	123	4,871	3,500	306	5	5,835	1,750	202	16	5,899	2,454	358	14
2010	4,954	1,439	143	103	4,257	559	13	1,449	5,101	930	29	842	4,780	812	37
2011	545	2,126	347	290	555	1,050	40	1,895	226	935	38	1,801	474	1,114	64
2012	1,002	327	527	3,946	505	99	59	10,067	1,070	159	216	6,416	829	217	139
2013	4,469	508	102	498	2,592	117	19	1,754	2,888	107	22	1,317	2,759	186	18
2014	818	936	48	10,157	483	268	17	24,896	537	149	0	10,238	480	253	13
2015	6,638	570	130	1,415	4,320	60	15	10,208	6,568	118	0	3,511	3,911	191	47
2016	2,404	909	41	7,199	1,710	314	4	14,830	1,696	290	0	8,965	1,386	279	14
2017	4,332	421	173	1,280	5,061	134	38	7,478	1,906	77	2	4,235	2,502	158	25
2018	1,139	850	147	5,096	586	144	12	20,632	674	246	3	6,115	578	201	7
2019	3,892	303	55	4,286	1,308	68	8	17,856	3,888	86	3	6,464	2,204	134	19
2020	6,078	1,121	83	3,126	5,343	227	8	36,298	3,417	530	0	8,463	3,858	612	10
2021	3,823	1,535	165	428	2,868	544	12	13,785	2,870	402	3	4,163	1,504	296	48
2022	1,588	817	156	6,770	952	252	40	12,218	2,580	816	74				

[1]International Bottom Trawl Survey (IBTS), arithmetic mean catch in no./h in standard area. In general, the quarter 1 (Q1) and quarter 3 (Q3) IBTS indices have been revised in 2012 and 2014 and 2015 and 2020 (see documentation on ICES DATRAS). The revised Q1 and Q3 IBTS survey indices introduced in 2020 are given, and used in the assessment. [2]English groundfish survey (EGFS): Arithmetic mean catch no./h. Data for 1996, 2001, 2002, and 2003 have been revised compared to the 2003 assessment. In 2007, numbers for 1997 and 1998 as well as 2002 has been adjusted based on new automatic calculation and processing process has been introduced. In September 2015, the EGFS Survey index was for all years and ages radically revised in order to incorporate the relevant primes within the Norway pout index area following the ICES IBTS manual (2015). [3]Minor GOV sweep changes in 2006 for the EGFS. [4]Scottish groundfish surveys (SGFS), arithmetic mean catch no./h. Survey design changed in 1998 and 2000. The SGFS survey area changed slightly in 2009 and onwards, which is evaluated to have no main effect for the Norway pout indices as the indices are weighted by sub-area. SGFS data for the full area, i.e. indices based on all hauls, are included in the presented indices. In September 2019, the indices from 2013 onwards for all age groups were corrected with removal of a few invalid hauls (including also the Q3 2019 survey) resulting in very minor changes of the indices for all age groups not affecting the assessment.

Table 12.3.1 Norway pout IV & IIIaN (Skagerak). Tuning fleets and stock indices and tuning fleets used in the final 2004 benchmark assessment, in the 2005-2015 assessments, as well as in the 2016-2022 assessments based on the 2016 benchmark assessment, compared to the 2003 assessment. (Changes from previous period marked with grey).

		2003 ASSESSMENT	2004, 2005, April 2006 ASSESSMENT	Sept. 2006 ASSESSMENT	2007-2015 ASSESSMENTS	2016-2022 ASSESSMENTS
Recruiting season		3rd quarter	2nd quarter (SXSA)	3rd quarter (SMS); 2nd quarter (SXSA	2nd quarter (SXSA), autumn assessm.	3rd quarter SESAM (1984-2022)
Last season in last year		3rd quarter	2nd quarter (SXSA)	3rd quarter (SMS); 2nd quarter (SXSA	2nd quarter (SXSA), autumn assessm.	3rd quarter SESAM (1984-2022)
Plus-group		4+	4+ (SXSA)	None (SMS); 4+ (SXSA)	4+ (SXSA)	3+ (SESAM) (1984-2022)
FLT01: comm Q1						
	Year range	1982-2003	1982-2004	1982-2004	1983-2004, 2006	NOT USED
	Quarter	1	1	1	1	
	Ages	1-3	1-3	1-3	1-3	
FLT01: comm Q2			NOT USED	NOT USED	NOT USED	NOT USED
	Year range	1982-2003				
	Quarter	2				
	Ages	1-3				
FLT01: comm Q3						
	Year range	1982-2003	1982-2004	1982-2004	1983-2004, 2006	NOT USED
	Quarter	3	3	3	3	
	Ages	0-3	1-3	1-3	1-3	
FLT01: comm Q4						
	Year range	1982-2003	1982-2004	1982-2004	1983-2004, 2006	NOT USED
	Quarter	4	4	4	4	
	Ages	0-3	0-3	0-2 (SMS); 0-3 (SXSA)	0-3 (SXSA)	
FLT02: ibtsq1						
	Year range	1982-2003	1982-2006	1982-2006	1983-2015	1984-2022
	Quarter	1	1	1	1	1
	Ages	1-3	1-3	1-3	1-3	1-3
FLT03: egfs						
	Year range	1982-2003	1992-2005	1992-2005	1992-2015	1992-2022
	Quarter	3	Q3 -> Q2	Q3 -> Q2	Q3 -> Q2	3
	Ages	0-3	0-1	0-1	0-1	0-1
FLT04: sgfs						
	Year range	1982-2003	1998-2006	1998-2006	1998-2015	1998-2022
	Quarter	3	Q3 -> Q2	Q3 -> Q2	Q3 -> Q2	3
	Ages	0-3	0-1	0-1	0-1	0-1
FLT05: ibtsq3		NOT USED				
	Year range		1991-2005	1991-2005	1991-2014	1991-2021
	Quarter		3	3	Q3	3
	Ages		2-3	2-3	2-3	2-3

Table 12.3.2 Norway pout IV & IIIaN (Skagerrak). Baseline run with SESAM seasonal stochastic assessment model. Settings and tuning fleets.

SURVIVORS ANALYSIS OF: Norway pout stock in September 2022

Run: September 2022 (NP_Sep2022_v2, www.stockassessment.org)

The following parameters were used:

Year range:	1984 - 2022
Seasons per year:	4
The last season in the last year is season:	3
Youngest age:	0
Oldest age:	2
Plus age:	3
Recruitment in season:	3
Spawning in season:	1

The following tuning fleets were included:

Fleet 2:	ibtsq1	(Age 1-3)
Fleet 3:	egfsq3	(Age 0-1)
Fleet 4:	sgfsq3	(Age 0-1)
Fleet 5:	ibtsq3	(Age 2-3)

Table 12.3.4. Norway pout IV & IIIaN (Skagerrak). Baseline run with SESAM seasonal model. Estimated fishing mortalities by quarter of year. (The last 2022 quarter 4 F-value is a Projection of F based on the population estimate by end of 3rd quarter).

Year\Age	0	1	2	3+
1984	0.001	0.351	0.971	0.397
1984.25	0.000	0.279	0.674	0.329
1984.5	0.010	1.050	1.846	0.355
1984.75	0.171	1.584	2.264	0.060
1985	0.001	0.417	1.154	0.471
1985.25	0.000	0.197	0.475	0.232
1985.5	0.009	0.975	1.714	0.329
1985.75	0.167	1.548	2.212	0.059
1986	0.001	0.359	0.993	0.406
1986.25	0.000	0.139	0.336	0.164
1986.5	0.006	0.646	1.136	0.218
1986.75	0.123	1.135	1.622	0.043
1987	0.001	0.312	0.863	0.352
1987.25	0.000	0.114	0.276	0.135
1987.5	0.005	0.503	0.884	0.170
1987.75	0.136	1.255	1.793	0.048
1988	0.000	0.238	0.659	0.269

Year\Age	0	1	2	3+
1988.25	0.000	0.100	0.241	0.118
1988.5	0.004	0.373	0.657	0.126
1988.75	0.095	0.881	1.259	0.033
1989	0.000	0.184	0.509	0.208
1989.25	0.000	0.155	0.375	0.183
1989.5	0.004	0.456	0.802	0.154
1989.75	0.089	0.823	1.176	0.031
1990	0.000	0.223	0.617	0.252
1990.25	0.000	0.214	0.517	0.253
1990.5	0.004	0.387	0.680	0.131
1990.75	0.070	0.650	0.929	0.025
1991	0.000	0.244	0.676	0.276
1991.25	0.000	0.178	0.430	0.210
1991.5	0.004	0.397	0.698	0.134
1991.75	0.065	0.604	0.863	0.023
1992	0.000	0.224	0.620	0.254
1992.25	0.000	0.150	0.363	0.177
1992.5	0.004	0.406	0.714	0.137
1992.75	0.063	0.584	0.835	0.022
1993	0.000	0.196	0.543	0.222
1993.25	0.000	0.149	0.359	0.176
1993.5	0.004	0.463	0.814	0.156
1993.75	0.067	0.619	0.884	0.024
1994	0.000	0.192	0.532	0.217
1994.25	0.000	0.132	0.318	0.155
1994.5	0.004	0.414	0.728	0.140
1994.75	0.048	0.448	0.640	0.017
1995	0.000	0.131	0.361	0.147
1995.25	0.000	0.112	0.271	0.132
1995.5	0.003	0.280	0.492	0.095
1995.75	0.040	0.370	0.529	0.014
1996	0.000	0.094	0.261	0.107
1996.25	0.000	0.076	0.183	0.090
1996.5	0.003	0.330	0.581	0.112
1996.75	0.036	0.329	0.470	0.013
1997	0.000	0.075	0.209	0.085
1997.25	0.000	0.054	0.130	0.063
1997.5	0.003	0.326	0.573	0.110
1997.75	0.039	0.364	0.520	0.014
1998	0.000	0.071	0.196	0.080

Year\Age	0	1	2	3+
1998.25	0.000	0.069	0.167	0.081
1998.5	0.003	0.264	0.464	0.089
1998.75	0.039	0.357	0.510	0.014
1999	0.000	0.059	0.162	0.066
1999.25	0.000	0.078	0.188	0.092
1999.5	0.003	0.282	0.496	0.095
1999.75	0.044	0.410	0.586	0.016
2000	0.000	0.056	0.155	0.063
2000.25	0.000	0.062	0.150	0.073
2000.5	0.002	0.197	0.346	0.066
2000.75	0.050	0.464	0.663	0.018
2001	0.000	0.066	0.182	0.074
2001.25	0.000	0.056	0.135	0.066
2001.5	0.001	0.124	0.218	0.042
2001.75	0.044	0.412	0.589	0.016
2002	0.000	0.062	0.173	0.071
2002.25	0.000	0.046	0.112	0.055
2002.5	0.002	0.231	0.405	0.078
2002.75	0.054	0.500	0.715	0.019
2003	0.000	0.042	0.115	0.047
2003.25	0.000	0.035	0.084	0.041
2003.5	0.002	0.214	0.376	0.072
2003.75	0.041	0.377	0.538	0.014
2004	0.000	0.033	0.091	0.037
2004.25	0.000	0.021	0.050	0.024
2004.5	0.002	0.173	0.304	0.058
2004.75	0.041	0.382	0.546	0.015
2005	0.000	0.000	0.000	0.000
2005.25	0.000	0.000	0.001	0.000
2005.5	0.000	0.000	0.001	0.000
2005.75	0.000	0.001	0.001	0.000
2006	0.000	0.020	0.077	0.027
2006.25	0.000	0.043	0.118	0.057
2006.5	0.001	0.119	0.275	0.058
2006.75	0.038	0.528	0.802	0.018
2007	0.000	0.004	0.014	0.004
2007.25	0.000	0.017	0.044	0.020
2007.5	0.000	0.034	0.080	0.017
2007.75	0.002	0.029	0.045	0.001
2008	0.000	0.002	0.007	0.002

Year\Age	0	1	2	3+
2008.25	0.000	0.018	0.047	0.021
2008.5	0.000	0.058	0.135	0.029
2008.75	0.004	0.063	0.097	0.002
2009	0.000	0.001	0.004	0.001
2009.25	0.000	0.018	0.047	0.021
2009.5	0.001	0.113	0.264	0.056
2009.75	0.004	0.072	0.111	0.002
2010	0.000	0.001	0.002	0.001
2010.25	0.000	0.025	0.063	0.029
2010.5	0.000	0.101	0.235	0.050
2010.75	0.006	0.110	0.169	0.003
2011	0.000	0.001	0.002	0.001
2011.25	0.000	0.008	0.020	0.009
2011.5	0.000	0.056	0.132	0.028
2011.75	0.007	0.127	0.197	0.004
2012	0.000	0.001	0.002	0.001
2012.25	0.000	0.010	0.026	0.012
2012.5	0.000	0.044	0.104	0.022
2012.75	0.021	0.358	0.552	0.011
2013	0.000	0.001	0.003	0.001
2013.25	0.000	0.026	0.066	0.030
2013.5	0.001	0.119	0.278	0.059
2013.75	0.029	0.497	0.767	0.016
2014	0.000	0.002	0.009	0.003
2014.25	0.000	0.029	0.073	0.034
2014.5	0.001	0.166	0.388	0.082
2014.75	0.023	0.402	0.621	0.013
2015	0.000	0.003	0.011	0.004
2015.25	0.000	0.036	0.093	0.043
2015.5	0.001	0.213	0.499	0.106
2015.75	0.022	0.375	0.579	0.012
2016	0.000	0.003	0.012	0.004
2016.25	0.000	0.048	0.123	0.056
2016.5	0.001	0.218	0.510	0.108
2016.75	0.024	0.410	0.633	0.013
2017	0.000	0.002	0.008	0.003
2017.25	0.000	0.045	0.115	0.052
2017.5	0.001	0.193	0.452	0.096
2017.75	0.024	0.410	0.633	0.013
2018	0.000	0.003	0.010	0.003

Year\Age	0	1	2	3+
2018.25	0.000	0.062	0.158	0.072
2018.5	0.001	0.185	0.434	0.092
2018.75	0.026	0.450	0.695	0.014
2019	0.000	0.005	0.020	0.006
2019.25	0.000	0.086	0.220	0.101
2019.5	0.001	0.212	0.495	0.105
2019.75	0.024	0.423	0.652	0.013
2020	0.000	0.010	0.037	0.012
2020.25	0.000	0.069	0.178	0.081
2020.5	0.001	0.188	0.441	0.094
2020.75	0.026	0.460	0.710	0.014
2021	0.000	0.007	0.027	0.009
2021.25	0.000	0.060	0.153	0.070
2021.5	0.001	0.142	0.333	0.071
2021.75	0.028	0.484	0.747	0.015
2022	0.000	0.003	0.013	0.004
2022.25	0.000	0.042	0.108	0.049
2022.5	0.000	0.103	0.240	0.051
2022.75	0.028	0.484	0.747	0.015

Table 12.3.5. Norway pout IV & IIIaN (Skagerrak). Baseline run with SESAM seasonal model. Diagnostics of the SESAM baseline assessment. Estimated catchabilities by survey tuning fleet.

Index	Fleet number	Age	Catchability	Low	High
1	2	1	0.12278	0.07376	0.20439
2	2	2	0.18537	0.10037	0.34234
3	2	3	0.18751	0.07577	0.46401
4	3	0	0.06539	0.03701	0.11553
5	3	1	0.18628	0.10305	0.33675
6	4	0	0.17692	0.09720	0.32202
7	4	1	0.19981	0.10722	0.37239
8	5	2	0.20128	0.09479	0.42740
9	5	3	0.10484	0.04014	0.27380

Table 12.3.5 (cont.). Norway pout IV & IIIaN (Skagerrak). Baseline run with SESAM seasonal model. Diagnostics of the SESAM baseline assessment. Likelihood values.

Model	Negative log likelihood	Number of parameters
Base	1303.05	19
Current	1303.05	19

Table 12.3.6 Norway pout IV & IIIaN (Skagerrak). Stock Summary Table. Baseline run with SESAM September 2022. Estimated yearly and quarterly recruitment (millions), spawning stock biomass SSB (t), total stock biomass TSB (t) and fishing mortality for ages 1-2 (F12).

Time	Re-cruits	Low	High	SSB	Low	High	TSB	Low	High	F12	Low	High
1984				350801	161655	539946	677603	345038	1010169	1.127	0.631	2.013
1984.25				227549	101282	353816	525701	251326	800075			
1984.5	39817	21019	75428	246645	108865	384425	676114	312396	1039832			
1984.75				122073	44312	199835	365248	151630	578865			
1985				213390	87369	339410	369987	180272	559701	1.087	0.579	2.040
1985.25				122474	46384	198565	264234	120393	408075			
1985.5	28819	15152	54815	128143	52489	203797	337538	154827	520249			
1985.75				63597	20403	106791	187340	74789	299891			
1986				117258	45022	189494	227544	102885	352203	0.796	0.426	1.486
1986.25				73742	25594	121890	174418	73089	275746			
1986.5	48432	25037	93687	83552	31540	135564	236245	100012	372478			
1986.75				47400	14939	79861	144708	55351	234064			
1987				128630	54625	202636	331561	145460	517663	0.750	0.390	1.443
1987.25				91867	36474	147259	288225	117493	458957			
1987.5	9969	4981	19953	115955	47972	183939	419465	171835	667095			
1987.75				72359	27133	117585	276416	106518	446314			
1988				160411	52181	268640	196901	76434	317367	0.551	0.303	1.003
1988.25				100397	27736	173057	137832	50679	224984			
1988.5	45725	23627	88488	112284	30203	194366	174121	66608	281633			
1988.75				71139	14318	127959	117370	39975	194764			
1989				114227	43394	185061	296369	123846	468892	0.560	0.307	1.022
1989.25				93431	33157	153705	270418	109249	431586			
1989.5	47217	24310	91710	112364	42404	182324	381986	153970	610002			
1989.75				72029	24455	119603	253086	96567	409605			
1990				197167	80882	313451	380205	172636	587775	0.527	0.287	0.968
1990.25				136445	52491	220398	316421	135090	497752			
1990.5	58282	29917	113542	151723	57252	246195	421619	173153	670086			
1990.75				95268	31873	158663	282058	108523	455593			
1991				235040	96051	374029	464408	206910	721906	0.511	0.275	0.950
1991.25				162957	61747	264167	384445	160085	608806			
1991.5	103234	52850	201650	186510	70772	302248	530158	214777	845540			

Time	Re-cruits	Low	High	SSB	Low	High	TSB	Low	High	F12	Low	High
1991.75				117948	39575	196320	359605	136141	583070			
1992				338117	140011	536222	751992	325278	1178707	0.487	0.259	0.916
1992.25				252346	95467	409226	650060	262551	1037570			
1992.5	54476	28231	105121	309145	113953	504338	914503	360922	1468083			
1992.75				196110	61062	331158	598482	216348	980616			
1993				426213	147538	704888	637305	259127	1015483	0.504	0.244	1.038
1993.25				273558	84209	462907	469624	180546	758702			
1993.5	47192	24156	92196	277667	85434	469899	563299	218730	907868			
1993.75				153588	35963	271213	333233	112770	553696			
1994				232539	75837	389241	409934	159263	660605	0.425	0.211	0.859
1994.25				161908	46318	277498	326598	118307	534889			
1994.5	134913	68039	267514	171810	51442	292179	416626	152315	680938			
1994.75				106838	24903	188773	274319	86778	461859			
1995				312993	114838	511149	856729	320142	1393316	0.318	0.156	0.648
1995.25				253997	86314	421680	789059	277551	1300567			
1995.5	52801	26433	105471	320941	108038	533844	1137066	392037	1882096			
1995.75				211839	62812	360866	772615	243223	1302007			
1996				554400	169647	939154	746631	269609	1223652	0.291	0.141	0.601
1996.25				370830	103182	638478	562637	195122	930152			
1996.5	112567	55762	227241	401209	107240	695177	695876	240184	1151568			
1996.75				253226	46543	459908	463385	131391	795378			
1997				427728	127270	728186	884613	307332	1461895	0.281	0.133	0.593
1997.25				332758	92689	572826	777480	260870	1294090			
1997.5	22077	10898	44725	385114	116015	654213	1107481	371494	1843468			
1997.75				252265	62431	442098	769118	222909	1315326			
1998				547178	141197	953158	635866	189704	1082028	0.262	0.125	0.552
1998.25				360390	85458	635322	449166	131161	767170			
1998.5	40137	20313	79307	363710	82665	644755	500541	150014	851068			
1998.75				228154	35655	420652	331097	81343	580851			
1999				258875	60476	457274	428976	136153	721799	0.282	0.133	0.601
1999.25				205396	43791	367000	379234	118020	640448			
1999.5	94317	47296	188086	210755	51263	370247	486538	159930	813146			
1999.75				136447	27973	244922	341608	98856	584360			
2000				330332	104473	556191	733085	258567	1207603	0.261	0.120	0.569
2000.25				264788	80561	449015	676720	229139	1124302			
2000.5	26141	13059	52328	333614	101396	565833	1007975	330398	1685552			
2000.75				226848	59633	394064	713088	209605	1216572			
2001				486142	121374	850911	587071	171733	1002409	0.223	0.100	0.497
2001.25				321254	71849	570658	418225	117879	718571			
2001.5	25858	12888	51880	323927	69708	578145	469419	135938	802900			

Time	Re-cruits	Low	High	SSB	Low	High	TSB	Low	High	F12	Low	High
2001.75				216868	36189	397547	322639	82010	563269			
2002				231870	47213	416528	340818	94691	586946	0.281	0.120	0.655
2002.25				172088	30898	313279	280506	75688	485325			
2002.5	21213	10245	43924	166621	35094	298148	329163	98581	559745			
2002.75				105483	17675	193291	216228	57494	374963			
2003				146433	35580	257285	224247	67933	380560	0.223	0.092	0.537
2003.25				103247	23697	182796	174823	52689	296958			
2003.5	8320	4060	17050	103945	25728	182162	206487	65988	346986			
2003.75				63902	12609	115195	133158	37146	229170			
2004				91317	22208	160427	124313	36493	212133	0.200	0.078	0.513
2004.25				65965	14542	117388	97420	27612	167228			
2004.5	7844	3843	16007	68740	15708	121773	118195	35020	201369			
2004.75				43596	7804	79388	78173	20045	136301			
2005				55963	12536	99389	87733	25350	150116	0.000	0.000	0.001
2005.25				43801	9086	78515	74922	21214	128630			
2005.5	31338	15350	63978	46941	10507	83375	95140	28300	161980			
2005.75				32258	6948	57568	68933	19858	118007			
2006				81381	28352	134411	209066	71672	346460	0.248	0.091	0.674
2006.25				68299	22603	113995	193025	63965	322085			
2006.5	22260	10825	45775	86356	27822	144890	280864	90644	471084			
2006.75				60198	17212	103185	205207	59219	351196			
2007				156069	37453	274685	245962	73691	418232	0.033	0.014	0.081
2007.25				112377	26130	198624	201142	59156	343128			
2007.5	32648	15920	66953	125648	28789	222507	261253	75851	446655			
2007.75				84763	17120	152407	184953	49015	320891			
2008				169341	48450	290231	304693	99033	510354	0.053	0.023	0.123
2008.25				134277	36007	232546	272641	84146	461135			
2008.5	48357	23350	100144	154594	40574	268613	375193	111607	638778			
2008.75				106768	24637	188899	278469	72696	484242			
2009				253373	72455	434291	477000	154100	799900	0.079	0.033	0.190
2009.25				194937	54759	335115	421576	133097	710056			
2009.5	71697	34949	147086	230944	64753	397136	600797	184759	1016836			
2009.75				155441	37606	273276	439513	118052	760973			
2010				406869	115638	698099	717313	232886	1201739	0.088	0.038	0.206
2010.25				336632	86245	587019	666171	199354	1132988			
2010.5	6395	3068	13330	398842	96685	700999	914307	262782	1565832			
2010.75				265161	52449	477874	629303	160021	1098584			
2011				428798	100115	757480	455512	113137	797887	0.068	0.028	0.167
2011.25				291063	62977	519148	317821	75629	560012			
2011.5	11016	5392	22505	292145	58726	525565	336025	78733	593316			

Time	Re-cruits	Low	High	SSB	Low	High	TSB	Low	High	F12	Low	High
2011.75				192471	30521	354421	225791	45008	406573			
2012				160656	27342	293970	206857	48394	365320	0.137	0.054	0.348
2012.25				131581	18443	244719	178344	39599	317090			
2012.5	56619	27778	115404	122479	18958	226000	198359	50426	346292			
2012.75				82516	11353	153679	142969	34455	251482			
2013				146893	42854	250933	382704	120620	644788	0.220	0.083	0.583
2013.25				125706	35924	215488	364925	111219	618631			
2013.5	16508	8128	33525	152999	45968	260030	510048	160249	859847			
2013.75				101326	28227	174425	346666	103489	589842			
2014				228053	56947	399160	293349	87621	499076	0.211	0.083	0.537
2014.25				151303	38264	264341	215065	66954	363176			
2014.5	95420	45162	201607	154378	39502	269254	251826	81100	422551			
2014.75				95007	18626	171388	166996	45981	288012			
2015				196948	56727	337169	567407	168916	965899	0.226	0.086	0.595
2015.25				161059	47096	275022	507928	154220	861636			
2015.5	35685	16795	75823	192131	59271	324992	690929	217604	1164255			
2015.75				118327	32103	204551	436019	126123	745915			
2016				298901	79855	517948	435398	136848	733949	0.245	0.092	0.651
2016.25				202107	54302	349913	328018	105529	550507			
2016.5	61908	29035	131998	208045	55233	360857	383387	125120	641655			
2016.75				122692	22217	223167	231128	62398	399858			
2017				191961	50310	333612	429124	128886	729362	0.232	0.089	0.610
2017.25				146932	38689	255175	361193	111503	610883			
2017.5	20576	9975	42444	160367	45569	275164	462934	147899	777970			
2017.75				99637	23539	175735	294617	84999	504234			
2018				196291	49626	342956	270700	83832	457569	0.250	0.098	0.637
2018.25				130683	33620	227746	201706	65221	338191			
2018.5	74574	36813	151069	129423	33169	225676	233257	77112	389403			
2018.75				78643	15497	141789	152950	44062	261838			
2019				165287	51821	278753	453657	153113	754201	0.264	0.109	0.641
2019.25				137804	43701	231906	417677	140946	694407			
2019.5	97178	47968	196875	166312	53576	279048	582804	195375	970233			
2019.75				111028	30909	191148	406349	121215	691484			
2020				363498	110024	616973	754411	257249	1251573	0.262	0.104	0.657
2020.25				270164	83794	456534	646146	220357	1071934			
2020.5	61834	29368	130192	314046	97615	530477	880856	294575	1467137			
2020.75				200033	52211	347856	592180	175369	1008991			
2021				428188	108207	748169	659830	203294	1116367	0.244	0.088	0.678
2021.25				296476	75193	517759	513626	161044	866208			
2021.5	25853	12140	55056	302130	76481	527780	614647	193294	1036001			

Time	Re-cruits	Low	High	SSB	Low	High	TSB	Low	High	F12	Low	High
2021.75				186978	37720	336235	393476	108656	678296			
2022				254690	50829	458551	354312	93316	615307			
2022.25				182153	33404	330902	286302	74327	498278			
2022.5	76654	28934	203083	185772	33881	337664	352641	90202	615080			
2022.75				122199	16800	227598	243900	50427	437373			

Table 12.3.6 (cont). Norway pout IV & IIIaN (Skagerrak). Stock Summary Table. Baseline run with SESAM September 2022. Long term arithmetic means of yearly recruitment (millions), quarterly spawning stock biomass SSB (t), quarterly total stock biomass TSB (t) and yearly fishing mortality for ages 1-2 (Fbar=F12) for the period 1984-2022. (Numbers are given for start of the season).

	value
Avg. recruitment	48099.28
Avg SSB Q 1	258569.78
Avg SSB Q 2	186275.36
Avg SSB Q 3	205075.04
Avg SSB Q 4	130062.14
Avg TSB Q 1	451568.87
Avg TSB Q 2	373883.91
Avg TSB Q 3	491171.34
Avg TSB Q 4	327497.18
Avg. FBAR	0.34

Table 12.6.1 NORWAY POUT IV and IIIaN (Skagerrak). Projected mean weight at age used in the forecast by quarter of year.

Age/Quarter	1	2	3	4
0	4.161	5.785	3.988	5.510
1	7.588	11.797	21.819	23.536
2	20.051	23.457	31.553	33.354
3	30.807	31.429	38.299	39.912

Table 12.6.2 NORWAY POUT IV and IIIaN (Skagerrak). Forecast of fishing mortality, SSB and median catch (t) with F scaled such that the fifth percentile of the SSB distribution one year ahead (1st October 2023) equals Blim.
Basis:
Fbar (2021 up to Q4) = estimated from in year assessment 1st October 2022, F(age1-2, quarter4 2021 & quarter1,2,3 2022) = 0.218, Table 12.3.4. SSB (2022 up to Q4) = estimated from in year assessment 1st October 2022 (start Q4) = 122 199 tonnes; R(2022) = estimated / observed from in year assessment 1st July 2022 (age 0 in start of Q3) = 76 654 million, Table 12.3.6; Biological parameters (2022-2023): Assume values for M, weight-at-age in the stock, and maturity-at-age for the projection period to be similar to the same parameter values used in the assessment. Assume projected mean weight at ages in the catches by quarter as given in Table 12.6.1. F, R (Q4 2022 - Q4 2023): (i) Draw K samples from the joint posterior distribution of the states (log N and log F) in the last year with data, and the recruitment in all years. (ii) Assume that log F_t = log F_{t-4} + log G_t, for all future values of t where G_t is some chosen vector of multipliers of the F-process. If G_t = 1 for all t this corresponds to assuming the same level and quarterly pattern in F for all future time-steps as in the last data year. (iii) Create K forecasting trajectories starting from the samples of joint posterior distribution of the states. This is done by sampling K recruitments from the vector of historic recruitments obtained in step 2, and then projecting the states forward in time using the stock equation with randomly sampled process errors from their estimated distribution. (iv) Find G_t such that the fifth (or any other) percentile of the catches (total mass) in the projections equals some desired level such as B_{lim} (optional).

	F12	SSB	SSB 5th quantile	median catch
2022.75	1.80	125.34	62.21	63775.20
2023	0.02	200.12	77.60	1295.46
2023.25	0.22	169.28	65.82	13877.09
2023.5	0.50	204.60	75.35	37874.80
2023.75		133.48	42.57	
Sum				116822.55

Table 12.6.3 NORWAY POUT IV and IIIaN (Skagerrak). Forecast of fishing mortality, SSB and median catch (t) with F scaled to zero (no catch) for the period 1st October 2022 to 1st October 2023.
Basis: Same as above

	F12	SSB	SSB 5th quantile	median catch
2022.75	0.00	125.34	62.21	0.00
2023	0.00	261.41	136.13	0.00
2023.25	0.00	217.70	106.67	0.00
2023.5	0.00	266.95	120.19	0.00
2023.75		190.62	80.12	
Sum				0.00

Table 12.6.4 NORWAY POUT IV and IIIaN (Skagerrak). Forecast of fishing mortality, SSB and median catch (t) with F scaled to F status quo for the previous year up to 1st October 2022.
Basis: Same as above

	F12	SSB	SSB 5th quantile	median catch
2022.75	0.62	125.34	62.21	24857.32
2023	0.01	234.46	110.52	514.28
2023.25	0.08	197.55	89.15	5338.48
2023.5	0.17	240.57	99.80	14853.67
2023.75		165.94	63.55	
Sum				45563.75

Table 12.6.5 NORWAY POUT IV and IIIaN (Skagerrak). Forecast of fishing mortality, SSB and median catch (t) with F scaled such that the median of the SSB distribution one year a head (1st October 2023) equals Blim.
Basis: Same as above.

	F12	SSB	SSB 5th quantile	median catch
2022.75	11.48	125.34	62.21	197500.72
2023	0.15	100.27	31.32	4655.42
2023.25	1.43	89.98	26.91	52613.22
2023.5	3.18	97.12	24.62	114633.09
2023.75		42.57	7.33	
Sum				369402.45

Table 12.6.6 NORWAY POUT IV and IIIaN (Skagerrak). Forecast of fishing mortality, SSB and median catch (t) with F scaled such that SSB one year a head (1st October 2023) equals Bpa.
Basis: Same as above.

	F12	SSB	SSB 5th quantile	median catch
2022.75	6.48	125.34	62.21	151332.09
2023	0.09	129.91	40.89	3254.01
2023.25	0.81	114.29	36.21	36831.80
2023.5	1.80	130.96	38.04	90092.38
2023.75		70.00	15.92	
Sum				281510.28

Table 12.6.7 NORWAY POUT IV and IIIaN (Skagerrak). Forecast of fishing mortality, SSB and median catch (t) with F scaled to 0.3 (Fcap = 0.3) for the period 1st October 2022 to 1st October 2023.
Basis: Same as above.

	F12	SSB	SSB 5th quantile	median catch
2022.75	0.85	125.34	62.21	33351.91
2023	0.01	226.07	101.85	688.14
2023.25	0.11	190.79	83.58	7176.35
2023.5	0.24	232.08	94.07	19916.44
2023.75		158.54	58.53	
Sum				61132.84

Table 12.6.8 NORWAY POUT IV and IIIaN (Skagerrak). Forecast of fishing mortality, SSB and median catch (t) with F scaled to 0.4 (F_{cap} = 0.4) for the period 1st October 2022 to 1st October 2023.
Basis: Same as above.

	F12	SSB	SSB 5th quantile	median catch
2022.75	1.14	125.34	62.21	43213.45
2023	0.02	216.99	93.45	885.47
2023.25	0.14	184.15	76.70	9320.97
2023.5	0.32	222.81	87.36	25742.08
2023.75		149.82	52.85	
Sum				79161.97

Table 12.6.9 NORWAY POUT IV and IIIaN (Skagerrak). Forecast of fishing mortality, SSB and median catch (t) with F scaled to 0.5 (F_{cap} = 0.5) for the period 1st October 2022 to 1st October 2023.
Basis: Same as above.

	F12	SSB	SSB 5th quantile	median catch
2022.75	1.42	125.34	62.21	52287.31
2023	0.02	209.36	86.28	1068.75
2023.25	0.18	177.31	71.99	11295.86
2023.5	0.39	214.60	82.37	31116.78
2023.75		142.22	48.01	
Sum				95768.70

Table 12.6.10 NORWAY POUT IV and IIIaN (Skagerrak). Forecast of fishing mortality, SSB and median catch (t) with F scaled to 0.6 (F_{cap} = 0.6) for the period 1st October 2022 to 1st October 2023.
Basis: Same as above.

	F12	SSB	SSB 5th quantile	median catch
2022.75	1.71	125.34	62.21	60944.70
2023	0.02	202.27	79.77	1237.83
2023.25	0.21	171.50	67.04	13220.84
2023.5	0.47	206.65	77.05	36232.89
2023.75		135.60	43.87	
Sum				111636.26

Table 12.6.11 NORWAY POUT IV and IIIaN (Skagerrak). Forecast of fishing mortality, SSB and median catch (t) with F scaled to 0.7 (F_{cap} = 0.7) for the period 1st October 2022 to 1st October 2023.
Basis: Same as above.

	F12	SSB	SSB 5th quantile	median catch
2022.75	1.99	125.34	62.21	68852.34
2023	0.03	195.45	74.83	1400.33
2023.25	0.25	165.18	63.23	15062.53
2023.5	0.55	200.03	72.39	40969.28
2023.75		129.06	40.52	
Sum				126284.48

Table 12.6.12 NORWAY POUT IV and IIIaN (Skagerrak). The quarterly minima of the estimated SSB time series (1984-2016) from the SESAM Benchmark Assessment Baseline Run from the Norway pout benchmark assessment under ICES WKPOUT 2016 with previous to 2020 IBTS Q1 and Q3 survey indices. The estimates are quarterly minima in tonnes estimated at the beginning of the season. The estimates are Bloss estimates which equals Blim according to the ICES WKPOUT 2016 benchmark assessment which by 1st October is Blim=39 450 t.

SSB	Quarter	Year
72101.23	1	2005
55109.70	2	2005
57961.80	3	2005
39447.18	4	2005

Table 12.6.13 NORWAY POUT IV and IIIaN (Skagerrak). The quarterly minima of the estimated SSB time series (1984-2016) from the SESAM updated Benchmark Assessment Run (Run: NP_Sep17_fixC_Benchmark2016Data_NewIBTS, www.stockassessment.org) with new IBTS Q1 and Q3 survey indices made available in 2020. The estimates are quarterly minima in tonnes estimated at the beginning of the season. The estimates are Bloss estimates which equals Blim according to the assessment run above which by 1st October is Blim=42 573 t.

SSB	Quarter	Year
77586	1	2005
59514	2	2005
62543	3	2005
42573	4	2005

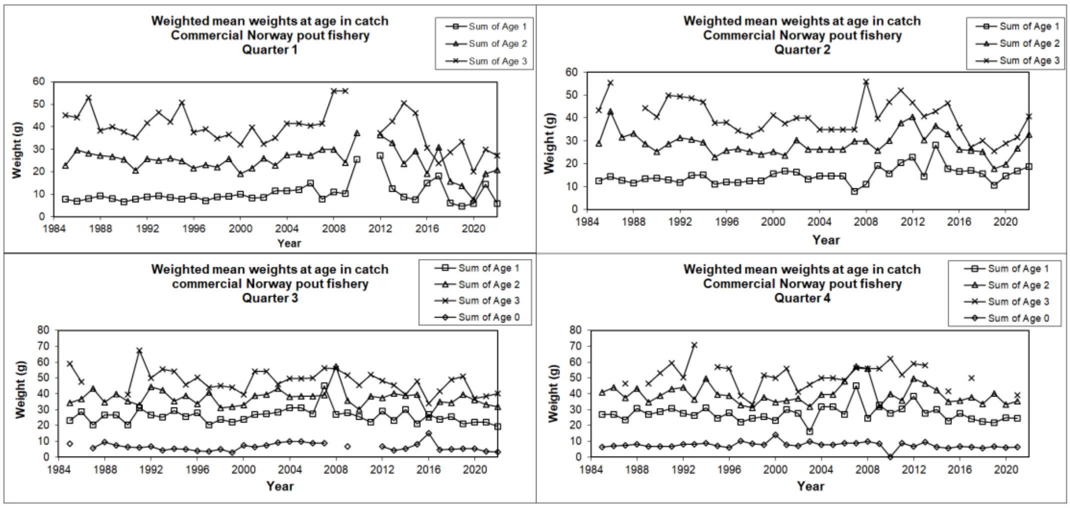


Figure 12.2.1. NORWAY POUT IV and IIIaN (Skagerrak). Weighted mean weights at age in catch of the Danish and Norwegian commercial fishery for Norway pout by quarter of year during the period 1984-2022.

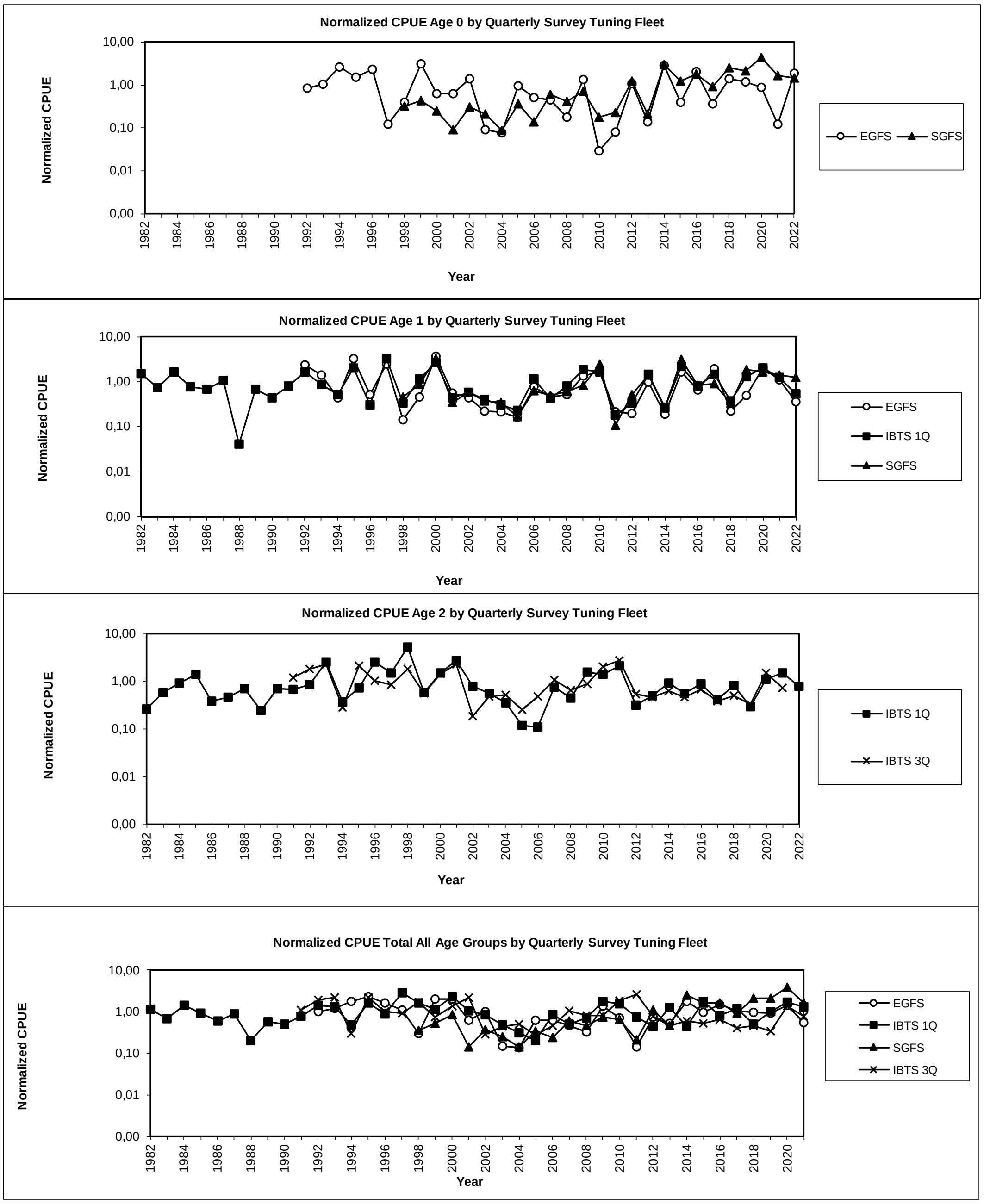


Figure 12.2.2 NORWAY POUT IV and IIIaN (Skagerrak). Trends in CPUE (normalized to unit mean) by quarterly survey tuning fleet used in the Norway pout assessment for each age group and all age groups together.

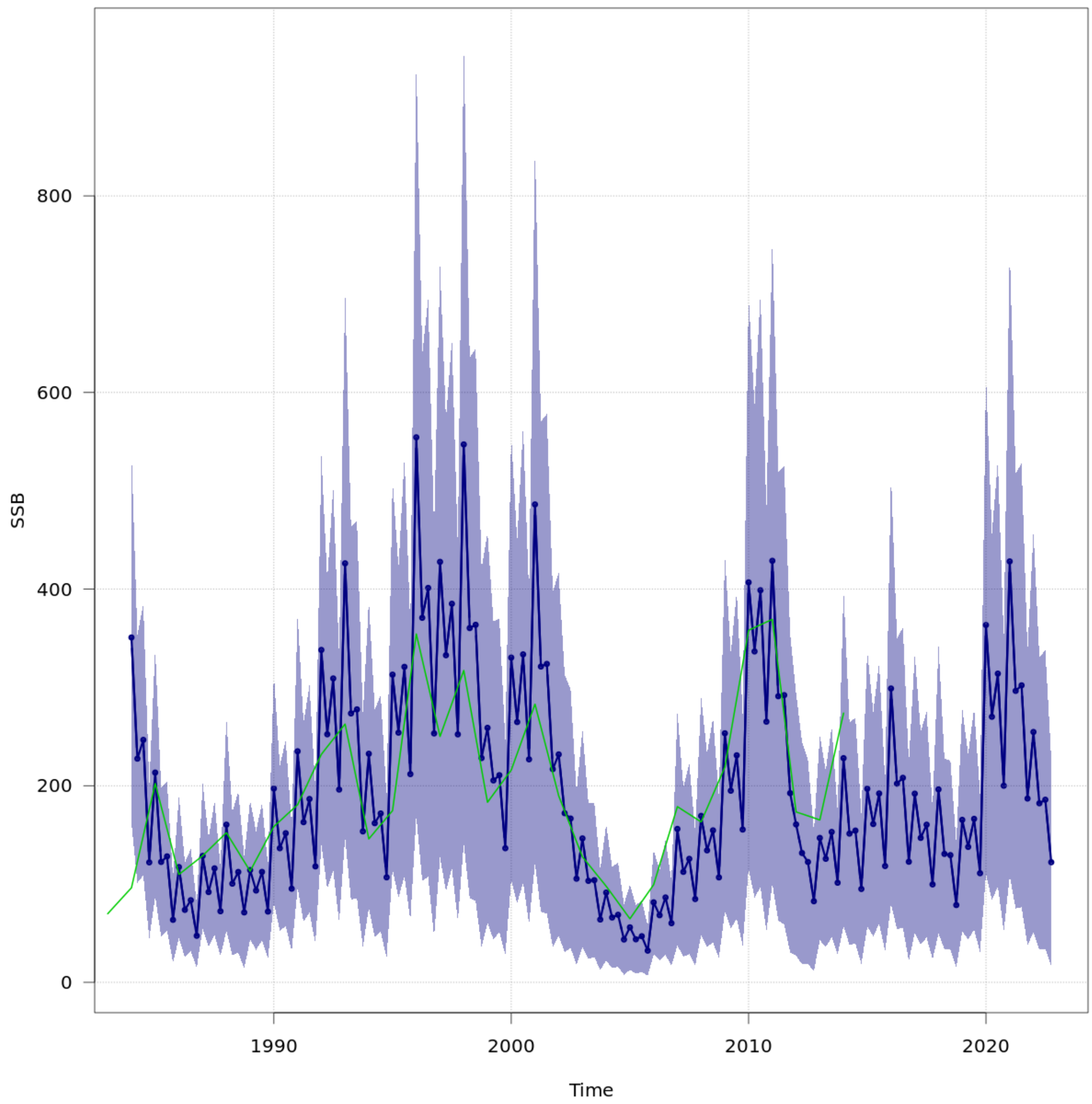


Figure 12.3.1. Norway Pout IV and IIIaN (Skagerrak). Stock Summary Plots: SSB (t), quarterly. SESAM baseline run September 2022. Quarterly estimated SSB and confidence interval from SESAM (blue) and SXSA (green, quarter 1 only – connecting lines are interpolations).

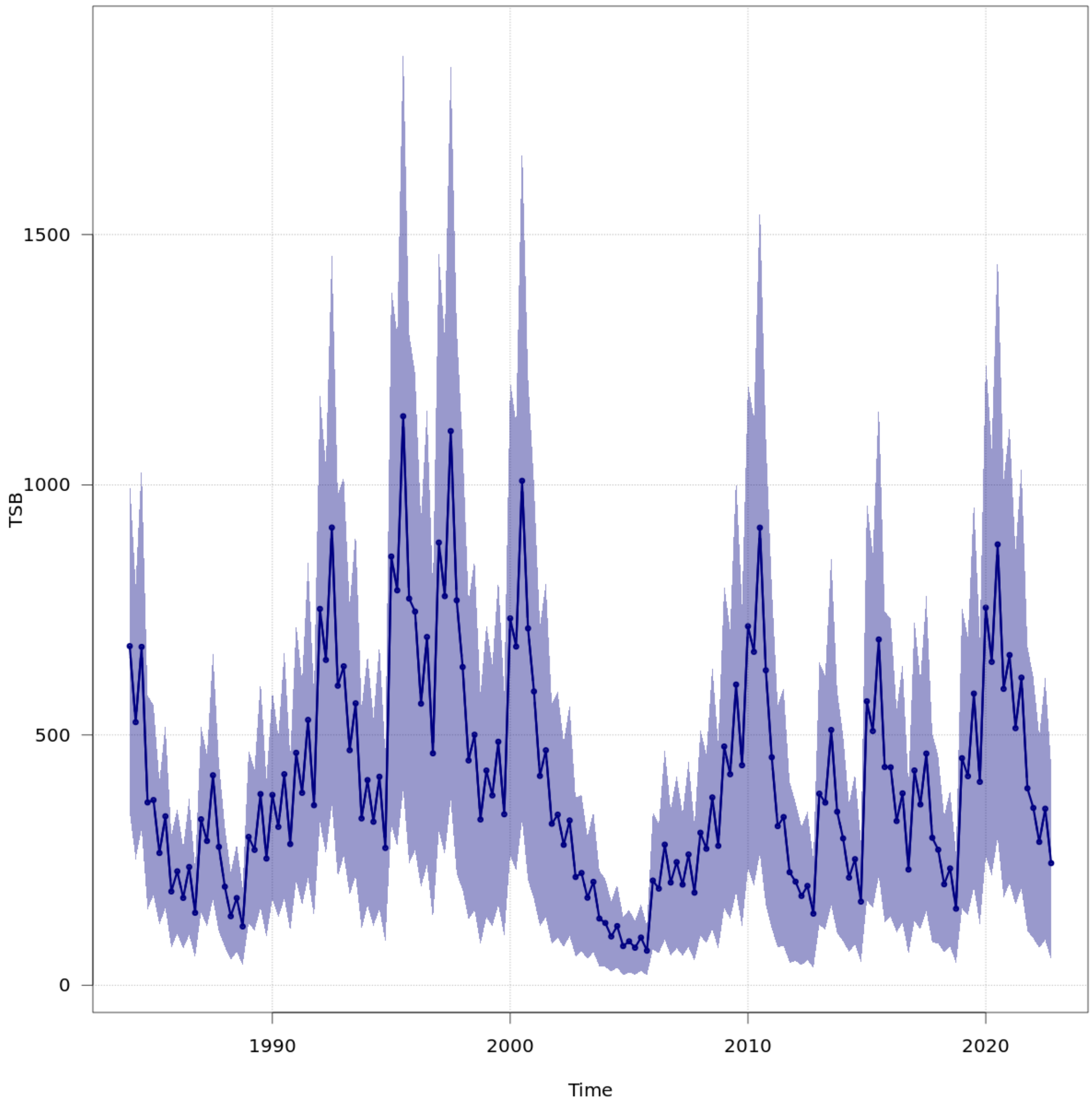


Figure 12.3.2. Norway Pout IV and IIIaN (Skagerrak). Stock Summary Plots: TSB (t), quarterly. SESAM baseline run September 2022.

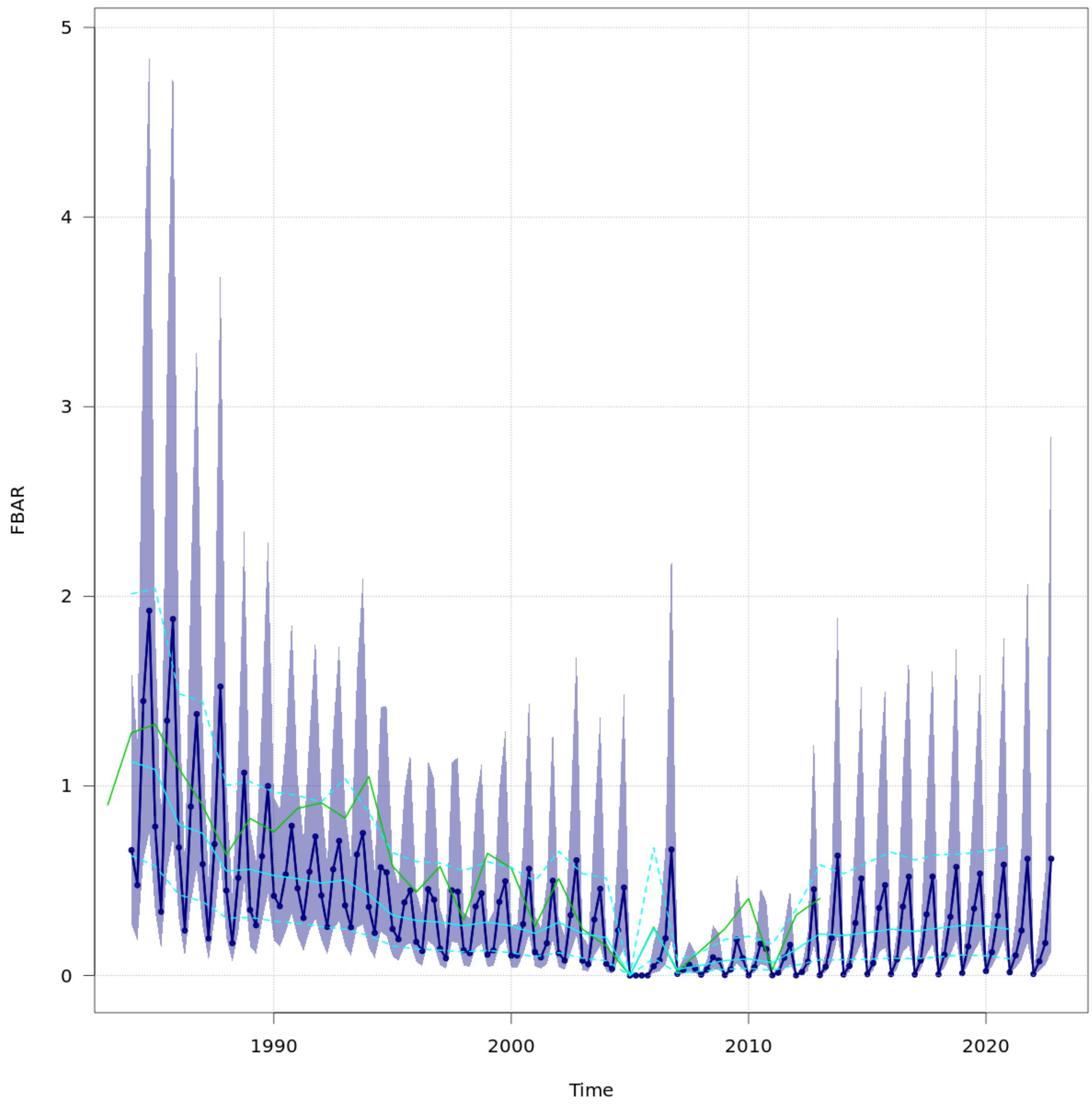


Figure 12.3.3. Norway Pout IV and IIIaN (Skagerrak). Stock Summary Plots: F1-2=Fbar, quarterly. SESAM baseline run September 2022. Blue is quarterly values from SESAM, cyan is the yearly average from SESAM, green is yearly average from SXSA.

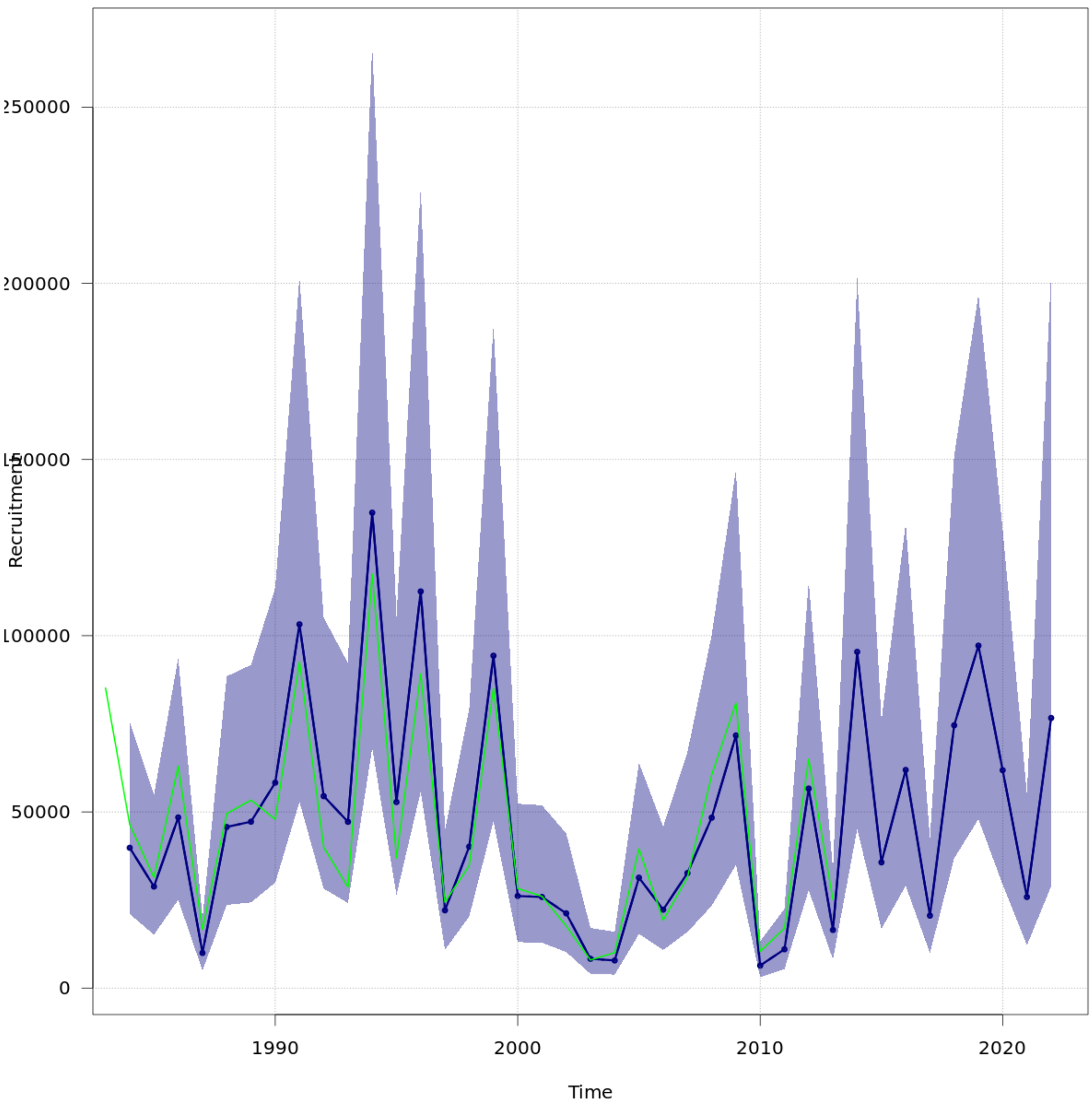
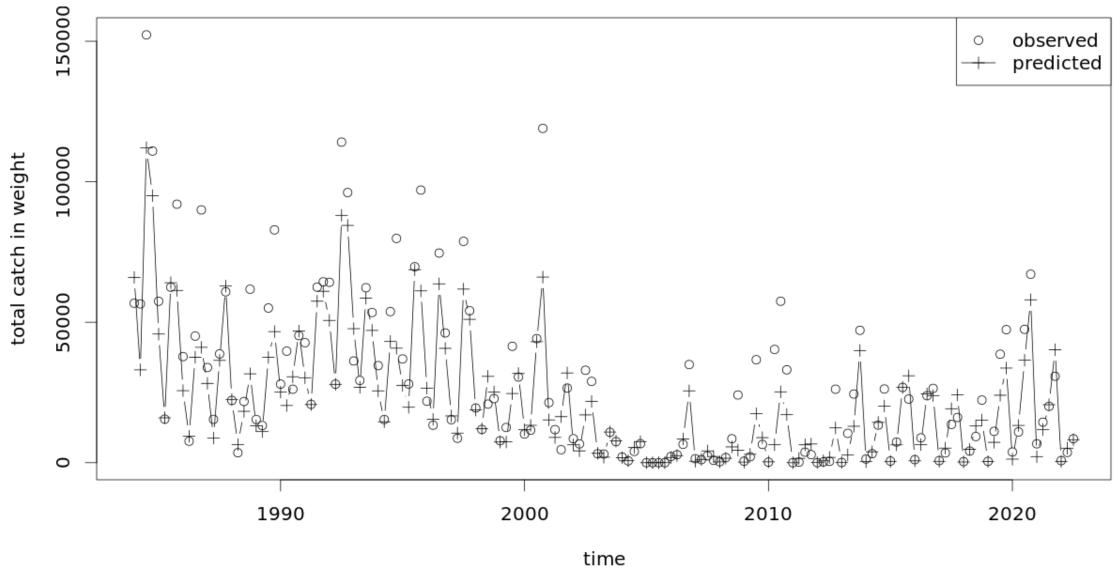


Figure 12.3.4. Norway Pout IV and IIIaN (Skagerrak). Stock Summary Plots: Recruitment (millions), yearly. SESAM baseline run September 2022. Blue is SESAM, green is SXSA.



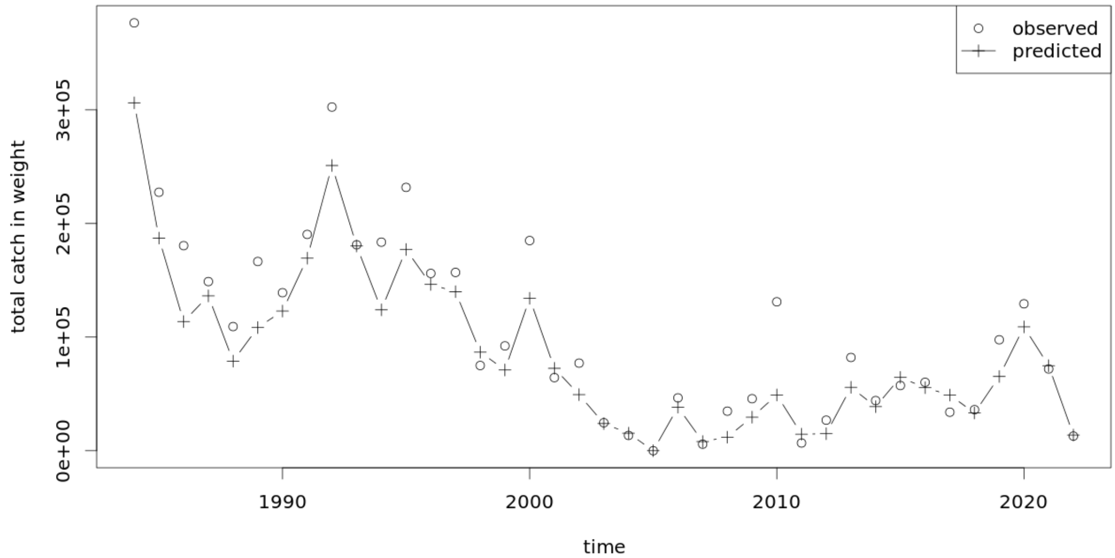


Figure 12.3.5. Norway Pout IV and IIIaN (Skagerrak). Stock Summary Plots: Yield = Total Catch (t), quarterly and yearly. SESAM baseline run September 2022.

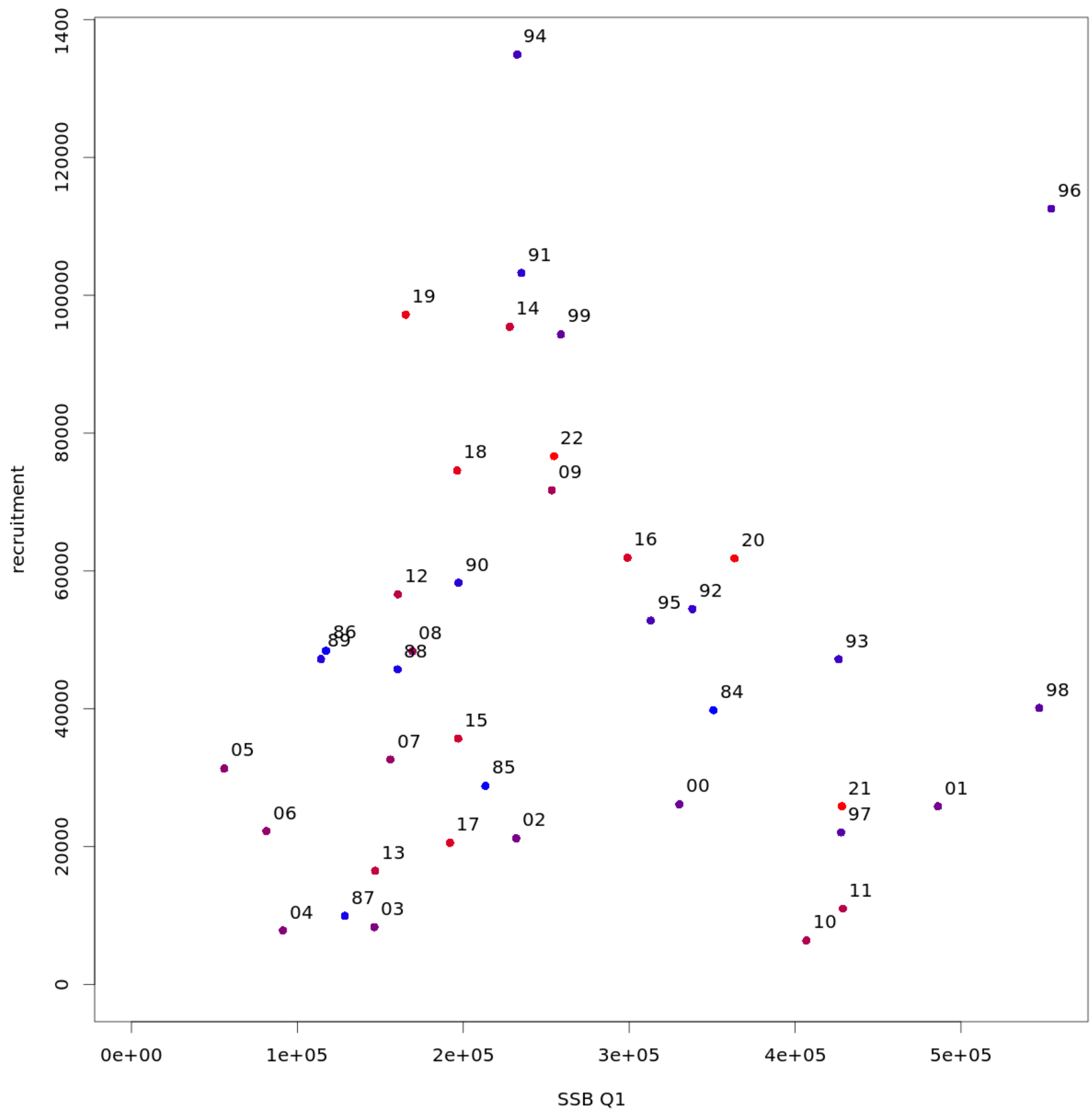


Figure 12.3.6. Norway Pout IV and IIIaN (Skagerrak). Stock Summary Plots: Stock (SSB) – Recruitment Plot Quarter 1. SESAM baseline run September 2022.

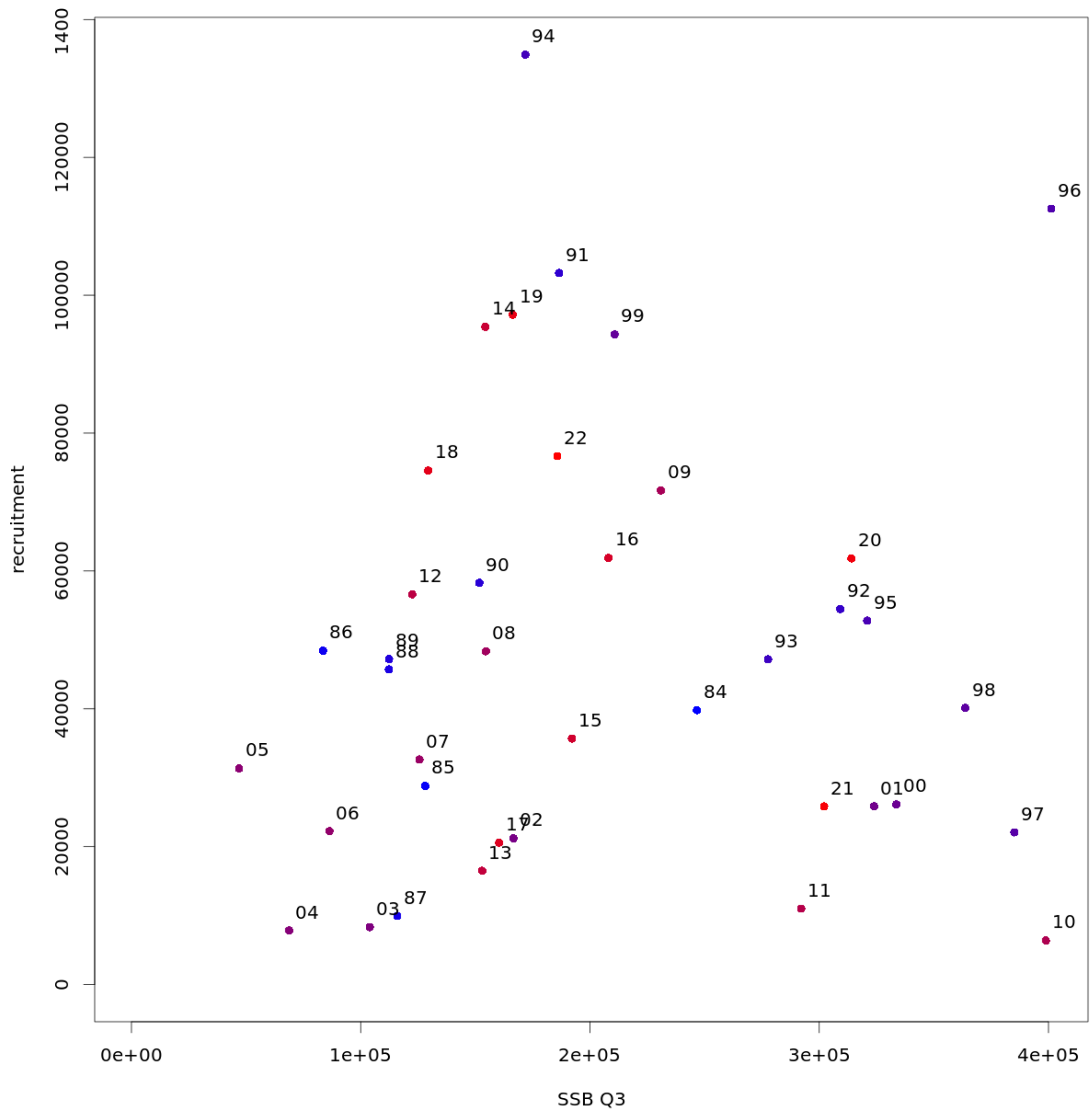


Figure 12.3.7. Norway Pout IV and IIIaN (Skagerrak). Stock Summary Plots: Stock (SSB) – Recruitment Plot Quarter 3. SESAM baseline run September 2022.

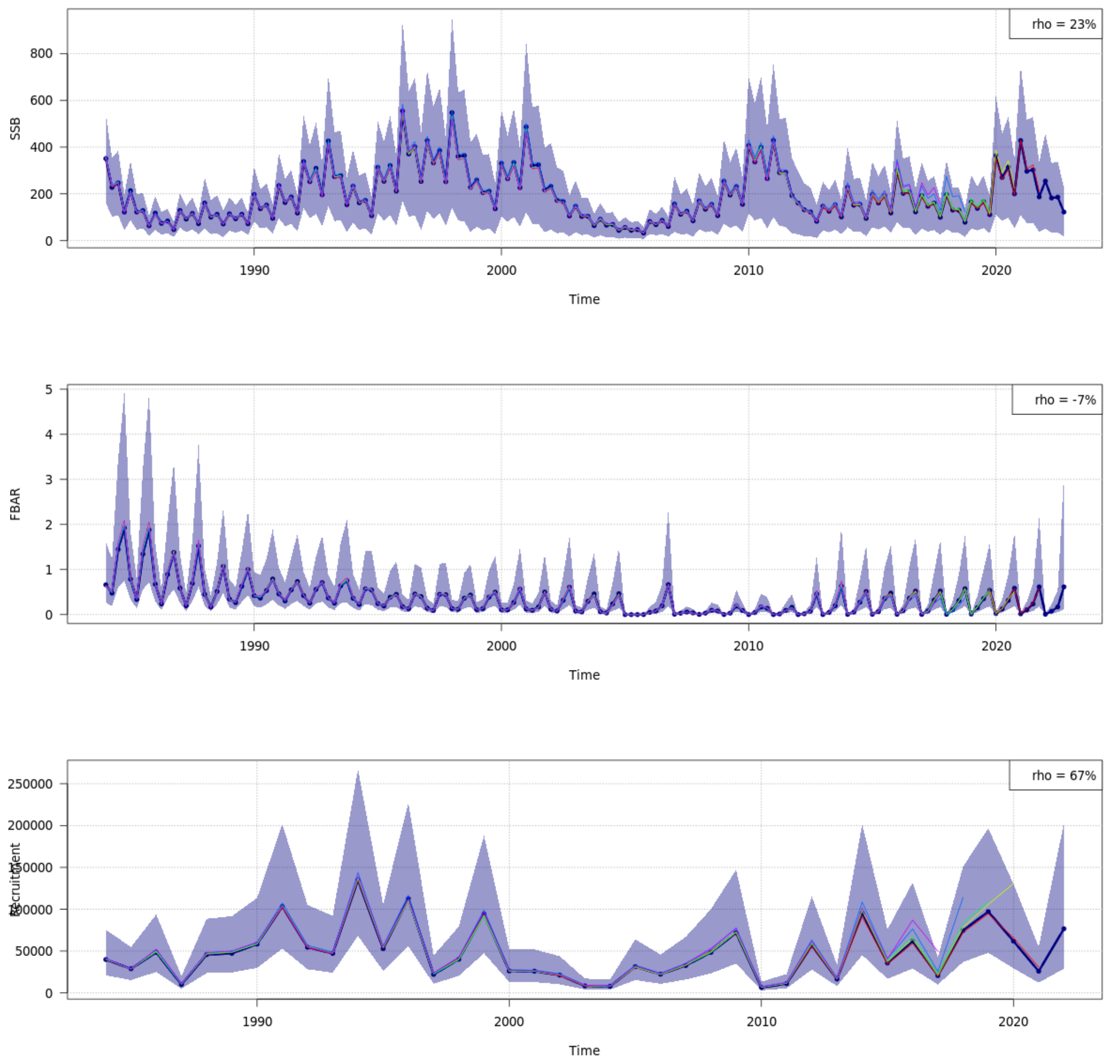


Figure 12.3.8. Norway pout IV & IIIaN (Skagerrak). Retrospective plots of baseline SESAM assessment September 2022, with terminal assessment year ranging from 2017-2022. Represent 5 year retrospective runs.

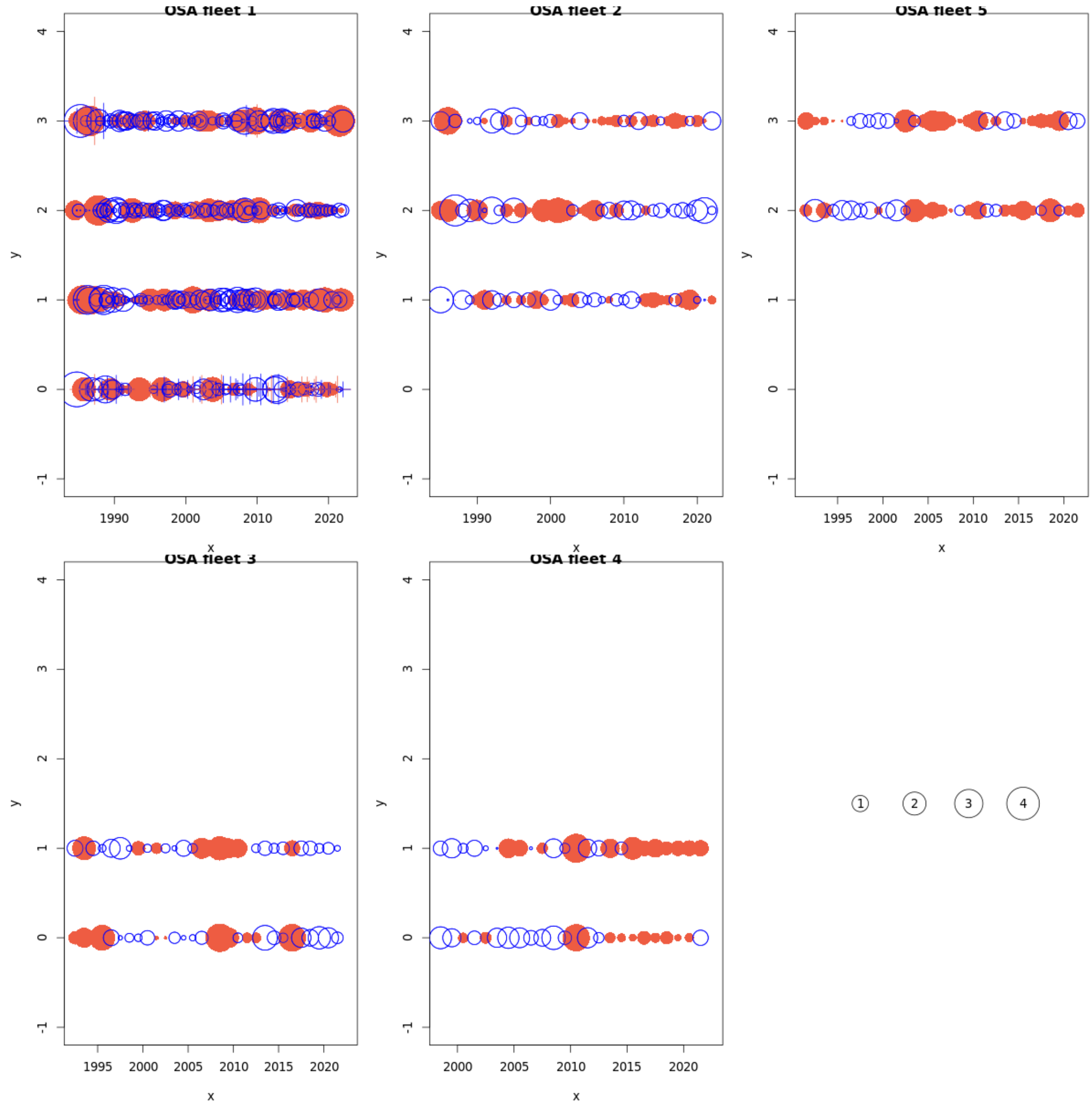


Figure 12.3.9. Norway Pout IV and IIIaN (Skagerrak). Assessment Diagnostics Plots by fleet: One step ahead residuals (see Berg and Nielsen 2016). SESAM baseline run September 2022.

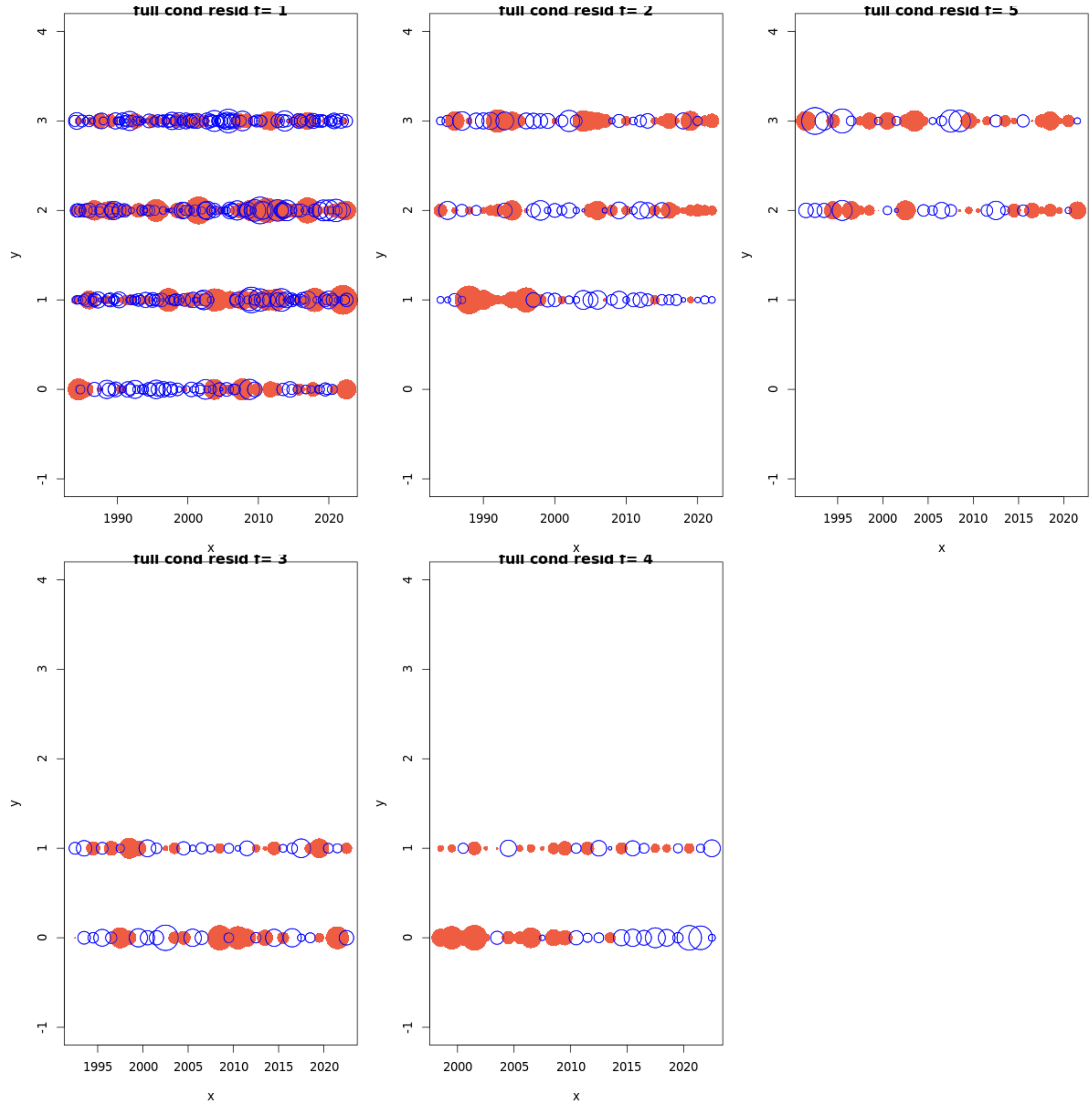


Figure 12.3.10. Norway Pout IV and IIIaN (Skagerrak). Assessment Diagnostics Plots: Full conditional residuals or auxiliary residuals (see Berg and Nielsen 2016). SESAM baseline run September 2022.

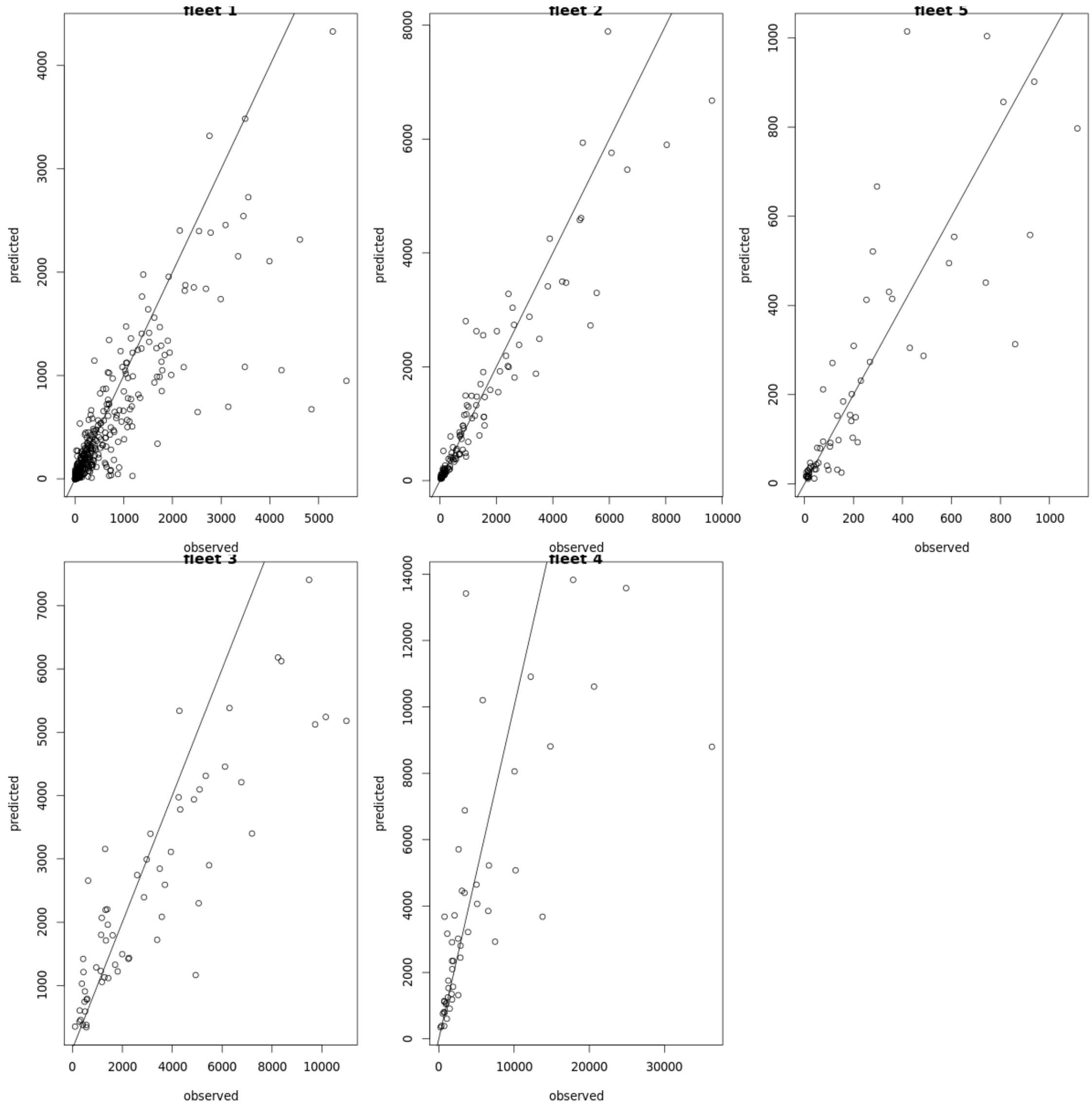


Figure 12.3.11. Norway Pout IV and IIIaN (Skagerrak). Assessment Diagnostics Plots by fleet. SESAM baseline run September 2022.

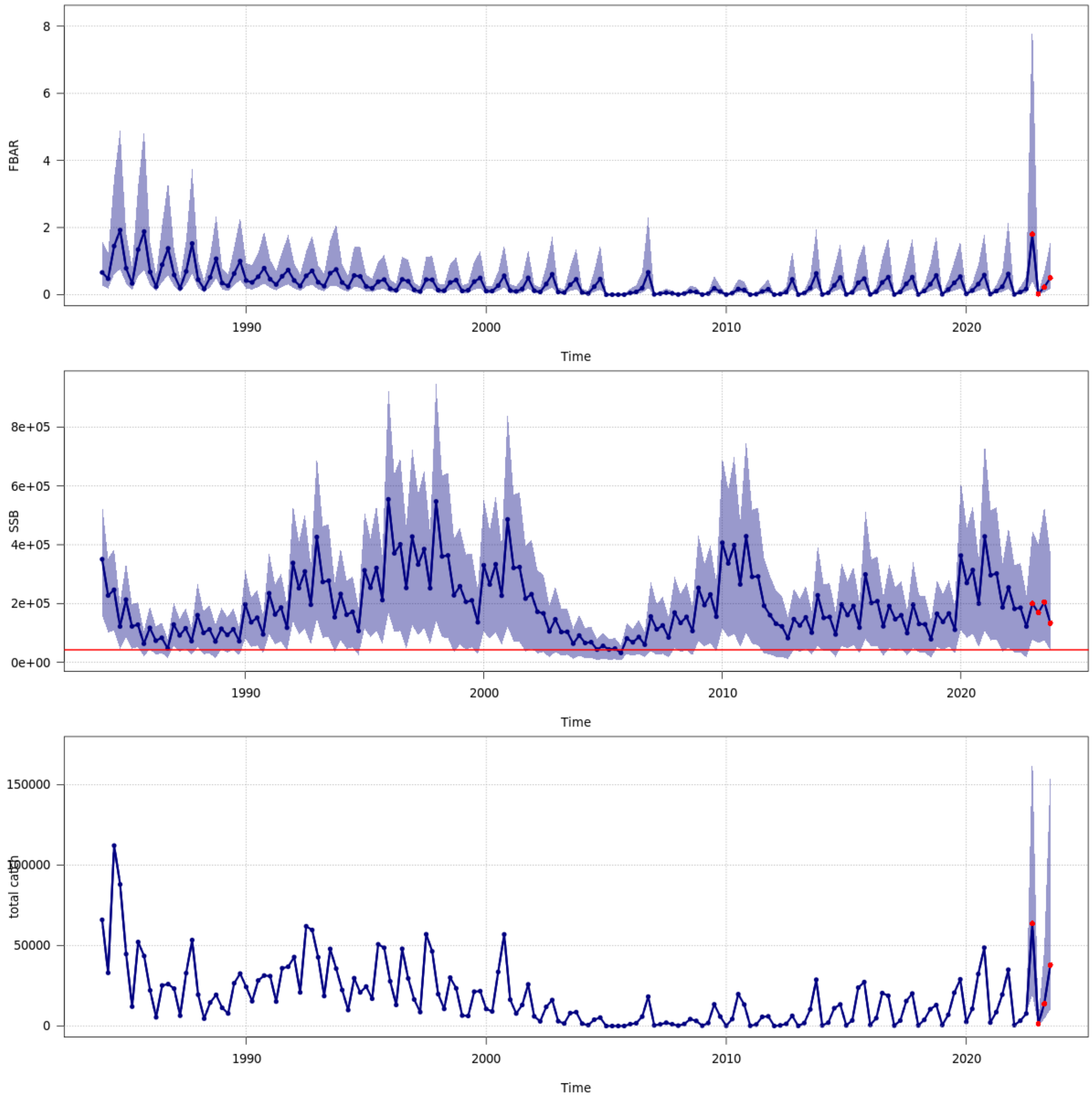


Figure 12.6.1. NORWAY POUT IV and IIIaN (Skagerrak). Forecast of fishing mortality, SSB and median catch (t) with F scaled such that the fifth percentile of the SSB distribution one year a head (1st October 2022) equals Blim.

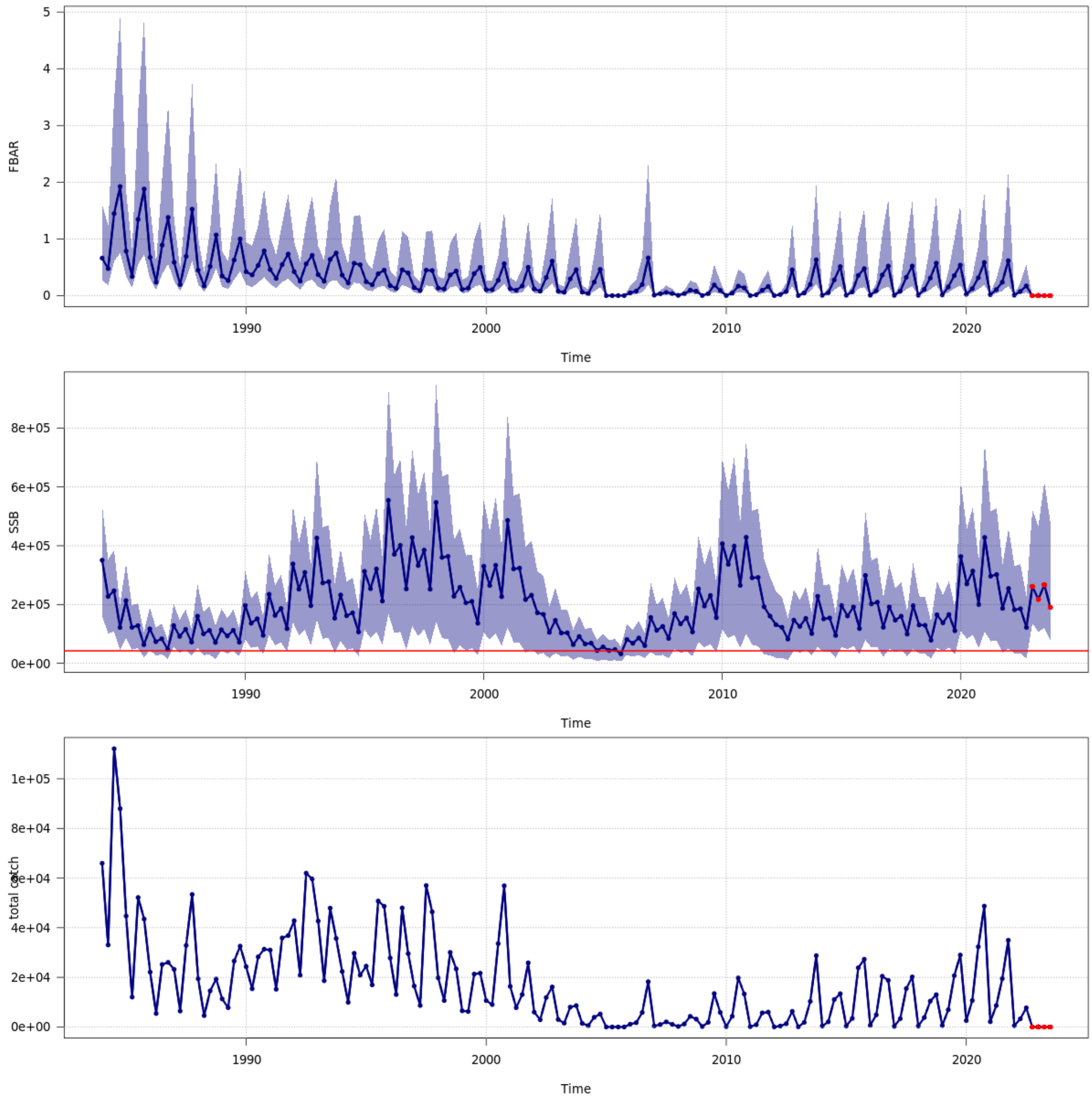


Figure 12.6.2. NORWAY POUT IV and IIIaN (Skagerrak). Forecast of fishing mortality, SSB and median catch (t) with F scaled to zero (no catch) for the period 1st October 2022 to 1st October 2023.

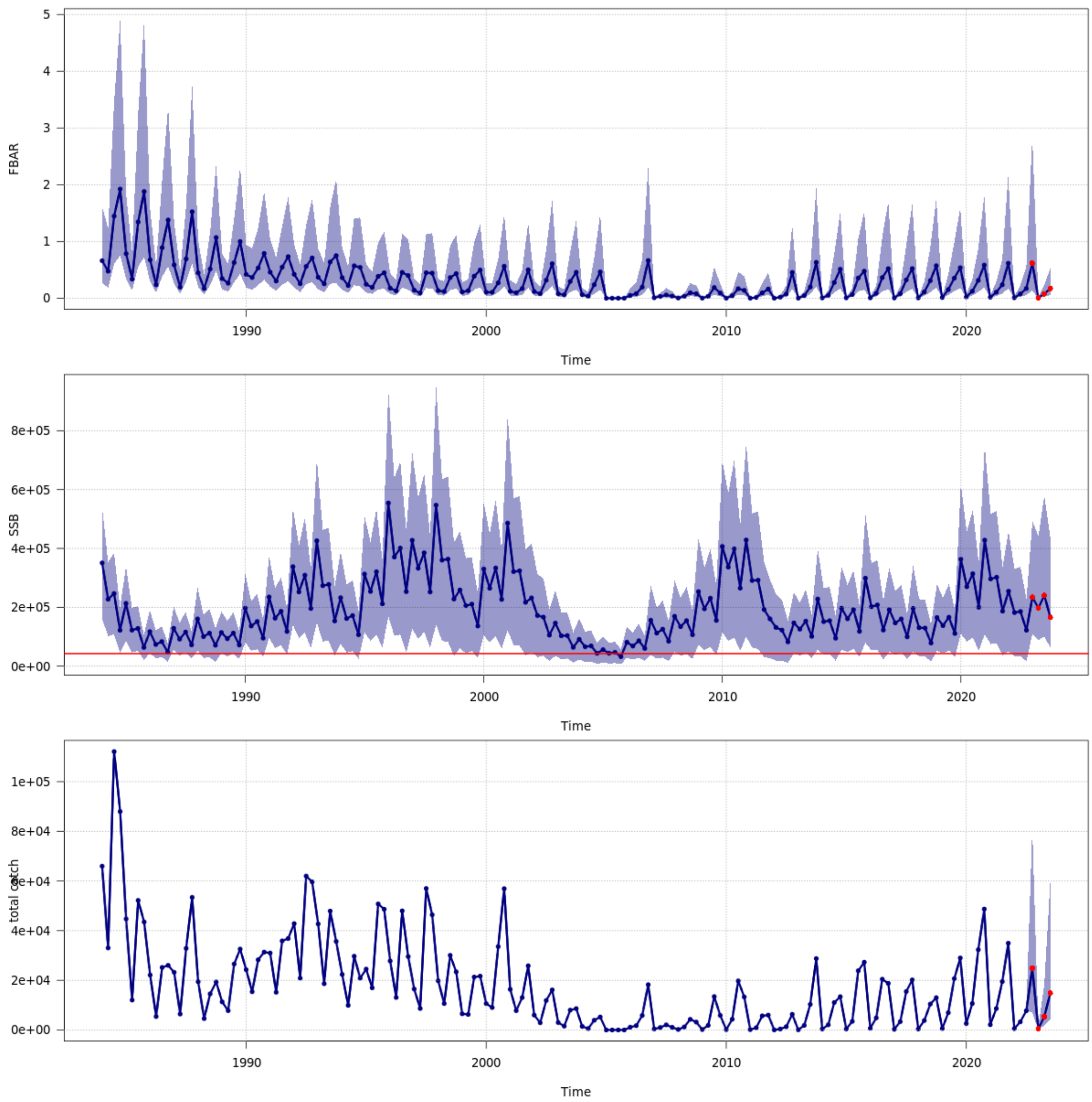


Figure 12.6.3. NORWAY POUT IV and IIIaN (Skagerrak). Forecast of fishing mortality, SSB and median catch (t) with F scaled to F status quo for the previous year to 1st October 2022.

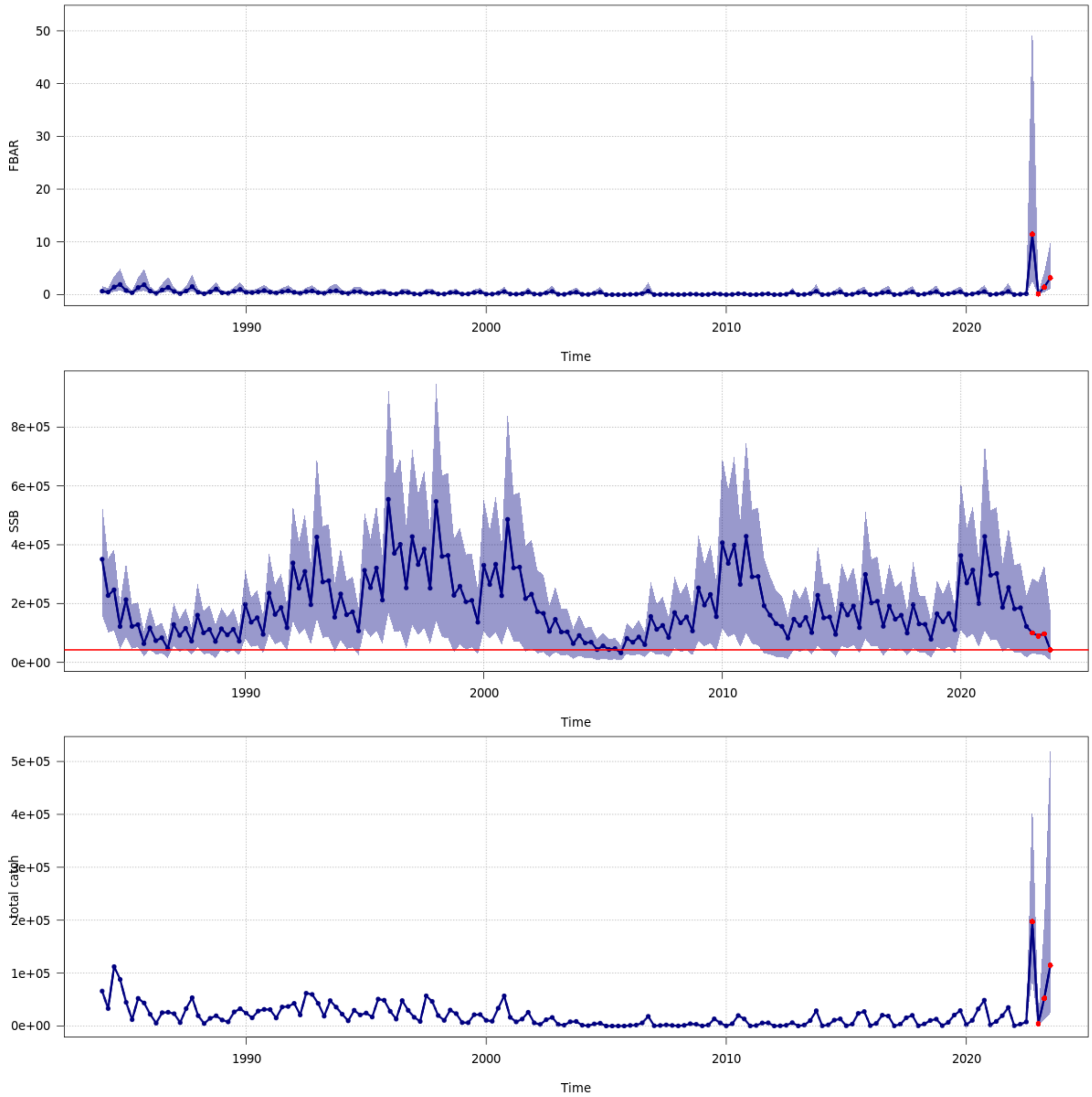


Figure 12.6.4. NORWAY POUT IV and IIIaN (Skagerrak). Forecast of fishing mortality, SSB and median catch (t) with F scaled such that the median of the SSB distribution one year a head (1st October 2023) equals Blim.

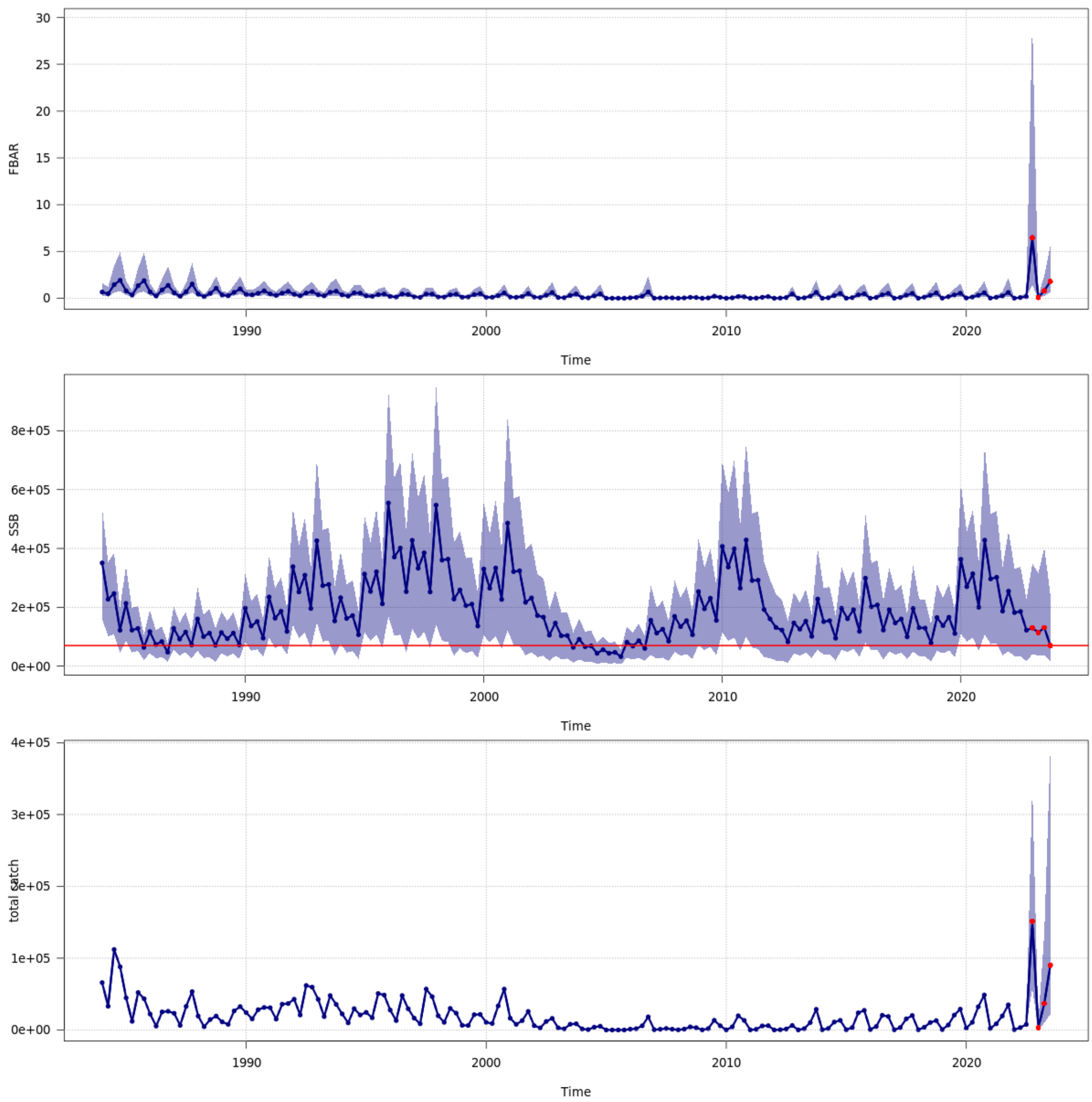


Figure 12.6.5. NORWAY POUT IV and IIIaN (Skagerrak). Forecast of fishing mortality, SSB and median catch (t) with F scaled such that the SSB distribution one year a head (1st October 2023) equals Bpa.

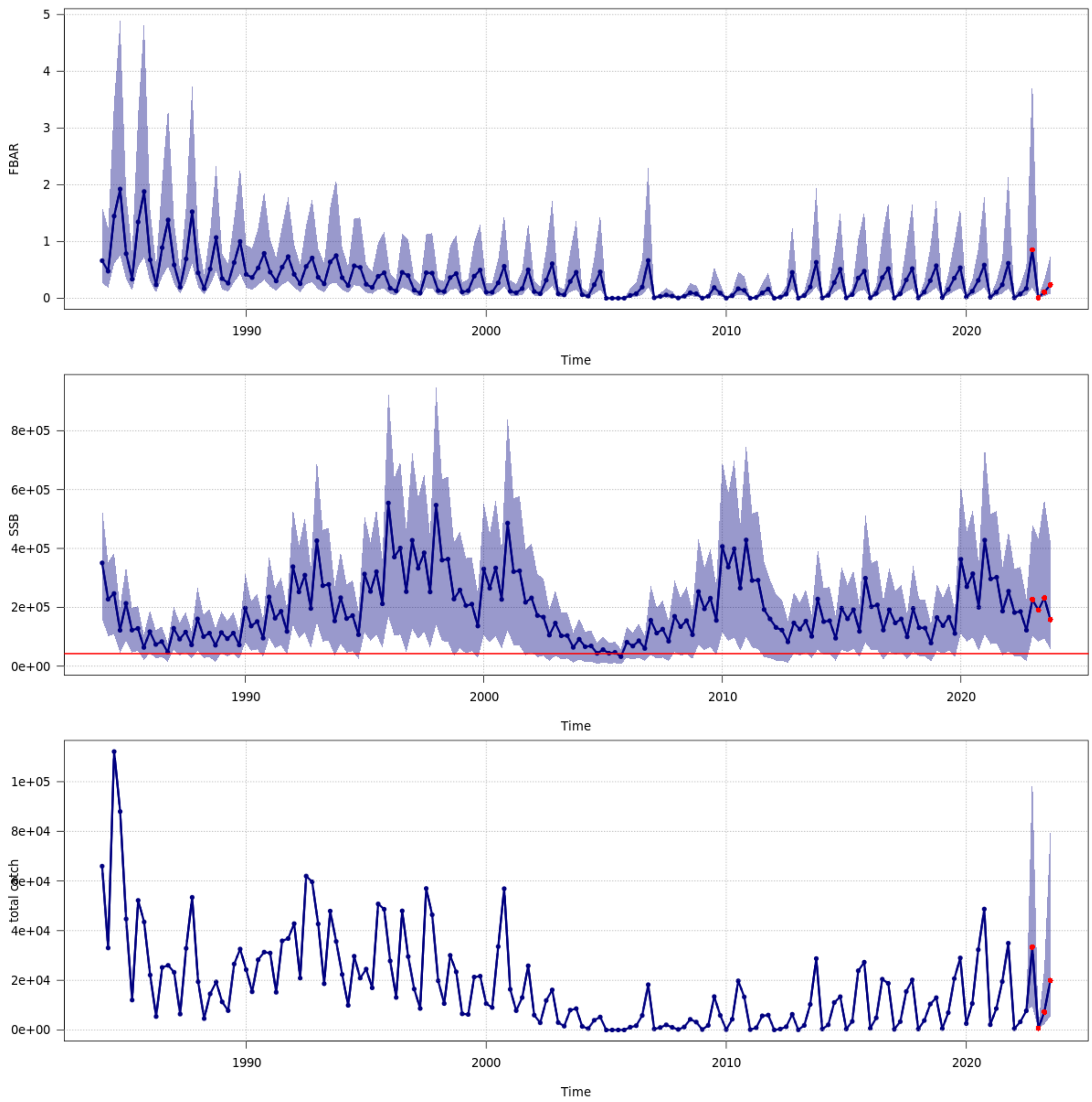


Figure 12.6.6. NORWAY POUT IV and IIIaN (Skagerrak). Forecast of fishing mortality, SSB and median catch (t) with F scaled to 0.3 (F_{cap} = 0.3) for the period 1st October 2022 to 1st October 2023.

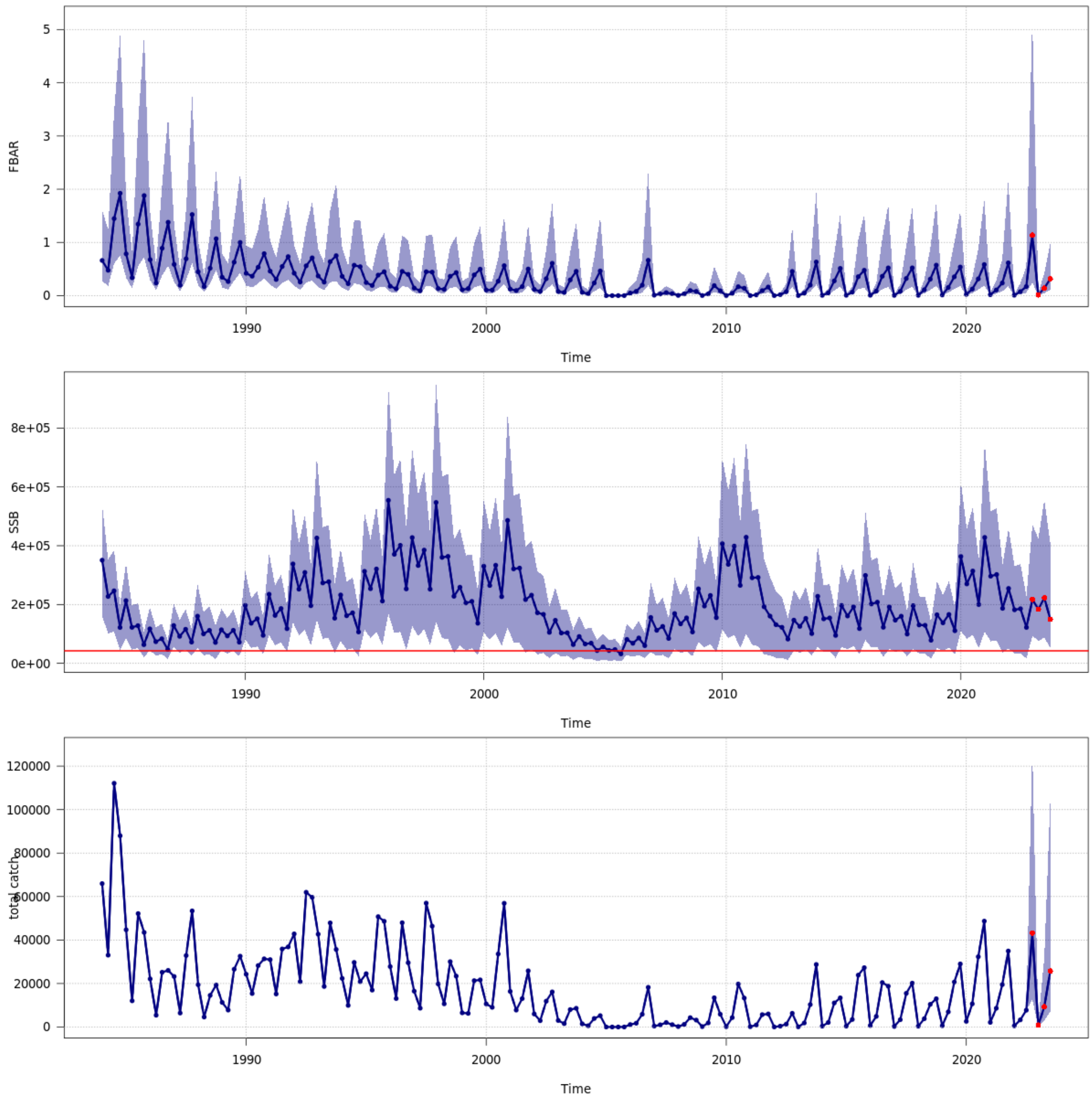


Figure 12.6.7. NORWAY POUT IV and IIIaN (Skagerrak). Forecast of fishing mortality, SSB and median catch (t) with F scaled to 0.4 (F_{cap} = 0.4) for the period 1st October 2022 to 1st October 2023.

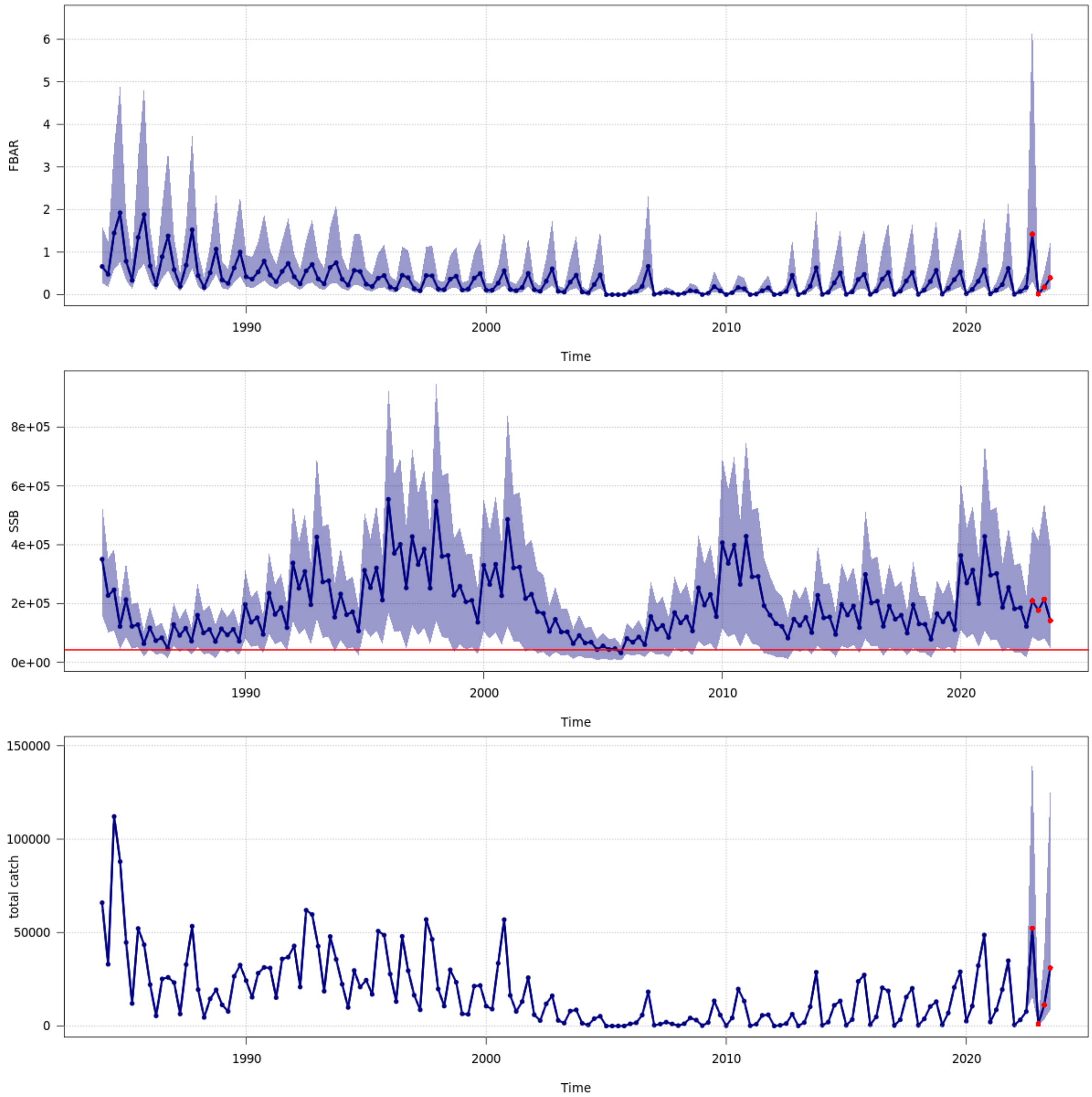


Figure 12.6.8. NORWAY POUT IV and IIIaN (Skagerrak). Forecast of fishing mortality, SSB and median catch (t) with F scaled to 0.5 (F_{cap} = 0.5) for the period 1st October 2022 to 1st October 2023.

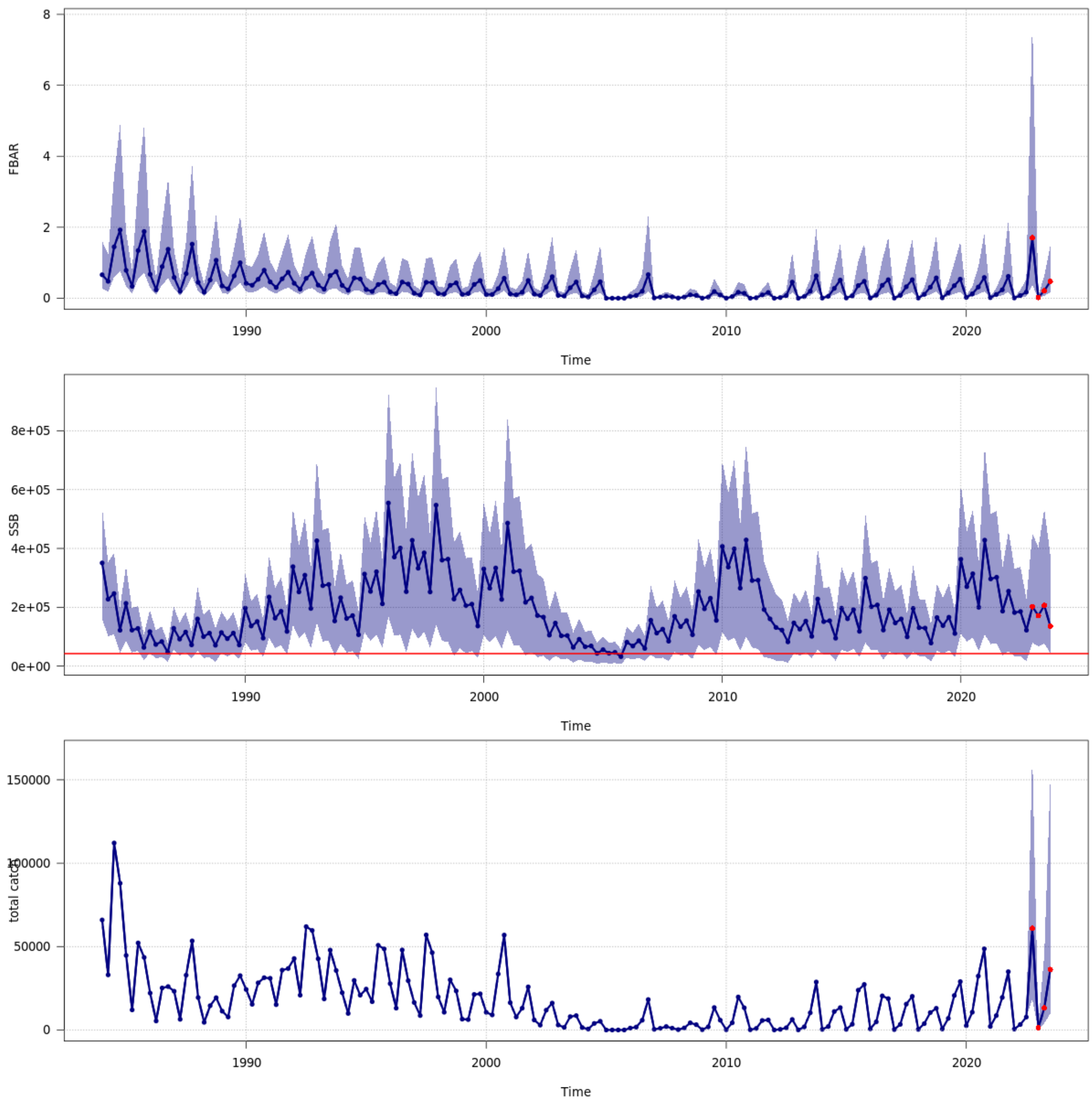


Figure 12.6.9. NORWAY POUT IV and IIIaN (Skagerrak). Forecast of fishing mortality, SSB and median catch (t) with F scaled to 0.6 (F_{cap} = 0.6) for the period 1[st] October 2022 to 1[st] October 2023.

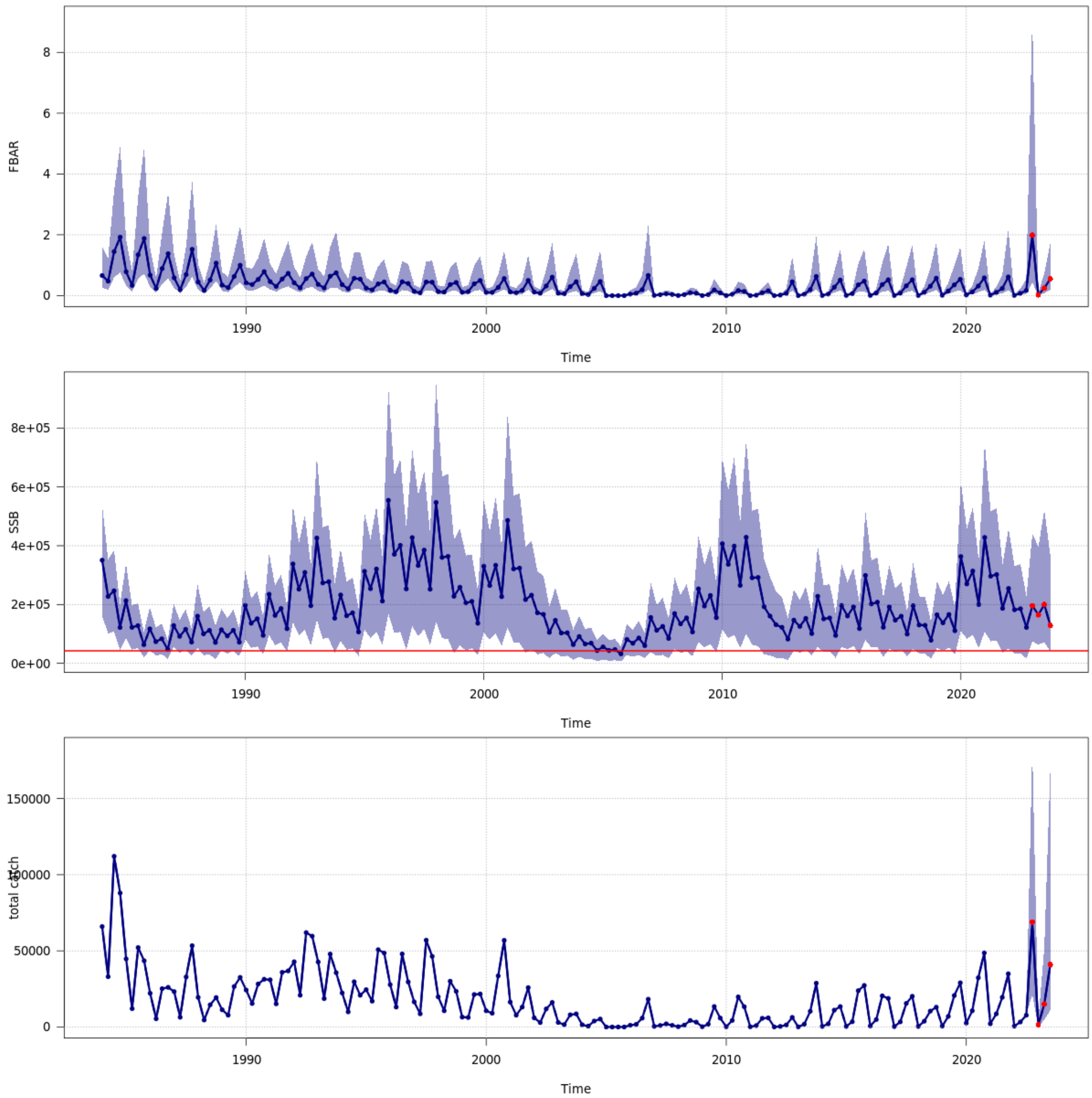


Figure 12.6.10. NORWAY POUT IV and IIIaN (Skagerrak). Forecast of fishing mortality, SSB and median catch (t) with F scaled to 0.7 (F_{cap} = 0.7) for the period 1st October 2022 to 1st October 2023.

13 Plaice in Subarea 4 (North Sea) and Subdivision 20 (Skagerrak)

The stock was benchmarked in 2022 and the stock Annex was updated. Therefore, only a comprehensive description of the stock assessment results and deviations from the stock annex are presented within this Section of the report.

13.1 General

13.1.1 Stock structure

Plaice in the Skagerrak (Subdivision 20) is considered to have two components: an Eastern and a Western. The latter occurs in a mix with plaice migrating in from the North Sea (Ulrich *et al.*, 2013) and the predominance of catches occurs on summer feeding aggregations in the Western Skagerrak. In a benchmark (WKPLE, 2015; ICES, 2015) it was decided that plaice in the Skagerrak would be assessed together with the North Sea stock.

In addition, as in previous years, 50% of the mature animals from 7.d in quarter 1 are included in the North Sea plaice assessment, since North Sea plaice migrates into the area in that season (ICES, 2010).

13.1.2 Ecosystem considerations

Available information on ecosystem aspects can be found in the Stock Annex. In addition, the ICES Working Group on the Ecosystem Effects of Fishing Activities (WGECO, ICES, 2014) met in April 2014 and addressed a specific question in relation to North Sea plaice, in response to a request from WGNSSK in 2013:

“According to WGNSSK estimates, the North Sea is currently ongoing a plaice outburst without precedent. However, plaice is not included in multispecies models, so the consequences of this outburst on the North Sea ecosystem are unclear and would potentially require additional focus”.

WGECO addressed the trends shown in the stock assessment of plaice, which show how increasing fishing pressure on the stock has progressively moved SSB away from the desired state (in the 1980s and 1990s), and then how management has rectified this situation in recent years, which has brought the North Sea plaice stock in a situation unlike any other over the whole 58-year period for which data is available. The group investigated a possible relationship of these trends with abundance of benthic biomass, which is a predominant food source for plaice. Q1 IBTS data showed a two-fold increase in demersal benthivore biomass over the last 29-year period of the survey, and that species composition of the demersal benthivore guild has changed as well. The data showed that predation loading by plaice on benthic invertebrates increased by a factor of 13.8 in just eleven years (2000–2011).

The increase in the consumption of benthic invertebrate prey by the whole demersal benthivore guild, and particularly by plaice, raises the question as to whether the abundance of benthic invertebrate prey might be becoming limiting. If the biomass of demersal benthivorous fish is approaching its carrying capacity, then growth rates in the dominant species in the guild might start to decline (which is in this case plaice growth rates). Computed growth coefficients for the 1956 to 2002 cohorts showed a strong declining linear trend over the whole period (albeit with clear systematic variation in the residuals), and this has been related to increasing water temperature in the North Sea. However, fitting a 4th order polynomial function to the data suggested a marked decline in cohort growth towards the end of the time-series. This is perhaps indicative of plaice becoming food limited, possibly suggesting that B_{MSY} targets for the stock might be marginally too high to be supported by available benthic invertebrate food supplies. However, this evidence is by no means conclusive as polynomial functions are known to show a tendency for marked swings at the extremes of the data range.

More in-depth analysis in WGECO 2018 using the recent years' data showed that the co-occurrence of reduced size at age and increasing stock abundance has led to a negative relationship in period 2006–2016. This correlative indication of density-dependent growth reduction, is further strengthened by a coinciding reduction in physical condition across a range of sizes, hinting that food scarcity may indeed be the mechanism behind the patterns (ICES, 2018b).

13.1.3 Fisheries

A basic description of the fisheries is available in the Stock Annex. In recent years, pulse trawling, aiming at reduction of fuel consumption and reduction of bottom disturbance, has been adopted in fisheries. In 2011, approximately 30 derogation licenses for pulse trawls were taken into operation, which increased to 42 in 2012. An additional 42 derogation licenses have been extended in spring 2014. In 2016 and 2018, ICES published advice on ecological and environmental effects of pulse trawling, compared to traditional beam trawls (ICES, 2016; ICES, 2018a). It was concluded that pulse trawling has fewer environmental and ecological effects than beam trawls. Pulse trawls have been increasingly used in the North Sea flatfish fisheries since 2009. Over this period, the fishing mortality has reduced and stock biomass has increased, mostly due to an overall decrease in effort. The shift in fishing method has resulted in a change in distribution of the fishery. Pulse trawling has increased in areas such as off the Thames estuary and the Belgian coast but decreased in others. This change is related to lighter gear, which can be used on softer grounds than the beam trawls (ICES, 2018a).

Following the EU decision in February 2019 to revise the technical measures regulations, pulse trawling is prohibited since 30 June 2021 which is expected to cause large changes in the Dutch beam trawl fleet in the coming years.

13.1.4 ICES Advice

The information in this Section is taken from the ICES advice sheet 2022:

ICES advises that when the MSY approach is applied, catches in 2023 should be no more than 150 705 tonnes.

13.1.5 Management

An EU multiannual management plan (MAP) has been agreed by the EU for this stock (EU, 2018). This plan is not adopted by Norway, thus, not used as the basis of the advice for this shared stock. ICES was requested by the EC to provide advice based on the MSY approach and to include the MAP as a catch option.

13.2 Data available

During the benchmark of the eastern channel (7.d) plaice stock (WKFLAT) it was decided that 50% of Q1 mature fish catches taken in the eastern channel are actually plaice from the North Sea stock migrating in and out of the area. Before 2015, 50% of the Q1 eastern channel (7.d) plaice landings were included in the assessment of the North Sea plaice stock. Since 2015, 50% of the mature fish in both landings and discards in Q1 were added to the North Sea stock and the time series was updated, such that in previous years also 50% of the mature catches from Q1 were added. See the stock annex for plaice in Division 7.d for further details.

During the benchmark on plaice (WKPLE ICES, 2015), it was decided that plaice from the Skagerrak would be added to the North Sea stock. Since then, the assessment has been a combined assessment with Skagerrak plaice.

13.2.1 InterCatch processing

Since 2012, national research institutes submitted landings and discard estimates by métier and quarter in InterCatch. Figures 13.2.1 and 13.2.2 show the landings and discards coverage by country and by métier in Subarea 4 and Subdivision 20. Approximately 53% and 62% of the landings in weight were sampled in Subarea 4 and Subdivision 20 respectively, to obtain information on age-composition. Of the metiers for which discards are monitored in sampling programmes, the largest part of these discards is covered in the TBB_DEF_70–99_mm fleet. In most discards monitoring programmes, age composition information is also collected. To raise the amount of discards for landings that had no discards and to raise the landings and discards for which no age distribution was known, the same grouping strategy was used (see table below). The TBB and OTB fleets that covered most of the catches each had their own group (TBB<100, TBB >=100, OTB/OTM<100, and OTB/OTM>=100). Other major groups include Seines, shrimper, gillnets. All discards raising and age allocations were done per quarter. If discards/age structures were present for data for the whole year only, these were added to all quarters. If there were no discards/age structures in a specific quarter and metier, a similar metier type (from the same quarter) or all other quarters (from the same metier) were used. Allocations to calculate the age compositions were done separately for discards and landings.

Summary of the imported/Raised/SampledOrEstimated data by area.

CatchCategory	RaisedOrImported	SampledOrEstimated	Area	CATON	perc
Landings	Imported_Data	Sampled_Distribution	27.4	15364	53
Landings	Imported_Data	Estimated_Distribution	27.4	13551	47
Discards	Imported_Data	Sampled_Distribution	27.4	26006	75
Discards	Raised_Discards	Estimated_Distribution	27.4	8327	24
Discards	Imported_Data	Estimated_Distribution	27.4	252.3	1
BMS landing	Imported_Data	Estimated_Distribution	27.4	20.2	100
Landings	Imported_Data	Sampled_Distribution	27.3.a.20	4200	62
Landings	Imported_Data	Estimated_Distribution	27.3.a.20	2575	38
Discards	Imported_Data	Sampled_Distribution	27.3.a.20	1343	51
Discards	Raised_Discards	Estimated_Distribution	27.3.a.20	1239	47
Discards	Imported_Data	Estimated_Distribution	27.3.a.20	45.8	2
BMS landing	Imported_Data	Estimated_Distribution	27.3.a.20	0	NA

Grouping strategies to raise discards and allocate age structures.

Group for discards raising and age allocation*	quarter + area	description
TBB<100(excluding CRU_16-31)	Each quarter + 4/320	Beam trawl, smaller mesh size
TBB>=100	Each quarter + 4/320	Beam trawl, larger mesh size
TBB/OTB_CRU_16-31	Each quarter + all area	shrimper
OTB/OTM-CRU/DEF/SPF<100(excluding CRU_16-31)	Each quarter + all area	Otter trawl, smaller mesh size
OTB/OTM-CRU/DEF/SPF>=100	Each quarter + all area	Otter trawl, larger mesh size
SSC/SDN<100	Each quarter + all area	Seines, smaller mesh size
SSC/SDN>=100	Each quarter + all area	Seines, larger mesh size
GNS/GTS/GTR<100	Each quarter + all area	Gillnet, smaller mesh size
GNS/GTS/GTR>=100	Each quarter + all area	Gillnet, larger mesh size
Others	All quarter + all area	All other metiers

*** all_0_0 are treated as >=100. TBB/OTB_CRU_16-31 is raised from OTB_CRU<100, because several countries have extremely high discard rates and their fisheries might have different regulations.**

For Subarea 4, 75% of the total discards in 2021 were obtained from sampling. For Subdivision 20, 51% of the total discards were obtained from sampling. BMS landings, where reported, were included as discards in the assessment since 2016.

13.2.2 Landings

According to ICES data, in 2021, BMS landings were 20 tonnes and majority were reported from UK. Meanwhile the official reported BMS landings were 204 tonnes from all countries. For the assessment in this report, BMS was treated as discards.

Total ICES estimated landings (including 7.d and Subdivision 20) of North Sea plaice in 2021 was 35 690 tonnes. Of these 28 915 tonnes came from the Subarea 4, 6 775 tonnes came from Subdivision 20, and 240 tonnes came from 7.d. The landings in Subarea 4 decreased 11.6% (of 2020). The landings in Subdivision 20 decreased 13.4% (of 2020). Total landings (in tonnes) are presented in Table 13.2.1 and landings in numbers at age in Table 13.2.2 and Figure 13.2.4. Since 2010, the majority of landings were age 3–6.

13.2.3 Discards

The discards time series used in the assessment includes Dutch, Danish, German and UK discards observations for 2000–2021, as described in the stock annex. From Belgium, discards data have been available as well but were only used in the assessment since 2012 when it became available in InterCatch. See Section 13.2.1 for more information on the use of InterCatch for raising discards rates across metiers and countries. The Dutch discards data for 2009 and 2010 were derived from a combination of the observer programme that has been running since 2000, and a new self-sampling programme. The estimates from both programmes were combined to come up with an overall estimate of discarding by the Dutch beam trawl fleet. Since 2011, estimates were derived exclusively from the self-sampling data. There is an on-going project within WMR to validate these estimates by examining matched (same vessel and haul) trips where both observer estimates and self-sampling estimates are derived.

To reconstruct the number of plaice discards at age before 2000, catch numbers at age data was reconstructed in 2005 based on a model-based analysis of growth, selectivity of the 80-mm beam trawl gear, and the availability of undersized plaice on the fishing grounds. Discards numbers at age are presented in Table 13.2.3 and Figure 13.2.4. Figure 13.2.3 presents a time series of landings, catches and discards from these different sources. The total discards weight has been gradually decreasing since our first year of observed discards 2000. The discards ratio are illustrated in Figure 13.2.6. Since 2010, the majority of discards were age 1–3.

13.2.4 Catch

The catches of 2021 in Subarea 4 reached 44% of the 143 419 tonnes catch TAC for 2021. The catches of 2021 in Subdivision 20 reached 49% of the 19 188 tonnes catch TAC for 2021. The total catch at age as used in the assessment including all landings and all discards are presented in Table 13.2.4. These include catch of NS plaice in the 1st quarter from 7.d and catch from the Subdivision 20. Table 13.2.5 presents details ICES catches estimates of NS plaice stock in Subarea 4, Subdivision 20 and in the 1st quarter from Subdivision 7.d. Landings-at-age, discards-at-age and catch-at-age plots are presented in Figures 13.2.4 and 13.2.5.

13.2.5 Weight-at-age

Stock weights at age are presented in Table 13.2.6. Stock weight at age has varied considerably over time, especially for the older ages. Landing, discards and catch weights at age are presented in Table 13.2.7, 13.2.8 and 13.2.9 respectively. Catch weights at age are derived from the discards and landings weights at age according to the relative contributions of each to the overall catch for each age. Figure 13.2.7 presents the stock, discards, landings and catch weights at age. Notably, there has been a long-term decline in the observed stock weight at age.

13.2.6 Maturity and natural mortality

During the benchmark in 2017, a time-varying maturity ogive was estimated using Dutch commercial landings 1957–2015, but the new ogives had marginal effect on the estimated SSB. Therefore, the previously-used, time-invariant maturity ogive (Table 13.2.10) was chosen.

An age-dependent natural mortality was adopted in the 2022 benchmark (ICES. 2022). A weight-dependent mortality was first estimated via Peterson-Wroblewski method based on the stock weight at age till 2020. The final natural mortality was then averaged across years for each age (Table 13.2.10). This age-dependent time-invariant M is expected to be fixed for the following assessment years.

13.2.7 Catch, effort and survey data

The following five survey indices are used in the plaice assessment:

- Beam Trawl Survey and IBTS Q3 combined (BTS-IBTS Q3); (1996–2021); Age 1–10^{+};
- Beam Trawl Survey RV Isis (BTS–Isis) for the older part of the time series; (1985–1995); Age 1–8
- Sole Net Survey 1 (SNS1); (1970–1999); Age 1–6
- Sole Net Survey 2 (SNS2); (2000–2021); Age 1–6
- IBTS Q1 plaice index; 2007–2021; Age 1–8^{+}.

The most important surveys for demersal fish species in the greater North Sea area are the BTS (3rd Quarter) and the IBTS (1st and 3rd Quarter). The BTS covers areas 4.b, 4.c and the Channel, while the IBTS also covers area 4.a and the Skagerrak and Kattegat (3.a). The spatial distributions of plaice biomass per haul for these 3 surveys in 2021 are illustrated in Figure 13.2.8. Both BTS-IBTS Q3 and IBTS Q1 indices were estimated using smoother based delta-GAM method (Berg *et al.*, 2014). The retrospective analysis of the two delta-GAM indices are shown in Figure 13.2.9, indicating very robust estimates across last 5 years.

An annual spatial abundance map could be estimated per age from the delta-GAM model for each of these two indices (Figure 13.2.10). The Q3 survey indicates that younger plaices are nursed in the Belgium-Netherlands-Germany-Denmark coastal area. As they get older, they move north-west towards the centre of North Sea and Scotland coastal area. On the other hand, the IBTS Q1 survey shows slightly different age distributions. This is likely due to the spawning and nursery season in Q1.

Table 13.2.11 and Figure 13.2.11 show the survey index values. Two moderately strong year class 2013 and 2016 were observed. A very strong 2018 year class was observed. Additionally, all surveys show an increasing trend for older fishes (age >= 5) during 2000 and 2015.

The internal consistency of the survey indices (Figure 13.2.12) appears relatively high for BTS-IBTS Q3, but low for the SNS and IBTS Q1 surveys. The log-catch curves of ages 1–6 for the surveys are illustrated in Figure 13.2.14. In general, SNS has a low selectivity for older ages. Compared to BTS, IBTS has a higher selectivity for older ages. Overall, all surveys show relatively consistent catch selectivity pattern over the time series (which is the assumption for the stock assessment), except for IBTS–Q1 where the time series is too short to validate.

The catch curves for both catches and surveys are illustrated in Figure 13.2.13 and 13.2.14. The catch and survey data are plotted together in Figure 13.2.15.

Before WGNSSK 2021, additional survey indices were used for recruitment estimates in the RCT3 analysis for short term forecast

- Demersal Fish Survey (DFS); (1990–2019); age–0;
- Sole Net Survey (SNS); (2000–2019); age-0

During WKNSROP 2020, it was decided that RCT3 analysis is only applicable during autumn update when new survey indices of the assessment year are available. Thus, RCT3 analysis on recruitment indices from these two surveys are no longer conducted in the WGNSSK May forecast.

13.3 Assessment

13.3.1 Model parameters and diagnostics

SAM assessment model was adopted since 2022 benchmark. The table below gives an overview of parameters used in the SAM assessment model:

```
$minAge

1

$maxAge

10

$maxAgePlusGroup

# Is last age group considered a plus group for each fleet (1 yes, or 0 no).

 1 0 1 1 0 0

$keyLogFsta

# Coupling of the fishing mortality states (normally only first row is used).

  0  1  2  3  4  5  6  7  8  8

 -1  -1  -1  -1  -1  -1  -1  -1  -1  -1

 -1  -1  -1  -1  -1  -1  -1  -1  -1  -1

 -1  -1  -1  -1  -1  -1  -1  -1  -1  -1

 -1  -1  -1  -1  -1  -1  -1  -1  -1  -1

 -1  -1  -1  -1  -1  -1  -1  -1  -1  -1

$corFlag

# Correlation of fishing mortality across ages (0 independent, 1 compound symmetry, 2 AR(1), 3 separable AR(1).

 2

$keyLogFpar

# Coupling of the survey catchability parameters (normally first row is not used, as that is covered by fishing mortality).

 -1  -1  -1  -1  -1  -1  -1  -1  -1  -1

  0  1  2  3  4  5  6  7  -1  -1

  8  9  10  11  12  12  12  12  12  12

 13  14  15  15  15  15  16  17  -1  -1

 18  19  20  21  22  23  -1  -1  -1  -1
```

24 25 26 27 28 29 -1 -1 -1 -1

$keyVarF

Coupling of process variance parameters for log(F)-process (normally only first row is used)

0 1 2 2 2 2 2 3 3 3

$keyVarLogN

Coupling of process variance parameters for log(N)-process

0 1 1 1 1 1 1 1 1 1

$keyVarObs

Coupling of the variance parameters for the observations.

0 1 1 1 1 1 1 2 2 2

3 4 4 4 4 4 5 5 -1 -1

6 7 7 7 7 7 7 8 9 10

11 12 12 12 12 12 13 13 -1 -1

14 15 16 17 17 17 -1 -1 -1 -1

18 19 20 21 22 22 -1 -1 -1 -1

$obsCorStruct

Covariance structure for each fleet ("ID" independent, "AR" AR(1), or "US" for unstructured). | Possible values are: "ID" "AR" "US"

"ID" "ID" "ID" "AR" "AR" "AR"

$keyCorObs

Coupling of correlation parameters can only be specified if the AR(1) structure is chosen above.

NA's indicate where correlation parameters can be specified (-1 where they cannot).

#1-2 2-3 3-4 4-5 5-6 6-7 7-8 8-9 9-10

NA NA NA NA NA NA NA NA NA

NA NA NA NA NA NA NA -1 -1

NA NA NA NA NA NA NA NA NA

0 0 0 0 0 0 0 -1 -1

1 1 1 1 1 -1 -1 -1 -1

2 2 2 2 2 -1 -1 -1 -1

$fbarRange

lowest and highest age included in Fbar

2 6

Model diagnostics including standardized catch and survey residuals and retrospective plots are illustrated in figures 13.3.2–13.3.4. There are age and year patterns in both catch (plus age) and BTS-IBTSQ3 survey (age 5+ in last 10 years) residuals, implying some lack of fitting from the model. Further investigations will be conducted to improve the assessment. The retrospective plot for SSB shows some downwards revise, but the Mohn's rho is within acceptance limits and peels fall within confidence intervals.

13.3.2 Assessment results

Figure 13.2.3 illustrates the trends in observed catch, landing and discards. Reported landings gradually increased up to the late 1980s and then rapidly declined until 1995, in line with the decrease in TAC. The landings show a general decline from 1989 onwards, increasing slowly but steadily since 2007, and decreasing again since 2016. Discards were particularly high in 1997 and 1998 (reconstructed), and in 2001 and 2003 (observed), resulting from strong year classes.

Figure 13.3.1 and Table 13.3.4 present the model estimated F(2–6), SSB, and recruitment. The estimated SSB in 2021 is 834 755 tonnes and it is well above MSY $B_{trigger}$. SSB has markedly increased since 2008, following a substantial reduction in fishing mortality (F) since 1999. The estimated F in 2021 is 0.080 year^{-1}, and it is below F_{MSY} since 2007. The estimated recruitment in 2021 is 3 599 961 thousand.

The estimated model parameters are presented in Table 13.3.1. The estimated fishing mortality and stock numbers are shown in Tables 13.3.2–13.3.3 and Figure 13.3.5, respectively.

The stock dynamics are partly affected by the occurrence of strong year-classes. Between 2000 and 2010, recruitment has been increasing. After 2010, recruitment has been fluctuating around its geometric mean. A high 2019 recruitment has been detected in all surveys (BTS-IBTS Q3, SNS and DYFS), but not shown in catches. The increased stock size in 2000-2014 is also partly the direct consequence of reduced fishing mortality. Additionally, the age composition in SSB (Figure 13.3.6) implies that the weight of older aged plaices (age >= 8) have been increasing since 2010. Information from surveys (BTS, IBTS-Q3, SNS and DFS) implies that older fishes are likely migrating to the north western part of the North Sea (ICES 2019a), where the targeted fishing effort is low (Figure 13.3.7). The leave-one-out analysis (Figure 13.3.8) indicates that BTS-IBTS Q3 is dominating the assessment, which is consistent to the fact that this survey has the highest area and age coverage as well as the lowest uncertainty in survey indices.

13.4 Short-term forecasts

A stochastic short-term forecast was conducted under SAM structure. This includes simulating from the uncertainties of stock number, F, N process error in survival. In forecasting, the process error for F is switched off. The settings of the forecast are listed in the table below.

Variable	Assumption	arguments in SAM forecast function
Initial stock size	Starting populations are simulated from the estimated distribution at the start of the base year (including co-variances).	year.base=last_data_year; deterministic=FALSE nr_sims=5001
survival	Forecast according to N processes	deterministic=FALSE
Maturity	Fixed values, time-invariant	-
Natural mortality	Fixed age-dependent Peterson M, determined during WKNSCS2022	-
F and M before spawning	zero	-
Weight at age in the catch	Average over the last 3 years	ave.years=last 3 years
Weight at age in the stock	Average over the last 3 years	ave.years= last 3 years

Variable	Assumption	arguments in SAM forecast function
Exploitation pattern	Simulated according to the estimated last data year exploitation pattern and its estimation uncertainty	overwriteSelYears=FALSE processNoiseF=FALSE
Median Fbar value in intermediate year	last data year (Fsq)	fval = c(...,Flast,...,...)
Proportion of landing	Average over the last 3 years	ave.years=last 3 years; splitLD = TRUE
Recruitment in intermediate year	Sampling from recent 10 years time interval, include the last data year, since the estimation has low uncertainty	rec.years=recent 10 years
Recruitment in TAC year	Sampling from recent 10 years time interval, include the last data year, since the estimation has low uncertainty	rec.years=recent 10 years

Given the choice of recruitment and F in the intermediate year, the estimated median values for the catches and stock size are listed below.

Assumption	$F_{(2–6)}$ 2022	SSB 2023	Recruitment 2022	Landings 2022	Discards 2022
F2022 = F2021	0.080	977 491 t	3 952 706 thousand	45 821 t	33 953 t

A series of F options were assumed for the TAC year. Resulting management options for 2023 are given in Table 13.5.1. The forecasting under Fmsy option is illustrated in Figure 13.4.1

13.5 Data analysis

The delta-GAM survey indices were calculated using the R surveyIndex package (version 1.9). The stock assessment using SAM model (Nielsen and Berg, 2014) was carried out using the stockassessment package (version 0.11.0) in R (version 4.0.2).

Since 2013, ICES does not operate with external review groups anymore. Audits were done by internal reviewers (members of the WGNSSK group) and potential issues were directly discussed between the auditors and the stock assessor. Therefore, there is no written review to be presented here.

13.6 Biological reference points

The latest F_{MSY} reference points were calculated in 2022 benchmark.

Framework	Reference point	Value	Technical basis	Source
MSY approach	MSY $B_{trigger}$	473 850	Bpa	ICES (2021)
	F_{MSY}	0.152	EqSim analysis based on the recruitment period 1957–2020.	ICES (2021)
	F_{MSY_upper}	0.182	$F_{p.05}$ with AR	ICES (2021)
	F_{MSY_lower}	0.117	Lower range of F_{MSY}	ICES (2021)
Precautionary approach	B_{lim}	341 003	Bloss: the lowest estimated SSB in the time series, which equals the SSB of year 1996.	ICES (2021)
	B_{pa}	473 850	$B_{lim} \times \exp(1.645 \times 0.2) \approx 1.4 \times B_{lim}$	ICES (2021)
	F_{lim}	0.270	EqSim analysis based on the recruitment period 1957–2020.	ICES (2021)
	F_{pa}	0.182	$F_{p.05}$ with AR: The F that provides a 95% probability for SSB to be above B_{lim}.	ICES (2021)

13.7 Quality of the assessment

The assessment was updated during a benchmark in early 2022 (ICES 2022a). A combined BTS and IBTS-Q3 index was applied to replace the two individual survey indices. Age-specific natural mortalities were applied to replace the fixed 0.1 value across all ages. The stock assessment model was changed from AAP to SAM. Reference points were updated.

The benchmark updates led to changes in the trajectory of fishing pressure, SSB and recruitment of the stock, including a reduction in the estimated proportion of older fish in the stock (the plus group accounts for 48% of 2020 SSB in 2021 assessment to 17% in the current assessment).

13.8 Status of the stock

SSB in 2021 is estimated around 834 755 tonnes which is well above MSY $B_{trigger}$, B_{pa}, and B_{lim}. Fishing mortality in 2021 is estimated to be at a value of 0.080, which is below F_{MSY} of 0.152 (Figure 13.3.9).

13.9 Management considerations

Plaice is mainly taken by beam trawlers in a mixed fishery with sole in the southern and central part of the North Sea. There are a number of EC regulations that affect the fisheries on plaice and sole in the North Sea, e.g. as a basis for setting the TAC, limiting effort, minimum landing size and minimum mesh size.

13.9.1 Multiannual plan North Sea

An EU multiannual management plan (MAP) has been agreed by the EU for this stock (EU, 2018). There is no agreement with Norway regarding this plan, and it is not used as the basis of the advice for this shared stock. ICES was requested by the EC and UK to provide advice based on the MSY approach and to include F_{MSY} ranges in the catch scenarios.

13.9.2 Effort regulations (North Sea)

Regulated effort restrictions in the EU were introduced in 2003 (annexes to the annual TAC regulations) for the protection of the North Sea cod stock. In addition, a long-term plan for the recovery of cod stocks was adopted in 2008 (EC regulation 1342/2008). In 2009, the effort management programme switched from a days-at-sea to a kW–day system (EC regulation 43/2009), in which different amounts of kW–days are allocated within each area by member state to different groups of vessels depending on gear and mesh size. Effort ceilings are updated annually. A minor part of the fleets exploiting sole, i.e. otter trawls (OTB) with a mesh size equal to or larger than 100 mm included in Figure 13.2.1, have since 2009 been affected by the regulation. The beam trawl fleet (BT2) was affected by this regulation only once in 2009 but not afterwards.

The overall fleet capacity and deployed effort of the North Sea beam trawl fleet has been substantially reduced since 1995, likely due to a number of reasons, including the above-mentioned effort limitations for the recovery of the cod stock. 25 vessels were decommissioned in 2014. In addition, the current sole and plaice long-term management plan specifically reduces effort as a management measure. However, the evaluation of amendments to the plan in 2012 showed that the plan is consistent with the precautionary approach and the principle of maximum sustainable yield (MSY) also without reductions of effort (Coers *et al*., 2012).

Between 2014 and 2018, the majority of the Dutch beam trawlers have switched to pulse trawls, resulting in reallocation of fishing effort to fishing grounds in the southern part of Division 4.c targeting sole. The discards ratio for plaice has been increasing in the same period (Figure 3), from 40% in 2014 to 51% in 2021. Following the EU decision in February 2019 to revise the technical measures regulations, pulse trawling is prohibited since 30 June 2021 which is expected to cause large changes in the Dutch beam trawl fleet in the coming years.

13.9.3 Technical measures

Technical measures applicable to the mixed flatfish beam-trawl fishery in the southern North Sea where sole has become relatively more abundant, affect both sole and plaice. The minimum mesh size of 80 mm selects sole at the minimum landing size. However, this mesh size generates high discards of plaice with a larger minimum landing size than sole. For the overall fleet the discards ratio has been slightly decreasing since 2003 and increasing up again since 2016. In 2020, discards ratio was approximately 48% by weight. Mesh enlargement would reduce the catch of undersized plaice, but would also result in loss of marketable sole. Furthermore, the size selectivity of the fleet may lead to a shift in the age and size at maturation. For example, in recent years plaice and sole have become mature at younger ages and at smaller sizes than in the past (Grift *et al*., 2003). The introduction of the Omega (mesh size) meter in 2010 has led to a slight increase in the effective mesh size in the fishery.

Technical management measures have caused a shift towards two categories of vessels: 2000 HP (the maximum engine power allowed) and 300 HP. The 300 HP vessels are allowed to fish within the 12–nautical mile coastal zone and in the Plaice Box. The Plaice Box is a partially closed area along the continental coast that was implemented in phases, starting in 1989. The area has been closed to most categories of vessels >300 HP all year round since 1995. The most recent EU-funded evaluation by Beare *et al*. (2010) reported the Plaice Box as having very little impact on the plaice stock.

13.10 Issues for future benchmarks

13.10.1 Data

- Plaice have heterogeneous age distributions in the North Sea: younger ages are distributed more closely to coastal area while older ages are distributed towards north-west of the North Sea. In recent years, strong younger age signals appeared in IBTS Q3 survey around Scotland coast. The accuracy and uncertainty of these signals need to be investigated, e.g., age readings, gear selectivity (Scottish gear has a different selectivity).
- Information from surveys (BTS, IBTS-Q3, SNS and DFS) implies that older fishes are likely migrating or expanding to the north western part of the North Sea (ICES, 2019). Further investigations are needed to confirm the spatial changes. If so, the current several surveys with not fully overlapped spatial coverages are no longer suitable for stock assessment. A combined survey index of all surveys needs to be considered.
- Explain stock ID trend and differences between North Sea and north west of North Sea, including genetics, maturity, mortality, sex-ratio, growth rate, etc.

13.10.2 Assessment

- Residual age and year patterns in BTS-IBTS Q3 survey as well as plus age in catches need to be solved.
- Reduce “error” in discards estimation by including non-zero survival in assessment

13.10.3 Short-term forecast

- The recruitment signal of age 0 in SNS and DFS surveys are no longer used in short term forecast. A new method needs to be considered to include SNS and DYFS age 0 indices in assessment model to predict recruitment in the intermediate year, e.g. combined indices of all surveys including age 0.

13.11 Reference

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Table 13.2.1. Plaice in Subarea 4 and Subdivision 20 (7.d Q1 not included): Official landings, ICES landings and TAC in tonnes.

North Sea														Skagerrak	
YEAR	Belgium	Denmark	France	Germany	Nether-lands	Norway	Sweden	UK	Others	Total	Un- allocated	ICES estimate	TAC NS	Total	TAC_SK
1982	6755	24532	1046	3626	41208	17	6	20740		97930	56616	154546	140000		
1983	9716	18749	1185	2397	51328	15	22	17400		100812	43218	144030	164000		
1984	11393	22154	604	2485	61478	16	13	16853		114996	41153	156149	182000		
1985	9965	28236	1010	2197	90950	23	18	15912		148311	11527	159838	200000		
1986	7232	26332	751	1809	74447	21	16	17294		127902	37445	165347	180000		
1987	8554	21597	1580	1794	76612	12	7	20638		130794	22876	153670	150000	15694	
1988	11527	20259	1773	2566	77724	21	2	24497	43	138412	16063	154475	175000	12858	
1989	10939	23481	2037	5341	84173	321	12	26104		152408	17410	169818	185000	7710	
1990	13940	26474	1339	8747	78204	1756	169	25632		156261	-21	156240	180000	12078	
1991	14328	24356	508	7926	67945	560	103	27839		143565	4438	148003	175000	8685	
1992	12006	20891	537	6818	51064	836	53	31277		123482	1708	125190	175000	11823	11200
1993	10814	16452	603	6895	48552	827	7	31128		115278	1835	117113	175000	11407	11200
1994	7951	17056	407	5697	50289	524	6	27749		109679	713	110392	165000	11334	11200
1995	7093	13358	442	6329	44263	527	3	24395		96410	1946	98356	115000	10766	11200
1996	5765	11776	379	4780	35419	917	5	20992		80033	1640	81673	81000	10517	11200
1997	5223	13940	254	4159	34143	1620	10	22134		81483	1565	83048	91000	10292	11200
1998	5592	10087	489	2773	30541	965	2	19915	1	70365	1169	71534	87000	8431	11200
1999	6160	13468	624	3144	37513	643	4	17061		78617	2045	80662	102000	8719	11200
2000	7260	13408	547	4310	35030	883	3	20710		82151	-1001	81150	97000	8826	11200
2001	6369	13797	429	4739	33290	1926	3	19147		79700	2147	81847	78000	11653	9400

	North Sea													Skagerrak	
YEAR	**Belgium**	**Denmark**	**France**	**Germany**	**Nether-lands**	**Norway**	**Sweden**	**UK**	**Others**	**Total**	**Un- allocated**	**ICES estimate**	**TAC NS**	**Total**	**TAC_SK**
2002	4859	12552	548	3927	29081	1996	2	16740		69705	512	70217	77000	8789	6400
2003	4570	13742	343	3800	27353	1967	2	13892		65669	820	66489	73250	9110	1400
2004	4314	12123	231	3649	23662	1744	1	15284		61008	428	61436	61000	9090	9500
2005	3396	11385	112	3379	22271	1660	0	12705		54908	792	55700	59000	6764	7600
2006	3487	11907	132	3599	22764	1614	0	12429		55933	2010	57943	57441	9565	7600
2007	3866	8128	144	2643	21465	1224	4	11557	-	49031	713	49744	50261	8747	8500
2008	3396	8229	125	3138	20312	1051	20	11411		47682	1193	48875	49000	8657	9300
2009	3474	NA*	NA*	2931	29142	1116	1	13143	-	NA*	-	54973	55500	6748	9300
2010	3699	435	383	3601	26689	1089	5	14765	-	50666	10008	60674	63825	9057	9300
2011	4466	11634	344	3812	29272	1223	3	15169	-	65923	1463	67386	73400	8251	7900
2012	4862	12245	281	3742	32201	1022	5	16888	-	71246	2584	73830	84410	7611	7900
2013	6462	13650	249	4903	33537	843	3	19334	-	78982	-77	78905	97070	6911	9142
2014	7105	12003	276	4203	29306	577	5	17370	-	69179	1668	70847	111631	9004	10056
2015	5522	14401	223	5171	32074	169	7	17240	-	74807	156	74963	128376	10171	10056
2016	6659	16398	169	4371	32227	94	9	18731	-	78659	2400	81059	131714	10883	11766
2017	5317	12518	151	2526	28775	67	5	14993	0	64352	1090	65442	129917	8467	17639
2018	4894	9666	112	2580	22586	69	3	9603	0	49513	1270	50783	112643	5958	15343
2019	3912	6583	61	2059	19289	57	3	7410	0	39374	596	39970	125435	4614	16782
2020	2560	5636	25	1396	16870	37	5	5582	0	32110	626	32736	146852	5179	19647
2021	2898	4901	9	1255	14757	24	4	4859	0	28708	207	28915	143419	4286	19188

*** Official estimates not available.**

Table 13.2.2. Plaice in Subarea 4 and Subdivision 20: Landings (SOP corrected) in numbers by age (including 1st quarter of 7.d) in thousands as input.

year	age									
	1	2	3	4	5	6	7	8	9	10+
1957	0	4792	66428	49659	35282	9867	12248	10026	5522	12059
1958	0	7581	23612	65979	36274	20836	8696	8507	6497	13981
1959	0	16914	31085	26040	41988	23432	14173	6547	6739	16530
1960	0	5998	62285	51359	21462	27510	14280	9073	5121	15253
1961	0	2299	33913	68965	33209	12958	14909	9900	6089	14889
1962	0	2075	34677	64548	48387	19939	8757	8733	5081	12373
1963	0	4424	21886	78412	55414	32413	13096	6965	7183	16912
1964	0	14818	40789	65219	57837	37368	15937	6644	4010	17012
1965	0	9913	42438	53486	43919	30320	18464	8602	4237	17686
1966	0	4220	66196	52428	37336	27870	16801	10981	6585	15201
1967	0	6101	30905	115157	42204	22490	16496	8163	6861	11397
1968	0	9750	41883	39251	127220	17638	10642	10396	4039	13754
1969	3	15892	47819	38185	37657	107955	11016	6440	8669	17029
1970	74	16850	49861	54712	39642	34174	76862	6149	4078	14459
1971	20	30568	49876	34580	26919	23659	17471	30711	6626	17468
1972	2296	37561	63958	54402	23695	17479	14787	11211	19111	16094
1973	1332	33342	62095	76769	44397	14517	9335	10347	6392	25194
1974	2305	23972	57595	43677	42588	20391	8300	6554	5773	22790
1975	1042	29877	65465	33211	27004	22509	12613	6292	4362	20923
1976	2892	34497	79621	98846	14129	10156	9352	6553	3022	12871
1977	3225	57061	43359	66120	83841	9157	5922	5030	4068	9206
1978	1102	58412	60114	52398	48310	34240	5728	3232	2333	7201
1979	1316	57933	118662	48879	47805	39864	24187	4154	2802	9272
1980	996	66095	136274	79035	25548	18321	14018	8621	1898	5497
1981	259	103354	125928	59565	36670	12750	9805	8295	5005	6091
1982	3373	48354	212188	71167	29191	16975	7704	5551	4539	8775
1983	1214	119696	115332	100473	29591	12960	8238	4224	3013	8308
1984	108	63507	280481	62835	41492	15417	6842	5593	2729	6551
1985	120	72806	146839	201629	37939	17106	7441	3780	2813	5830
1986	1669	66935	165986	106461	101684	27971	9839	4704	2834	7083
1987	1	85153	118416	120782	81304	44590	13539	4669	2346	5610
1988	1	15200	253815	85347	59950	31492	19347	6198	3434	6402
1989	1254	46810	108272	238243	58767	21667	11605	8025	2321	5806
1990	1546	33766	104796	119829	169465	29946	9053	4689	3803	4206
1991	1425	43064	87196	122233	76075	78728	15410	5390	3215	5634
1992	3386	43769	86358	81470	88534	37542	30444	7229	3295	6976
1993	3416	53555	99805	80856	63275	35042	14745	11500	3704	5883

year	age									
	1	2	3	4	5	6	7	8	9	10+
1994	1375	44554	105863	86992	47577	27680	17279	6661	5449	5458
1995	7779	36761	82649	84778	47911	24572	14746	5285	2495	3896
1996	1103	43346	68155	52961	37285	19160	12400	5881	2799	4989
1997	897	43122	88687	49362	31750	18673	9518	5037	3054	4400
1998	197	30594	74441	62339	22793	9151	5703	2870	1983	3360
1999	549	8690	158088	47391	31778	14077	4038	2625	1597	3234
2000	2603	15656	40819	171994	25935	12586	2979	1135	953	2121
2001	4523	37095	58678	57195	101524	11492	4739	1212	650	2364
2002	1229	15868	60204	55511	44243	43066	6527	2256	794	1638
2003	700	44801	50607	54864	34689	20311	18128	1774	689	880
2004	544	12049	119093	39053	23766	13309	5152	4774	460	569
2005	2948	18885	29734	90989	20175	10900	5905	2760	2303	647
2006	363	20214	79934	34221	51057	8057	5589	2301	1318	1408
2007	1436	21357	41941	55949	20379	21837	3095	2011	604	1303
2008	400	13190	52382	45336	34035	7566	8066	978	735	936
2009	1563	12420	61907	42545	24886	18544	3400	4260	587	821
2010	2114	19874	49030	69702	25181	12622	9766	1866	2520	1267
2011	407	12977	45353	62017	51581	14815	6643	6984	1261	2743
2012	163	6164	60603	62070	44968	32037	7556	3402	3482	1924
2013	550	10530	63366	77056	42315	29486	15349	3955	2468	3795
2014	7	5384	40649	77966	52266	21932	12955	8387	2472	3440
2015	0	3844	42673	67065	60967	32309	12793	8902	4055	4834
2016	0	4179	39190	85205	60972	39883	19146	7710	5310	5125
2017	27	5289	24694	58141	57766	30891	16860	7600	3068	3213
2018	17	7829	24768	34001	43504	31018	15991	8987	5394	4159
2019	0	6528	43711	32251	18781	18124	11446	6948	3924	4055
2020	80	5638	19007	44780	19082	10224	11645	7614	4813	6395
2021	35	6396	21013	25221	32858	8703	5309	5744	3807	4373

Table 13.2.3. Plaice in Subarea 4 and Subdivision 20: Discards in numbers by age (including 1st quarter of 7.d) in thousands as input.

year	age									
	1	2	3	4	5	6	7	8	9	10+
1957	32356	45596	9220	909	961	25	0	0	0	0
1958	66199	73552	23655	2572	2137	65	0	0	0	0
1959	116086	127771	46402	11407	4737	106	0	0	0	0
1960	73939	167893	44948	997	1067	519	0	0	0	0
1961	75578	144609	89014	538	1612	130	0	0	0	0
1962	51265	181321	87599	21716	799	186	0	0	0	0
1963	90913	136183	129778	9964	2112	188	0	0	0	0
1964	66035	153274	64156	33825	3011	323	0	0	0	0
1965	43708	426021	59262	3404	923	267	0	0	0	0
1966	38496	163125	349358	14399	1402	125	0	0	0	0
1967	20199	133545	87532	152496	623	260	0	0	0	0
1968	73971	72192	46339	26530	22436	58	0	0	0	0
1969	85192	67378	16747	19334	773	2024	0	0	0	0
1970	123569	152480	27747	1287	5061	161	0	0	0	0
1971	69337	96968	42354	2675	426	81	0	0	0	0
1972	70002	55470	33899	5714	567	73	0	0	0	0
1973	132352	49815	4008	673	1289	67	0	0	0	0
1974	211139	308411	3652	285	611	109	0	0	0	0
1975	244969	280130	190536	4807	253	123	0	0	0	0
1976	183879	140921	71054	18013	174	41	0	0	0	0
1977	256628	103696	79317	33552	9317	129	0	0	0	0
1978	226872	154113	27257	10775	1244	570	0	0	0	0
1979	293166	215084	57578	18382	589	310	0	0	0	0
1980	226371	122561	932	687	193	86	0	0	0	0
1981	134142	193241	1850	373	431	55	0	0	0	0
1982	411307	204572	4624	1109	216	98	0	0	0	0
1983	261400	436331	30716	2235	804	72	0	0	0	0
1984	310675	313490	52651	24529	1492	69	0	0	0	0
1985	405385	229208	35566	2221	200	78	0	0	0	0
1986	1117345	490965	48510	26470	1451	146	0	0	0	0
1987	361519	1374202	180969	1427	1348	248	0	0	0	0
1988	348597	608109	459385	61167	882	177	0	0	0	0
1989	213291	485845	193176	85758	7224	115	0	0	0	0
1990	145314	279298	168674	28102	5011	177	0	0	0	0
1991	183126	301575	141567	40739	5528	939	0	0	0	0
1992	138755	219619	94581	34348	4307	880	0	0	0	0

year	age									
	1	2	3	4	5	6	7	8	9	10+
1993	96371	154083	48088	11966	1635	216	0	0	0	0
1994	62122	95703	35703	1038	822	144	0	0	0	0
1995	118863	82676	15753	860	663	120	0	0	0	0
1996	111250	331065	27606	3930	451	116	0	0	0	0
1997	128653	510918	193828	588	271	108	0	0	0	0
1998	104538	646250	191631	53354	297	33	0	0	0	0
1999	127321	208401	231769	54869	278	58	0	0	0	0
2000	103468	171213	51092	64971	1230	241	263	167	1	0
2001	30346	352452	186900	74744	54276	152	45	1	1	0
2002	310442	178402	78296	13940	2834	718	109	1	1	0
2003	67798	523336	56580	20184	4358	419	5756	1	2	0
2004	233682	183508	127876	10650	1975	450	41	1	2	0
2005	93936	332157	46454	23763	4494	6007	287	6	54	0
2006	220982	226944	117342	9785	2369	251	736	195	1	1080
2007	77687	210407	73043	13942	1594	7028	190	1644	1349	1056
2008	135504	255948	37983	5356	1785	336	8852	885	41	613
2009	148666	193174	68975	9471	2007	1108	138	3220	3	8472
2010	167387	180364	59943	22776	2699	1736	2074	283	531	810
2011	117902	153773	62696	37050	12949	2924	143	2273	0	16534
2012	91961	313013	123821	32986	9439	1547	226	7	620	3084
2013	128227	156837	125878	24797	4679	1033	219	15	7	0
2014	293515	192537	116178	55315	19141	2610	478	67	291	0
2015	83433	288990	130826	38858	12591	2367	521	209	17	406
2016	79202	144049	133284	48501	21078	7479	2068	1857	180	1
2017	129559	144559	77236	59006	16045	3812	1268	268	11	7
2018	64618	266462	101461	39258	21422	4803	1480	243	55	17
2019	134637	115302	119582	29708	11846	8537	3134	1412	133	30
2020	93983	191175	64298	55815	9809	3645	4399	1189	1047	39
2021	74250	108150	155035	30279	17223	3730	560	1089	573	7

Table 13.2.4. Plaice in Subarea 4 and Subdivision 20: Catch in numbers by age (including 1st quarter of 7.d) in thousands as input.

year	age									
	1	2	3	4	5	6	7	8	9	10+
1957	32356	50388	75648	50568	36243	9892	12248	10026	5522	12059
1958	66199	81133	47267	68551	38411	20901	8696	8507	6497	13981
1959	116086	144685	77487	37447	46725	23538	14173	6547	6739	16530
1960	73939	173891	107233	52356	22529	28029	14280	9073	5121	15253
1961	75578	146908	122927	69503	34821	13088	14909	9900	6089	14889
1962	51265	183396	122276	86264	49186	20125	8757	8733	5081	12373
1963	90913	140607	151664	88376	57526	32601	13096	6965	7183	16912
1964	66035	168092	104945	99044	60848	37691	15937	6644	4010	17012
1965	43708	435934	101700	56890	44842	30587	18464	8602	4237	17686
1966	38496	167345	415554	66827	38738	27995	16801	10981	6585	15201
1967	20199	139646	118437	267653	42827	22750	16496	8163	6861	11397
1968	73971	81942	88222	65781	149656	17696	10642	10396	4039	13754
1969	85195	83270	64566	57519	38430	109979	11016	6440	8669	17029
1970	123643	169330	77608	55999	44703	34335	76862	6149	4078	14459
1971	69357	127536	92230	37255	27345	23740	17471	30711	6626	17468
1972	72298	93031	97857	60116	24262	17552	14787	11211	19111	16094
1973	133684	83157	66103	77442	45686	14584	9335	10347	6392	25194
1974	213444	332383	61247	43962	43199	20500	8300	6554	5773	22790
1975	246011	310007	256001	38018	27257	22632	12613	6292	4362	20923
1976	186771	175418	150675	116859	14303	10197	9352	6553	3022	12871
1977	259853	160757	122676	99672	93158	9286	5922	5030	4068	9206
1978	227974	212525	87371	63173	49554	34810	5728	3232	2333	7201
1979	294482	273017	176240	67261	48394	40174	24187	4154	2802	9272
1980	227367	188656	137206	79722	25741	18407	14018	8621	1898	5497
1981	134401	296595	127778	59938	37101	12805	9805	8295	5005	6091
1982	414680	252926	216812	72276	29407	17073	7704	5551	4539	8775
1983	262614	556027	146048	102708	30395	13032	8238	4224	3013	8308
1984	310783	376997	333132	87364	42984	15486	6842	5593	2729	6551
1985	405505	302014	182405	203850	38139	17184	7441	3780	2813	5830
1986	1119014	557900	214496	132931	103135	28117	9839	4704	2834	7083
1987	361520	1459355	299385	122209	82652	44838	13539	4669	2346	5610
1988	348598	623309	713200	146514	60832	31669	19347	6198	3434	6402
1989	214545	532655	301448	324001	65991	21782	11605	8025	2321	5806
1990	146860	313064	273470	147931	174476	30123	9053	4689	3803	4206
1991	184551	344639	228763	162972	81603	79667	15410	5390	3215	5634
1992	142141	263388	180939	115818	92841	38422	30444	7229	3295	6976
1993	99787	207638	147893	92822	64910	35258	14745	11500	3704	5883
1994	63497	140257	141566	88030	48399	27824	17279	6661	5449	5458

year	age									
	1	2	3	4	5	6	7	8	9	10+
1995	126642	119437	98402	85638	48574	24692	14746	5285	2495	3896
1996	112353	374411	95761	56891	37736	19276	12400	5881	2799	4989
1997	129550	554040	282515	49950	32021	18781	9518	5037	3054	4400
1998	104735	676844	266072	115693	23090	9184	5703	2870	1983	3360
1999	127870	217091	389857	102260	32056	14135	4038	2625	1597	3234
2000	106071	186869	91911	236965	27165	12827	3242	1302	954	2121
2001	34869	389547	245578	131939	155800	11644	4784	1213	651	2364
2002	311671	194270	138500	69451	47077	43784	6636	2257	795	1638
2003	68498	568137	107187	75048	39047	20730	23884	1775	691	880
2004	234226	195557	246969	49703	25741	13759	5193	4775	462	569
2005	96884	351042	76188	114752	24669	16907	6192	2766	2357	647
2006	221345	247158	197276	44006	53426	8308	6325	2496	1319	2488
2007	79123	231764	114984	69891	21973	28865	3285	3655	1953	2359
2008	135904	269138	90365	50692	35820	7902	16918	1863	776	1549
2009	150229	205594	130882	52016	26893	19652	3538	7480	590	9293
2010	169501	200238	108973	92478	27880	14358	11840	2149	3051	2077
2011	118309	166750	108049	99067	64530	17739	6786	9257	1261	19277
2012	92124	319177	184424	95056	54407	33584	7782	3409	4102	5008
2013	128777	167367	189244	101853	46994	30519	15568	3970	2475	3795
2014	293522	197921	156827	133281	71407	24542	13433	8454	2763	3440
2015	83433	292834	173499	105923	73558	34676	13314	9111	4071	5240
2016	79202	148228	172474	133706	82050	47362	21214	9567	5490	5126
2017	129586	149848	101930	117147	73811	34703	18128	7868	3079	3220
2018	64635	274291	126229	73259	64926	35821	17471	9230	5449	4176
2019	134636	121830	163295	61961	30628	26662	14581	8360	4057	4085
2020	94063	196813	83305	100596	28891	13868	16044	8803	5860	6434
2021	74285	114546	176048	55500	50081	12433	5869	6833	4380	4380

Table 13.2.5. Plaice in Subarea 4 and Subdivision 20: Catches ICES estimates including catches in 7d during spawning migration in the 1rst quarter.

North Sea and Skagerrak			Eastern English Channel (Q1)	
Year	ICES Landings	ICES Discards	ICES Landings	ICES Discards
1980	150461	31080	328	
1981	148198	33031	585	
1982	162619	49127	635	
1983	151160	74483	731	
1984	164070	70816	702	
1985	169933	60549	786	
1986	176725	129953	893	
1987	166173	190524	1046	
1988	165295	156423	1258	
1989	175815	107793	1281	
1990	166288	71225	1306	
1991	154682	80935	1116	
1992	134744	57049	860	
1993	126967	35016	655	
1994	119943	23785	826	
1995	107736	21828	718	
1996	89676	52049	741	
1997	90862	100145	867	
1998	77983	103751	716	
1999	87711	70976	814	
2000	88139	44311	1149	
2001	91078	100309	682	
2002	77319	55099	716	
2003	73632	79275	366	
2004	69469	57478	418	
2005	61799	56250	389	
2006	66288	64160	324	16
2007	57365	42373	477	25
2008	57231	46993	451	37
2009	61487	45902	335	43
2010	69374	46570	385	76
2011	75604	41593	275	76
2012	81510	59914	418	225
2013	85717	40025	402	200
2014	80060	52937	496	432
2015	84767	50108	593	348
2016	91959	43971	785	395

	North Sea and Skagerrak		Eastern English Channel (Q1)	
Year	ICES Landings	ICES Discards	ICES Landings	ICES Discards
2017	74217	38966	711	762
2018	57012	47792	788	446
2019	48063	36713	681	657
2020	40562	38110	326	223
2021	35690	37213	241	316

Table 13.2.6. Plaice in Subarea 4 and Subdivision 20: Stock weight at age (kg).

year	age									
	1	2	3	4	5	6	7	8	9	10+
1957	0.038	0.102	0.157	0.242	0.325	0.485	0.719	0.682	0.844	0.918
1958	0.041	0.093	0.180	0.272	0.303	0.442	0.577	0.778	0.793	0.945
1959	0.045	0.106	0.173	0.264	0.329	0.470	0.650	0.686	0.908	0.897
1960	0.038	0.111	0.181	0.272	0.364	0.469	0.633	0.726	0.845	0.918
1961	0.037	0.098	0.185	0.306	0.337	0.483	0.579	0.691	0.779	0.911
1962	0.036	0.096	0.173	0.301	0.424	0.573	0.684	0.806	0.873	1.335
1963	0.041	0.103	0.176	0.273	0.378	0.540	0.663	0.788	0.882	0.961
1964	0.024	0.113	0.184	0.296	0.373	0.477	0.645	0.673	0.845	0.973
1965	0.031	0.068	0.198	0.294	0.333	0.43	0.516	0.601	0.722	0.578
1966	0.031	0.099	0.127	0.305	0.403	0.455	0.503	0.565	0.581	0.848
1967	0.029	0.104	0.179	0.205	0.442	0.528	0.585	0.650	0.703	0.833
1968	0.055	0.094	0.175	0.287	0.344	0.532	0.592	0.362	0.667	0.746
1969	0.047	0.158	0.188	0.266	0.344	0.390	0.565	0.621	0.679	0.635
1970	0.043	0.113	0.236	0.274	0.369	0.410	0.468	0.636	0.732	0.747
1971	0.051	0.109	0.251	0.344	0.413	0.489	0.512	0.583	0.696	0.707
1972	0.056	0.158	0.218	0.407	0.473	0.534	0.579	0.606	0.655	0.759
1973	0.037	0.134	0.237	0.308	0.468	0.521	0.566	0.583	0.617	0.690
1974	0.049	0.105	0.217	0.416	0.437	0.524	0.570	0.629	0.652	0.690
1975	0.063	0.141	0.187	0.388	0.483	0.544	0.610	0.668	0.704	0.762
1976	0.082	0.169	0.226	0.308	0.484	0.550	0.593	0.658	0.694	0.743
1977	0.064	0.184	0.265	0.311	0.405	0.551	0.627	0.690	0.667	0.759
1978	0.064	0.151	0.319	0.373	0.411	0.467	0.547	0.630	0.704	0.773
1979	0.062	0.179	0.258	0.365	0.414	0.459	0.543	0.667	0.764	0.826
1980	0.049	0.163	0.289	0.428	0.444	0.524	0.582	0.651	0.778	1.025
1981	0.041	0.140	0.239	0.421	0.473	0.536	0.570	0.624	0.707	0.849
1982	0.048	0.128	0.250	0.351	0.490	0.589	0.631	0.679	0.726	0.828
1983	0.045	0.128	0.242	0.381	0.494	0.559	0.624	0.712	0.754	0.791
1984	0.048	0.129	0.216	0.413	0.464	0.571	0.649	0.692	0.787	0.898
1985	0.048	0.146	0.232	0.320	0.452	0.536	0.635	0.656	0.764	0.869

year	age									
	1	2	3	4	5	6	7	8	9	10+
1986	0.043	0.126	0.245	0.311	0.440	0.533	0.692	0.779	0.888	0.971
1987	0.036	0.105	0.200	0.383	0.401	0.503	0.573	0.711	0.747	0.817
1988	0.036	0.097	0.172	0.264	0.426	0.467	0.547	0.644	0.706	0.897
1989	0.039	0.101	0.192	0.247	0.362	0.484	0.553	0.616	0.759	0.837
1990	0.043	0.108	0.176	0.261	0.343	0.422	0.555	0.647	0.701	0.760
1991	0.048	0.131	0.184	0.260	0.342	0.401	0.463	0.633	0.652	0.744
1992	0.043	0.121	0.199	0.270	0.318	0.403	0.500	0.573	0.683	0.730
1993	0.050	0.119	0.208	0.315	0.330	0.391	0.490	0.587	0.633	0.723
1994	0.053	0.141	0.214	0.290	0.360	0.404	0.462	0.533	0.653	0.702
1995	0.050	0.142	0.254	0.336	0.399	0.448	0.509	0.584	0.678	0.789
1996	0.044	0.117	0.229	0.368	0.390	0.462	0.488	0.554	0.660	0.791
1997	0.035	0.115	0.233	0.359	0.439	0.492	0.521	0.543	0.627	0.734
1998	0.038	0.081	0.207	0.333	0.474	0.577	0.581	0.648	0.656	0.642
1999	0.044	0.091	0.150	0.319	0.437	0.524	0.586	0.644	0.664	0.620
2000	0.051	0.106	0.165	0.219	0.408	0.467	0.649	0.695	0.656	0.744
2001	0.061	0.122	0.202	0.233	0.331	0.452	0.560	0.641	0.798	0.816
2002	0.048	0.118	0.213	0.301	0.319	0.403	0.446	0.612	0.685	0.781
2003	0.057	0.111	0.227	0.269	0.344	0.391	0.464	0.600	0.714	0.960
2004	0.047	0.116	0.201	0.306	0.384	0.430	0.489	0.495	0.780	0.921
2005	0.053	0.106	0.216	0.237	0.378	0.422	0.434	0.527	0.621	0.815
2006	0.052	0.130	0.190	0.316	0.354	0.424	0.439	0.506	0.583	0.688
2007	0.047	0.093	0.235	0.238	0.337	0.394	0.458	0.412	0.526	0.512
2008	0.048	0.114	0.196	0.274	0.355	0.429	0.484	0.627	0.598	0.449
2009	0.052	0.114	0.194	0.344	0.373	0.412	0.472	0.540	0.565	0.576
2010	0.053	0.116	0.179	0.340	0.361	0.401	0.448	0.572	0.568	0.655
2011	0.039	0.100	0.187	0.209	0.355	0.483	0.438	0.422	0.530	0.580
2012	0.052	0.093	0.142	0.188	0.331	0.393	0.484	0.479	0.480	0.518
2013	0.043	0.107	0.153	0.208	0.320	0.354	0.434	0.493	0.662	0.468
2014	0.048	0.104	0.158	0.202	0.312	0.380	0.439	0.484	0.458	0.615
2015	0.024	0.065	0.120	0.207	0.279	0.323	0.379	0.435	0.465	0.457
2016	0.030	0.066	0.117	0.198	0.260	0.329	0.380	0.434	0.479	0.514
2017	0.032	0.069	0.132	0.181	0.270	0.333	0.359	0.458	0.476	0.557
2018	0.036	0.064	0.116	0.165	0.215	0.276	0.327	0.366	0.412	0.595
2019	0.022	0.063	0.117	0.173	0.240	0.261	0.352	0.391	0.415	0.443
2020	0.026	0.058	0.114	0.163	0.208	0.248	0.323	0.351	0.424	0.458
2021	0.033	0.069	0.104	0.165	0.219	0.263	0.330	0.356	0.464	0.494

Table 13.2.7. Plaice in Subarea 4 and Subdivision 20: Landings weight at age (kg).

year	age									
	1	2	3	4	5	6	7	8	9	10+
1957	0.000	0.165	0.201	0.258	0.353	0.456	0.533	0.589	0.396	0.998
1958	0.000	0.198	0.221	0.259	0.337	0.453	0.513	0.615	0.665	0.992
1959	0.000	0.218	0.246	0.293	0.362	0.473	0.592	0.623	0.750	1.000
1960	0.000	0.200	0.236	0.289	0.386	0.485	0.601	0.683	0.724	1.094
1961	0.000	0.191	0.233	0.302	0.412	0.509	0.604	0.671	0.812	1.071
1962	0.000	0.211	0.248	0.300	0.400	0.541	0.570	0.692	0.777	1.127
1963	0.000	0.253	0.286	0.319	0.399	0.533	0.624	0.667	0.715	1.028
1964	0.000	0.250	0.273	0.312	0.388	0.487	0.628	0.700	0.737	1.005
1965	0.000	0.242	0.282	0.321	0.385	0.471	0.539	0.663	0.726	0.887
1966	0.000	0.232	0.270	0.348	0.436	0.484	0.559	0.624	0.690	0.933
1967	0.000	0.232	0.279	0.322	0.425	0.547	0.597	0.662	0.738	0.978
1968	0.000	0.267	0.298	0.331	0.366	0.517	0.590	0.596	0.686	0.911
1969	0.217	0.294	0.310	0.333	0.359	0.412	0.573	0.655	0.658	0.893
1970	0.315	0.286	0.318	0.356	0.419	0.443	0.499	0.672	0.744	0.892
1971	0.256	0.318	0.356	0.403	0.448	0.514	0.542	0.607	0.699	0.891
1972	0.246	0.296	0.352	0.428	0.493	0.541	0.608	0.646	0.674	0.939
1973	0.272	0.316	0.344	0.405	0.486	0.539	0.605	0.627	0.677	0.842
1974	0.285	0.311	0.354	0.405	0.476	0.554	0.609	0.693	0.707	0.926
1975	0.249	0.300	0.330	0.420	0.495	0.587	0.636	0.703	0.783	1.019
1976	0.265	0.295	0.338	0.375	0.513	0.594	0.641	0.705	0.741	0.980
1977	0.254	0.323	0.353	0.380	0.418	0.556	0.647	0.721	0.715	0.978
1978	0.244	0.315	0.369	0.397	0.438	0.491	0.609	0.687	0.776	0.950
1979	0.235	0.311	0.349	0.388	0.429	0.474	0.550	0.675	0.796	0.960
1980	0.238	0.286	0.344	0.401	0.473	0.545	0.588	0.662	0.772	1.013
1981	0.237	0.274	0.329	0.416	0.505	0.558	0.604	0.642	0.725	1.007
1982	0.279	0.262	0.311	0.424	0.514	0.608	0.664	0.712	0.738	0.984
1983	0.200	0.250	0.300	0.383	0.515	0.604	0.677	0.771	0.815	0.984
1984	0.231	0.263	0.283	0.364	0.480	0.591	0.677	0.726	0.839	1.036
1985	0.245	0.264	0.290	0.335	0.445	0.563	0.667	0.730	0.807	1.021
1986	0.221	0.269	0.303	0.339	0.405	0.473	0.668	0.750	0.856	1.014
1987	0.000	0.249	0.299	0.345	0.378	0.472	0.574	0.728	0.835	0.993
1988	0.000	0.254	0.278	0.341	0.418	0.478	0.590	0.680	0.808	1.017
1989	0.236	0.280	0.308	0.331	0.385	0.515	0.591	0.668	0.785	0.940
1990	0.271	0.284	0.297	0.315	0.364	0.441	0.586	0.690	0.761	1.010
1991	0.227	0.286	0.292	0.302	0.360	0.452	0.526	0.666	0.743	0.924
1992	0.251	0.263	0.290	0.312	0.330	0.415	0.530	0.607	0.719	0.891
1993	0.249	0.273	0.288	0.319	0.343	0.408	0.512	0.630	0.720	0.856
1994	0.229	0.263	0.284	0.333	0.375	0.417	0.491	0.610	0.731	0.906

year	age									
	1	2	3	4	5	6	7	8	9	10+
1995	0.272	0.277	0.301	0.335	0.375	0.420	0.474	0.593	0.734	0.906
1996	0.240	0.279	0.304	0.346	0.415	0.465	0.490	0.553	0.712	0.858
1997	0.208	0.271	0.313	0.355	0.410	0.474	0.541	0.574	0.616	0.912
1998	0.151	0.260	0.306	0.384	0.452	0.546	0.613	0.673	0.687	0.899
1999	0.245	0.253	0.280	0.347	0.415	0.416	0.538	0.637	0.748	0.804
2000	0.228	0.267	0.283	0.312	0.378	0.461	0.597	0.689	0.752	0.888
2001	0.238	0.267	0.291	0.307	0.360	0.412	0.582	0.701	0.796	0.799
2002	0.237	0.264	0.289	0.311	0.336	0.430	0.477	0.644	0.760	0.904
2003	0.232	0.252	0.285	0.320	0.353	0.389	0.482	0.635	0.763	0.857
2004	0.214	0.246	0.281	0.328	0.391	0.429	0.508	0.560	0.797	0.872
2005	0.272	0.265	0.280	0.330	0.382	0.426	0.465	0.555	0.617	0.910
2006	0.253	0.267	0.282	0.322	0.383	0.389	0.457	0.477	0.531	0.748
2007	0.263	0.268	0.303	0.343	0.364	0.432	0.507	0.486	0.587	0.632
2008	0.249	0.269	0.309	0.341	0.400	0.446	0.531	0.720	0.640	0.638
2009	0.176	0.260	0.308	0.355	0.415	0.481	0.531	0.608	0.668	0.792
2010	0.206	0.265	0.308	0.348	0.418	0.476	0.516	0.625	0.682	0.649
2011	0.235	0.242	0.281	0.341	0.414	0.504	0.604	0.521	0.556	0.804
2012	0.236	0.258	0.305	0.351	0.380	0.436	0.518	0.558	0.558	0.680
2013	0.031	0.242	0.281	0.313	0.364	0.417	0.494	0.600	0.607	0.680
2014	0.207	0.252	0.285	0.318	0.368	0.418	0.479	0.543	0.628	0.650
2015	NA	0.251	0.284	0.321	0.359	0.409	0.473	0.487	0.582	0.600
2016	NA	0.249	0.271	0.296	0.350	0.385	0.450	0.531	0.556	0.684
2017	0.212	0.247	0.276	0.299	0.357	0.410	0.455	0.543	0.642	0.735
2018	0.167	0.243	0.259	0.287	0.306	0.356	0.400	0.447	0.439	0.589
2019	NA	0.249	0.258	0.295	0.349	0.388	0.431	0.488	0.504	0.601
2020	0.211	0.236	0.264	0.269	0.302	0.333	0.372	0.422	0.451	0.562
2021	0.182	0.245	0.249	0.272	0.296	0.366	0.398	0.431	0.530	0.628

Table 13.2.8. Plaice in Subarea 4 and Subdivision 20: Discards weight at age (kg).

year	age									
	1	2	3	4	5	6	7	8	9	10+
1957	0.044	0.104	0.146	0.181	0.206	0.244	0.244	0.231	0	0
1958	0.047	0.096	0.158	0.188	0.2	0.244	0	0	0	0
1959	0.051	0.107	0.155	0.186	0.197	0.231	0	0	0	0
1960	0.045	0.112	0.159	0.188	0.204	0.212	0.244	0	0	0
1961	0.044	0.1	0.16	0.194	0.204	0.22	0.22	0	0	0
1962	0.042	0.098	0.155	0.193	0.213	0.221	0.221	0.231	0	0
1963	0.048	0.105	0.156	0.188	0.205	0.231	0.221	0.231	0	0
1964	0.032	0.114	0.16	0.192	0.204	0.221	0.244	0.231	0	0
1965	0.038	0.072	0.166	0.192	0.212	0.221	0.231	0	0	0
1966	0.038	0.101	0.125	0.194	0.205	0.231	0.231	0.244	0	0
1967	0.036	0.105	0.158	0.169	0.22	0.22	0.244	0.244	0	0
1968	0.06	0.096	0.156	0.191	0.192	0.244	0.22	0	0	0
1969	0.052	0.146	0.162	0.186	0.211	0.212	0	0.231	0	0
1970	0.049	0.114	0.179	0.189	0.196	0	0.22	0.231	0	0
1971	0.057	0.11	0.183	0.2	0.212	0	0	0.231	0	0
1972	0.061	0.147	0.173	0.211	0.211	0.244	0	0	0	0
1973	0.043	0.131	0.179	0.195	0.211	0.244	0	0	0	0
1974	0.054	0.106	0.173	0.212	0.22	0.231	0.244	0	0	0
1975	0.068	0.136	0.162	0.206	0.221	0.244	0.244	0	0	0
1976	0.085	0.153	0.176	0.195	0.22	0	0.244	0	0	0
1977	0.069	0.16	0.186	0.196	0.198	0.22	0	0	0	0
1978	0.069	0.143	0.197	0.205	0.211	0.213	0.231	0	0	0
1979	0.066	0.158	0.185	0.204	0.22	0.231	0.221	0.244	0	0
1980	0.055	0.149	0.191	0.212	0.231	0	0	0	0	0
1981	0.048	0.135	0.179	0.212	0.22	0	0	0	0	0
1982	0.054	0.126	0.182	0.203	0.231	0.244	0.244	0	0	0
1983	0.051	0.126	0.18	0.205	0.211	0.244	0	0	0	0
1984	0.053	0.127	0.172	0.211	0.205	0	0.244	0	0	0
1985	0.054	0.139	0.177	0.197	0.231	0.244	0	0	0	0
1986	0.049	0.124	0.181	0.196	0.22	0.244	0.244	0	0	0
1987	0.043	0.105	0.166	0.205	0.22	0.231	0	0	0	0
1988	0.043	0.098	0.153	0.185	0.22	0.244	0	0	0	0
1989	0.046	0.102	0.163	0.181	0.196	0	0	0	0	0
1990	0.051	0.111	0.157	0.186	0.212	0.231	0	0	0	0
1991	0.055	0.13	0.161	0.185	0.203	0.221	0.231	0.231	0	0
1992	0.05	0.122	0.167	0.188	0.204	0.212	0.231	0.244	0	0
1993	0.056	0.121	0.171	0.197	0.211	0.231	0.244	0	0	0
1994	0.06	0.14	0.175	0.194	0.213	0.244	0.244	0.221	0	0

year	age									
	1	2	3	4	5	6	7	8	9	10+
1995	0.058	0.141	0.186	0.201	0.22	0.232	0.232	0.244	0	0
1996	0.052	0.122	0.179	0.205	0.221	0.232	0	0	0	0
1997	0.044	0.117	0.178	0.203	0.221	0.244	0	0	0	0
1998	0.047	0.086	0.17	0.199	0.22	0	0.244	0	0	0
1999	0.053	0.097	0.143	0.197	0.22	0	0	0	0	0
2000	0.059	0.11	0.151	0.174	0.244	0	0.203	0	0	0
2001	0.068	0.122	0.167	0.178	0.197	0.244	0	0.244	0	0
2002	0.056	0.119	0.17	0.182	0.172	0.208	0.003	0	0	0
2003	0.064	0.113	0.174	0.185	0.198	0.204	0.221	0	0	0
2004	0.054	0.117	0.164	0.183	0.189	0.192	0.196	0	0	0
2005	0.061	0.109	0.17	0.175	0.215	0.205	0.21	0.176	0	0
2006	0.06	0.128	0.164	0.193	0.198	0.204	0.212	0.22	0	0
2007	0.055	0.098	0.177	0.178	0.188	0.199	0.225	0.2	0	0
2008	0.056	0.116	0.163	0.186	0.187	0.23	0.22	0.191	0	0
2009	0.06	0.116	0.164	0.199	0.202	0.212	0.21	0.22	0	0
2010	0.06	0.117	0.159	0.199	0.19	0.198	0.211	0.234	0.001	0
2011	0.047	0.104	0.162	0.171	0.192	0.196	0.199	0.211	0	0
2012	0.052	0.093	0.142	0.188	0.198	0.206	0.215	0.215	0	0
2013	0.051	0.081	0.127	0.151	0.17	0.194	0.228	0.346	0	0
2014	0.025	0.089	0.132	0.162	0.18	0.212	0.3	0.37	0.255	0
2015	0.026	0.078	0.122	0.149	0.164	0.185	0.173	0.218	0.404	0.291
2016	0.048	0.079	0.124	0.15	0.151	0.179	0.166	0.192	0.251	0.5
2017	0.051	0.08	0.121	0.139	0.161	0.194	0.208	0.206	0.513	0.758
2018	0.058	0.084	0.121	0.137	0.149	0.152	0.159	0.179	0.196	0.163
2019	0.044	0.083	0.118	0.135	0.146	0.148	0.158	0.172	0.182	0.194
2020	0.054	0.079	0.119	0.133	0.146	0.148	0.154	0.164	0.159	0.166
2021	0.052	0.085	0.111	0.131	0.137	0.149	0.168	0.168	0.173	0.311

Table 13.2.9. Plaice in Subarea 4 and Subdivision 20: Catch weight at age (kg).

year	age									
	1	2	3	4	5	6	7	8	9	10+
1957	0.044	0.11	0.194	0.257	0.349	0.455	0.533	0.589	0.396	0.998
1958	0.047	0.106	0.189	0.256	0.329	0.452	0.513	0.615	0.665	0.992
1959	0.051	0.12	0.192	0.26	0.345	0.472	0.592	0.623	0.75	1
1960	0.045	0.115	0.204	0.287	0.377	0.48	0.601	0.683	0.724	1.094
1961	0.044	0.101	0.18	0.301	0.402	0.506	0.604	0.671	0.812	1.071
1962	0.042	0.099	0.181	0.273	0.397	0.538	0.57	0.692	0.777	1.127
1963	0.048	0.11	0.175	0.304	0.392	0.531	0.624	0.667	0.715	1.028
1964	0.032	0.126	0.204	0.271	0.379	0.485	0.628	0.7	0.737	1.005
1965	0.038	0.076	0.214	0.313	0.381	0.469	0.539	0.663	0.726	0.887
1966	0.038	0.104	0.148	0.315	0.428	0.483	0.559	0.624	0.69	0.933
1967	0.036	0.111	0.19	0.235	0.422	0.543	0.597	0.662	0.738	0.978
1968	0.06	0.116	0.223	0.275	0.34	0.516	0.59	0.596	0.686	0.911
1969	0.052	0.174	0.272	0.284	0.356	0.408	0.573	0.655	0.658	0.893
1970	0.049	0.131	0.268	0.352	0.394	0.441	0.499	0.672	0.744	0.892
1971	0.057	0.16	0.277	0.388	0.444	0.512	0.542	0.607	0.699	0.891
1972	0.067	0.207	0.29	0.407	0.486	0.54	0.608	0.646	0.674	0.939
1973	0.045	0.205	0.334	0.403	0.478	0.538	0.605	0.627	0.677	0.842
1974	0.056	0.121	0.343	0.404	0.472	0.552	0.609	0.693	0.707	0.926
1975	0.069	0.152	0.205	0.393	0.492	0.585	0.636	0.703	0.783	1.019
1976	0.088	0.181	0.262	0.347	0.509	0.592	0.641	0.705	0.741	0.98
1977	0.071	0.218	0.245	0.318	0.396	0.551	0.647	0.721	0.715	0.978
1978	0.07	0.19	0.315	0.364	0.432	0.486	0.609	0.687	0.776	0.95
1979	0.067	0.19	0.295	0.338	0.426	0.472	0.55	0.675	0.796	0.96
1980	0.056	0.197	0.343	0.399	0.471	0.542	0.588	0.662	0.772	1.013
1981	0.048	0.183	0.327	0.415	0.502	0.556	0.604	0.642	0.725	1.007
1982	0.056	0.152	0.308	0.421	0.512	0.606	0.664	0.712	0.738	0.984
1983	0.052	0.153	0.275	0.379	0.507	0.602	0.677	0.771	0.815	0.984
1984	0.053	0.15	0.265	0.321	0.47	0.588	0.677	0.726	0.839	1.036
1985	0.054	0.169	0.268	0.333	0.444	0.562	0.667	0.73	0.807	1.021
1986	0.049	0.141	0.275	0.311	0.402	0.472	0.668	0.75	0.856	1.014
1987	0.043	0.113	0.219	0.343	0.375	0.471	0.574	0.728	0.835	0.993
1988	0.043	0.102	0.197	0.276	0.415	0.477	0.59	0.68	0.808	1.017
1989	0.047	0.118	0.215	0.291	0.364	0.512	0.591	0.668	0.785	0.94
1990	0.053	0.13	0.211	0.29	0.36	0.44	0.586	0.69	0.761	1.01
1991	0.056	0.149	0.211	0.273	0.349	0.449	0.526	0.666	0.743	0.924
1992	0.055	0.145	0.226	0.275	0.324	0.41	0.53	0.607	0.719	0.891
1993	0.063	0.16	0.25	0.303	0.34	0.407	0.512	0.63	0.72	0.856
1994	0.064	0.179	0.257	0.331	0.372	0.416	0.491	0.61	0.731	0.906

year	age									
	1	2	3	4	5	6	7	8	9	10+
1995	0.071	0.183	0.283	0.334	0.373	0.419	0.474	0.593	0.734	0.906
1996	0.054	0.14	0.268	0.336	0.413	0.464	0.49	0.553	0.712	0.858
1997	0.045	0.129	0.22	0.353	0.408	0.473	0.541	0.574	0.616	0.912
1998	0.047	0.094	0.208	0.299	0.449	0.544	0.613	0.673	0.687	0.899
1999	0.054	0.103	0.199	0.267	0.413	0.414	0.538	0.637	0.748	0.804
2000	0.063	0.123	0.21	0.274	0.372	0.452	0.565	0.601	0.751	0.888
2001	0.09	0.136	0.197	0.234	0.303	0.41	0.577	0.701	0.795	0.799
2002	0.057	0.131	0.222	0.285	0.326	0.426	0.469	0.644	0.759	0.904
2003	0.066	0.124	0.226	0.284	0.336	0.385	0.419	0.635	0.761	0.857
2004	0.054	0.125	0.22	0.297	0.376	0.421	0.506	0.56	0.794	0.872
2005	0.067	0.117	0.213	0.298	0.352	0.347	0.453	0.554	0.603	0.91
2006	0.06	0.139	0.212	0.293	0.375	0.383	0.428	0.457	0.531	0.423
2007	0.059	0.114	0.223	0.31	0.351	0.375	0.491	0.357	0.181	0.349
2008	0.057	0.123	0.248	0.325	0.389	0.437	0.368	0.469	0.606	0.385
2009	0.061	0.125	0.232	0.327	0.399	0.466	0.518	0.441	0.665	0.07
2010	0.062	0.132	0.226	0.311	0.396	0.442	0.463	0.574	0.563	0.396
2011	0.048	0.115	0.212	0.277	0.369	0.453	0.595	0.445	0.556	0.114
2012	0.052	0.096	0.196	0.294	0.348	0.425	0.509	0.557	0.474	0.261
2013	0.051	0.091	0.179	0.274	0.345	0.409	0.49	0.599	0.605	0.68
2014	0.025	0.093	0.172	0.253	0.318	0.396	0.473	0.542	0.589	0.65
2015	0.026	0.08	0.162	0.258	0.326	0.394	0.461	0.481	0.581	0.576
2016	0.048	0.084	0.157	0.243	0.299	0.352	0.422	0.465	0.546	0.684
2017	0.051	0.086	0.159	0.218	0.314	0.386	0.438	0.532	0.642	0.735
2018	0.058	0.089	0.148	0.207	0.254	0.329	0.38	0.44	0.437	0.62
2019	0.044	0.092	0.155	0.218	0.27	0.311	0.372	0.435	0.493	0.598
2020	0.054	0.083	0.152	0.194	0.249	0.284	0.312	0.387	0.399	0.56
2021	0.052	0.094	0.127	0.195	0.241	0.301	0.376	0.389	0.483	0.627

Table 13.2.10. Plaice in Subarea 4 and Subdivision 20: Natural mortality at age and maturity at age.

age	1	2	3	4	5	6	7	8	9	10+
natural mortality	0.495	0.394	0.343	0.311	0.292	0.278	0.268	0.260	0.252	0.246
maturity	0	0.5	0.5	1	1	1	1	1	1	1

Table 13.2.11. Plaice in Subarea 4 and Subdivision 20: Survey tuning indices.

	BTS–Isis				age			
year	1	2	3	4	5	6	7	8
1985	137	173.9	36.1	11	1.27	0.973	0.336	0.155
1986	667	131.7	50.2	9.21	3.78	0.4	0.418	0.147
1987	226	764.2	33.8	4.88	1.84	0.607	0.252	0.134
1988	680	147	182.3	9.99	2.81	0.814	0.458	0.036
1989	468	319.3	314.7	47.3	5.85	0.833	0.311	0.661
1990	185	146.1	79.3	26.35	5.47	0.758	0.189	0.383
1991	291	159.4	34	13.57	4.31	5.659	0.239	0.204
1992	361	174.5	29.3	5.96	3.75	2.871	1.186	0.346
1993	189	283.4	62.8	14.27	1.13	1.13	0.584	0.464
1994	193	77.1	34.5	10.59	2.67	0.6	0.8	0.895
1995	266	40.6	13.2	7.53	1.11	0.806	0.33	1.051

BTS–IBTS Q3	1	2	3	4	5	6	7	8	9	10+
1996	20704.9	21981.3	6712.6	3090.7	3254.7	2040.0	861.7	549.8	298.3	472.1
1997	72152.8	36673.9	10452.3	3529.7	2724.0	1837.7	995.0	839.6	324.3	383.5
1998	39847.1	73020.1	13797.7	5592.1	2088.5	1438.9	939.7	721.6	403.3	416.4
1999	29088.8	25133.3	40567.7	5961.9	2729.4	1167.1	583.9	531.4	405.2	315.9
2000	34620.7	17758.6	14633.0	16021.6	2189.7	1049.8	572.6	483.3	191.9	337.3
2001	24764.9	23138.8	11409.9	6992.1	8052.7	1491.7	660.5	535.4	404.0	813.7
2002	132916.9	25138.6	14103.7	7470.3	4140.9	2973.5	775.3	676.7	347.9	666.3
2003	28963.9	48225.0	11771.6	6739.9	3263.1	2082.0	2068.0	530.2	467.4	924.5
2004	42646.6	19363.1	30406.1	6081.6	3686.9	2285.3	1521.7	1684.1	386.9	1097.0
2005	37090.2	41122.2	10107.9	15728.5	2723.4	3031.4	1754.4	777.6	1416.6	1388.1
2006	35910.8	26028.7	22440.3	6336.6	8018.5	2509.6	2452.7	981.8	571.9	1942.8
2007	73914.4	38058.2	23538.0	19358.2	5473.3	7738.4	2013.7	2300.9	714.6	3292.5
2008	78574.9	78367.0	29714.7	19346.3	12687.7	4203.9	4990.5	1608.7	1509.6	3048.7
2009	51839.8	40861.5	45777.6	16358.8	9950.0	6892.3	2795.5	4176.9	1019.5	3871.6
2010	70244.3	38754.9	31511.9	27356.7	8855.5	5546.9	5623.5	2352.1	2500.5	4905.9
2011	106916.3	64045.7	39730.4	24046.4	16071.9	5778.6	3796.0	4494.5	1190.5	6212.6
2012	42266.4	86133.8	65680.3	31916.1	17404.6	11269.4	4870.8	3869.3	3903.8	6187.0
2013	54374.8	60255.0	68970.2	38926.0	17019.4	9559.3	6913.0	3156.5	2101.5	7292.2
2014	93591.6	73725.1	47897.5	39097.6	17499.6	7660.7	4908.4	3599.8	2252.9	6355.2

BTS–IBTS Q3	1	2	3	4	5	6	7	8	9	10+
2015	29464.8	69122.8	57270.0	35467.3	25643.8	11925.3	5656.2	3810.2	3291.5	8413.4
2016	41400.9	39862.0	55356.6	36265.4	17891.7	12288.9	7363.5	4221.0	3117.1	8407.7
2017	79158.1	51727.5	27091.8	30442.2	17018.6	9340.8	6099.0	4184.4	2133.8	6505.9
2018	41602.4	65209.9	32674.7	18710.7	17193.8	9574.2	6366.2	3882.4	3077.4	7125.4
2019	151645.4	51781.1	38209.2	15262.6	9105.0	7447.6	5164.6	3766.8	2155.3	5064.2
2020	73870.2	90194.4	35039.9	25111.0	9650.5	6141.7	4992.2	3741.3	2156.3	5055.0
2021	68212.0	63336.2	63683.6	26702.2	15599.1	7119.4	4183.8	3603.3	2284.6	5810.8

	SNS1							SNS2					
	age							age					
year	1	2	3	4	5	6	year	1	2	3	4	5	6
1970	9311	9732	3273	770	170	37.5	2000	22855	2493	891	983	17	2.0
1971	13538	28164	1415	101	50	23.6	2001	11511	2898	370	176	691	105.8
1972	13207	10780	4478	89	84	0.0	2002	30809	1103	265	65	69	30.7
1973	65643	5133	1578	461	15	5.7	2003	NA	NA	NA	NA	NA	NA
1974	15366	16509	1129	160	82	7.0	2004	18202	1350	1081	51	27	29.7
1975	11628	8168	9556	65	15	0.0	2005	10118	1819	142	366	8	19.0
1976	8537	2403	868	236	0	2.3	2006	12164	1571	385	52	54	0.0
1977	18537	3424	1737	590	213	0.0	2007	14175	2134	140	52	0	7.4
1978	14012	12678	345	135	45	13.6	2008	14706	2700	464	179	34	6.7
1979	21495	9829	1575	161	17	42.2	2009	14860	2019	492	38	20	0.0
1980	59174	12882	491	180	24	7.8	2010	11947	1812	529	55	10	0.0
1981	24756	18785	834	38	32	4.7	2011	18349	1143	308	75	60	28.0
1982	69993	8642	1261	88	8	8.7	2012	5893	2929	682	82	30	15.0
1983	33974	13909	249	71	6	1.3	2013	15395	3021	1638	428	89	31.1
1984	44965	10413	2467	42	0	0.0	2014	17313	2258	514	458	58	16.4
1985	28101	13848	1598	328	17	1.5	2015	16727	5040	1882	478	200	97.5
1986	93552	7580	1152	145	30	6.6	2016	10385	2434	1086	522	223	131.7
1987	33402	32991	1227	200	30	16.7	2017	15936	1716	1212	534	144	70.6
1988	36609	14421	13153	1350	88	12.1	2018	9465	5250	993	533	489	88
1989	34276	17810	4373	7126	289	113.6	2019	28309	1886	1533	338	196	62
1990	25037	7496	3160	816	422	48.8	2020	11393	3931	283	607	118	5
1991	57221	11247	1518	1077	128	74.4	2021	6014	1290	1135	249	230	143
1992	46798	13842	2268	613	176	52.0							
1993	22098	9686	1006	98	60	58.8							
1994	19188	4977	856	76	23	2.7							
1995	24767	2796	381	97	38	0.0							
1996	23015	10268	1185	45	47	0.0							
1997	95901	4473	497	32	0	13.3							
1998	33666	30242	5014	50	10	0.0							

year	SNS1						SNS2						
	age							age					
	1	2	3	4	5	6	year	1	2	3	4	5	6
1999	32951	10272	13783	1058	17	0.0							

IBTS Q1	1	2	3	4	5	6	7	8+
2007	2240.2	5617.9	6202.8	7254.0	2603.2	1339.4	754.1	595.1
2008	2236.8	12356.4	9095.2	4294.2	3294.8	907.8	876.6	587.0
2009	3027.7	8787.6	15752.2	5263.8	2814.1	1128.2	597.1	811.4
2010	1100.2	5627.9	9037.7	8582.8	4254.1	1453.0	986.3	885.1
2011	1220.4	6743.3	7871.1	8231.2	6697.0	2334.3	1196.2	1296.1
2012	1906.3	15325.3	19984.0	9078.3	6533.2	4289.7	1724.9	2388.6
2013	1540.4	6173.1	12343.4	8153.6	4027.1	2318.4	1220.8	1026.0
2014	2572.4	9018.5	11359.1	11197.3	6213.3	2230.7	1344.2	1445.4
2015	637.0	9180.0	11677.7	9892.1	7237.9	3410.2	1477.6	1589.0
2016	1360.3	4399.7	9495.7	8105.0	5940.0	2884.2	1648.2	2197.9
2017	2230.2	8209.1	5547.3	9134.5	6380.4	3976.8	1944.3	2670.0
2018	799.0	6826.7	7714.5	3102.2	4048.7	2430.2	1693.1	3073.3
2019	4389.3	4716.4	7717.5	3939.4	2349.7	1770.0	1531.1	2791.6
2020	2000.1	9285.8	4868.9	4197.4	2126.0	1574.3	1244.5	1917.5
2021	1251.4	7731.8	11919.0	5080.0	3222.1	1663.0	923.5	2255.4

Table 13.3.1. Plaice in Subarea 4 and Subdivision 20: Estimated parameters from SAM model.

	par	sd(par)	exp(par)	Low	High
logFpar_0	-8.768	0.158	0.000	0.000	0.000
logFpar_1	-8.644	0.132	0.000	0.000	0.000
logFpar_2	-9.368	0.132	0.000	0.000	0.000
logFpar_3	-10.122	0.133	0.000	0.000	0.000
logFpar_4	-10.849	0.136	0.000	0.000	0.000
logFpar_5	-11.115	0.140	0.000	0.000	0.000
logFpar_6	-11.364	0.199	0.000	0.000	0.000
logFpar_7	-11.097	0.208	0.000	0.000	0.000
logFpar_8	-3.852	0.076	0.021	0.018	0.025
logFpar_9	-3.447	0.066	0.032	0.028	0.036
logFpar_10	-3.307	0.072	0.037	0.032	0.042
logFpar_11	-3.295	0.080	0.037	0.032	0.044
logFpar_12	-3.406	0.098	0.033	0.027	0.040
logFpar_13	-7.743	0.119	0.000	0.000	0.001
logFpar_14	-5.695	0.092	0.003	0.003	0.004
logFpar_15	-4.889	0.089	0.008	0.006	0.009
logFpar_16	-4.976	0.120	0.007	0.005	0.009
logFpar_17	-5.541	0.136	0.004	0.003	0.005
logFpar_18	-4.058	0.087	0.017	0.015	0.021
logFpar_19	-4.424	0.100	0.012	0.010	0.015
logFpar_20	-5.561	0.146	0.004	0.003	0.005
logFpar_21	-6.951	0.171	0.001	0.001	0.001
logFpar_22	-7.923	0.179	0.000	0.000	0.001
logFpar_23	-8.560	0.197	0.000	0.000	0.000
logFpar_24	-5.220	0.110	0.005	0.004	0.007
logFpar_25	-6.442	0.113	0.002	0.001	0.002
logFpar_26	-7.224	0.155	0.001	0.001	0.001
logFpar_27	-7.822	0.214	0.000	0.000	0.001
logFpar_28	-8.389	0.256	0.000	0.000	0.000
logFpar_29	-8.800	0.267	0.000	0.000	0.000
logSdLogFsta_0	-1.876	0.202	0.153	0.102	0.230
logSdLogFsta_1	-1.818	0.134	0.162	0.124	0.212
logSdLogFsta_2	-1.910	0.099	0.148	0.121	0.181
logSdLogFsta_3	-1.910	0.131	0.148	0.114	0.192
logSdLogN_0	-0.707	0.100	0.493	0.404	0.602
logSdLogN_1	-2.406	0.100	0.090	0.074	0.110
logSdLogObs_0	-0.860	0.117	0.423	0.335	0.535
logSdLogObs_1	-2.298	0.096	0.100	0.083	0.122
logSdLogObs_2	-1.355	0.074	0.258	0.223	0.299
logSdLogObs_3	-0.679	0.224	0.507	0.324	0.793
logSdLogObs_4	-0.864	0.100	0.421	0.345	0.515
logSdLogObs_5	-0.498	0.160	0.608	0.442	0.836
logSdLogObs_6	-1.301	0.161	0.272	0.197	0.376
logSdLogObs_7	-1.729	0.081	0.178	0.151	0.209

	par	sd(par)	exp(par)	Low	High
logSdLogObs_8	-1.341	0.171	0.261	0.186	0.368
logSdLogObs_9	-1.196	0.173	0.302	0.214	0.428
logSdLogObs_10	-0.868	0.185	0.420	0.290	0.607
logSdLogObs_11	-0.957	0.188	0.384	0.263	0.559
logSdLogObs_12	-1.325	0.095	0.266	0.220	0.322
logSdLogObs_13	-1.193	0.146	0.303	0.227	0.406
logSdLogObs_14	-0.785	0.139	0.456	0.345	0.602
logSdLogObs_15	-0.634	0.137	0.530	0.403	0.697
logSdLogObs_16	-0.239	0.128	0.788	0.610	1.018
logSdLogObs_17	-0.085	0.083	0.919	0.778	1.084
logSdLogObs_18	-0.855	0.157	0.425	0.311	0.581
logSdLogObs_19	-0.829	0.152	0.436	0.322	0.591
logSdLogObs_20	-0.448	0.152	0.639	0.472	0.865
logSdLogObs_21	-0.086	0.148	0.917	0.683	1.232
logSdLogObs_22	0.088	0.125	1.092	0.850	1.402
transfIRARdist_0	0.414	0.277	1.514	0.870	2.632
transfIRARdist_1	0.145	0.215	1.156	0.753	1.777
transfIRARdist_2	-0.605	0.266	0.546	0.321	0.929
itrans_rho_0	1.669	0.182	5.305	3.690	7.628

Table 13.3.2. Plaice in Subarea 4 and Subdivision 20: Estimated Harvest (F) at age.

year	age									
	1	2	3	4	5	6	7	8	9	10+
1957	0.027	0.087	0.111	0.124	0.124	0.103	0.095	0.089	0.086	0.086
1958	0.031	0.102	0.129	0.143	0.143	0.12	0.109	0.101	0.096	0.096
1959	0.035	0.119	0.148	0.162	0.161	0.136	0.122	0.111	0.106	0.106
1960	0.036	0.122	0.152	0.164	0.164	0.142	0.126	0.114	0.108	0.108
1961	0.035	0.121	0.151	0.163	0.164	0.143	0.125	0.113	0.107	0.107
1962	0.038	0.132	0.164	0.176	0.176	0.155	0.133	0.118	0.11	0.11
1963	0.042	0.149	0.186	0.199	0.199	0.18	0.153	0.134	0.125	0.125
1964	0.043	0.152	0.192	0.206	0.206	0.186	0.157	0.137	0.128	0.128
1965	0.04	0.136	0.173	0.184	0.185	0.17	0.146	0.128	0.121	0.121
1966	0.044	0.149	0.187	0.197	0.196	0.18	0.154	0.134	0.127	0.127
1967	0.047	0.153	0.189	0.2	0.198	0.181	0.154	0.133	0.125	0.125
1968	0.046	0.14	0.171	0.179	0.176	0.163	0.141	0.123	0.116	0.116
1969	0.051	0.15	0.182	0.19	0.188	0.178	0.155	0.136	0.129	0.129
1970	0.066	0.194	0.231	0.243	0.24	0.224	0.195	0.167	0.156	0.156
1971	0.061	0.171	0.206	0.221	0.222	0.208	0.185	0.163	0.154	0.154
1972	0.068	0.185	0.221	0.239	0.241	0.222	0.197	0.175	0.165	0.165
1973	0.077	0.21	0.25	0.273	0.274	0.244	0.214	0.192	0.179	0.179
1974	0.088	0.233	0.274	0.294	0.292	0.256	0.226	0.204	0.19	0.19
1975	0.105	0.276	0.314	0.332	0.328	0.286	0.253	0.229	0.212	0.212
1976	0.092	0.235	0.266	0.274	0.267	0.235	0.211	0.192	0.179	0.179
1977	0.105	0.268	0.305	0.314	0.304	0.261	0.231	0.205	0.188	0.188
1978	0.1	0.254	0.295	0.304	0.29	0.252	0.224	0.197	0.179	0.179
1979	0.131	0.348	0.406	0.422	0.398	0.343	0.297	0.257	0.23	0.23
1980	0.11	0.293	0.356	0.37	0.34	0.289	0.25	0.218	0.197	0.197
1981	0.107	0.289	0.353	0.374	0.344	0.291	0.253	0.221	0.2	0.2
1982	0.114	0.314	0.38	0.408	0.373	0.315	0.273	0.238	0.216	0.216
1983	0.109	0.303	0.362	0.396	0.365	0.31	0.267	0.234	0.213	0.213
1984	0.11	0.312	0.364	0.406	0.384	0.331	0.283	0.248	0.225	0.225
1985	0.101	0.291	0.338	0.382	0.372	0.327	0.281	0.244	0.222	0.222
1986	0.119	0.36	0.408	0.457	0.467	0.415	0.352	0.3	0.27	0.27
1987	0.122	0.384	0.436	0.489	0.514	0.46	0.392	0.328	0.293	0.293
1988	0.114	0.367	0.419	0.466	0.499	0.453	0.388	0.329	0.295	0.295
1989	0.097	0.316	0.369	0.404	0.434	0.396	0.34	0.288	0.261	0.261
1990	0.087	0.288	0.345	0.381	0.414	0.379	0.325	0.273	0.246	0.246
1991	0.092	0.316	0.381	0.421	0.457	0.423	0.366	0.305	0.272	0.272
1992	0.084	0.295	0.368	0.416	0.456	0.425	0.375	0.312	0.279	0.279
1993	0.075	0.265	0.339	0.387	0.42	0.392	0.352	0.292	0.258	0.258
1994	0.073	0.27	0.348	0.393	0.411	0.384	0.348	0.282	0.244	0.244
1995	0.075	0.29	0.375	0.418	0.418	0.38	0.338	0.265	0.222	0.222

year	age									
	1	2	3	4	5	6	7	8	9	10+
1996	0.083	0.335	0.42	0.451	0.423	0.371	0.321	0.249	0.206	0.206
1997	0.094	0.401	0.5	0.526	0.467	0.392	0.316	0.239	0.193	0.193
1998	0.082	0.342	0.44	0.486	0.412	0.332	0.252	0.186	0.147	0.147
1999	0.073	0.299	0.383	0.455	0.405	0.333	0.242	0.172	0.131	0.131
2000	0.06	0.241	0.299	0.358	0.325	0.264	0.188	0.129	0.095	0.095
2001	0.085	0.36	0.42	0.468	0.415	0.316	0.22	0.143	0.098	0.098
2002	0.073	0.298	0.336	0.369	0.344	0.28	0.205	0.13	0.085	0.085
2003	0.075	0.301	0.322	0.341	0.315	0.26	0.188	0.117	0.073	0.073
2004	0.064	0.248	0.252	0.25	0.219	0.175	0.123	0.078	0.048	0.048
2005	0.061	0.229	0.229	0.225	0.201	0.16	0.112	0.074	0.046	0.046
2006	0.057	0.207	0.203	0.192	0.167	0.132	0.094	0.065	0.042	0.042
2007	0.046	0.161	0.159	0.152	0.135	0.108	0.078	0.057	0.037	0.037
2008	0.037	0.124	0.123	0.121	0.108	0.089	0.067	0.049	0.032	0.032
2009	0.034	0.11	0.11	0.111	0.1	0.082	0.06	0.047	0.032	0.032
2010	0.033	0.103	0.107	0.112	0.101	0.083	0.061	0.047	0.032	0.032
2011	0.031	0.097	0.108	0.119	0.109	0.09	0.065	0.052	0.036	0.036
2012	0.034	0.104	0.117	0.126	0.115	0.093	0.066	0.051	0.034	0.034
2013	0.032	0.094	0.109	0.118	0.11	0.09	0.065	0.05	0.032	0.032
2014	0.034	0.101	0.117	0.126	0.117	0.094	0.068	0.052	0.032	0.032
2015	0.036	0.108	0.125	0.134	0.123	0.099	0.073	0.055	0.034	0.034
2016	0.038	0.117	0.14	0.154	0.144	0.116	0.085	0.063	0.037	0.037
2017	0.036	0.108	0.134	0.146	0.133	0.105	0.077	0.057	0.033	0.033
2018	0.037	0.114	0.144	0.156	0.139	0.108	0.081	0.06	0.034	0.034
2019	0.03	0.09	0.119	0.13	0.116	0.091	0.071	0.054	0.031	0.031
2020	0.026	0.073	0.102	0.114	0.103	0.082	0.067	0.052	0.031	0.031
2021	0.022	0.062	0.087	0.096	0.086	0.066	0.054	0.043	0.026	0.026

Table 13.3.3. Plaice in Subarea 4 and Subdivision 20: Estimated stock numbers (thousands).

year	age									
	1	2	3	4	5	6	7	8	9	10+
1957	1777447	736111	876809	504551	340270	125465	152224	123229	75552	163809
1958	2574779	1048368	457679	573030	327383	216487	91670	105448	86099	171239
1959	3051492	1527395	652903	286408	363379	210857	143045	65088	73650	181995
1960	2704808	1786548	903400	403899	177171	232129	138675	96807	46040	178429
1961	2913510	1581868	1042551	547475	255632	114802	148358	93778	66675	157740
1962	2094935	1742364	952664	627434	344653	160376	78461	99619	63835	156734
1963	2463849	1219741	1023847	579711	383910	215506	103198	54000	68829	157504
1964	6266903	1395620	700786	587542	357948	243316	130898	66403	36738	159948
1965	2422182	4106804	765522	403044	328602	215510	153512	85514	44418	139632
1966	1901768	1419929	2701885	438197	246792	203104	132672	101299	58338	128254
1967	1281557	1141816	809335	1695272	255611	151040	132642	83327	68339	127109
1968	1314378	763406	659365	467152	1075298	144051	92513	90671	54621	136587
1969	1882310	741197	461779	393624	282214	717392	90172	59876	63551	134968
1970	1739388	1099644	426046	284391	242748	185453	457205	59158	39452	135416
1971	1144435	1029053	587888	228221	161683	145741	114566	272762	39944	119455
1972	1010330	656975	600194	333881	133323	97319	92250	72879	172825	107409
1973	3345467	546995	360371	354062	197542	78300	57877	58799	46716	182373
1974	2586583	1972229	294808	198454	193007	108143	47281	36519	37359	148023
1975	1836871	1483719	1113621	153696	107767	103143	64157	29720	23176	118122
1976	1504720	1002378	769468	592604	78214	56315	56083	38690	18413	87352
1977	2157308	809601	545462	430326	352663	47438	33507	33390	24719	67144
1978	1930926	1183504	409702	288730	237241	183912	30080	20687	20364	58188
1979	1865315	1071139	617833	221341	162031	142222	105817	18835	13334	51227
1980	2705160	966044	493580	292540	106660	83219	74506	58490	11364	40063
1981	2130023	1474723	491539	227390	145494	58859	48388	44587	35971	33745
1982	4597953	1150729	748205	244583	110283	74948	35333	28859	27482	45299
1983	3084917	2558446	570589	346117	117369	56333	41441	21227	17554	46082
1984	2924046	1657053	1300752	293646	156537	62026	31795	25051	13235	40174
1985	3695236	1536012	800991	660375	148358	74094	34183	18807	15291	33852
1986	9413689	2067630	772168	426134	315192	83983	39562	19794	11656	31607
1987	4262104	5353912	979841	367627	212482	141582	43500	21557	11364	26539
1988	4221792	2328690	2482992	461355	171500	95996	68398	21929	12448	23266
1989	2878911	2319031	1101689	1159692	218914	77283	46048	36149	12155	21694
1990	2543192	1553119	1129730	543527	557512	107298	38734	25279	21012	20734
1991	2405496	1441462	807728	567134	265855	260350	56039	22089	15078	26162
1992	2100116	1283371	692454	396999	276835	125638	116069	29980	12903	25548
1993	1348263	1138043	631270	338472	199509	127009	58920	56839	16986	23177
1994	1164663	728618	575682	317197	171360	98636	63624	31004	31023	23899
1995	2471067	619859	368418	285893	156915	87923	52873	32128	17271	31090

year	age									
	1	2	3	4	5	6	7	8	9	10+
1996	2764040	1430122	325866	180874	135429	76592	46884	27880	17818	28700
1997	5114056	1702437	699848	159677	93426	66491	40345	26428	16412	27748
1998	2076286	3009908	747803	292013	80941	42601	32110	22532	15752	26789
1999	1999642	1099935	1550369	300574	118387	45921	22777	18547	14307	26941
2000	2459946	1105309	548463	822183	118163	56044	23355	13966	11504	26712
2001	1708452	1404995	645142	347024	441941	59651	30280	14893	9490	26372
2002	4842997	954997	610856	294064	175582	204898	34751	19225	10059	23899
2003	1817149	2624688	473242	307897	160931	95240	125450	20635	12844	22529
2004	3461146	984070	1291842	245895	167830	95355	54484	78428	13713	24121
2005	2682394	2023932	476253	693283	139771	118832	64411	37348	57194	27473
2006	3160040	1532397	1110842	287103	411683	85076	82402	45233	27376	65555
2007	4538757	1814749	860001	641321	193387	288111	58818	61054	34478	72840
2008	4055831	2768710	976618	533037	412881	121319	223733	42448	44877	85292
2009	3987082	2267118	1600002	577233	335908	276567	82013	160924	30381	113482
2010	4333843	2240444	1352938	1006874	360733	209461	209119	59651	120082	110998
2011	6119852	2543439	1338919	922701	667689	235668	138215	156488	43140	193818
2012	3755868	3724120	1826459	887181	593499	424198	156322	100631	115435	171830
2013	4414532	2356158	2181453	1128991	537417	374189	270725	110238	73629	195338
2014	5410268	2689681	1577960	1324145	711453	324544	234942	180350	81299	186776
2015	2704338	3099788	1733877	1039448	786332	438937	217145	165760	127062	191870
2016	3026454	1615495	1699846	1092803	673515	468461	286431	151522	120264	217471
2017	4726987	1810003	949150	1011513	655524	404438	277462	191475	104502	221732
2018	2840331	2846217	1073863	572061	595420	389257	258591	184583	137534	222940
2019	6543052	1705879	1631902	599853	337756	349727	244901	178529	128413	244411
2020	4155293	3696339	1056237	1008574	364431	211003	242689	173920	130043	262846
2021	3599961	2401118	2342000	724096	649097	241430	139978	170224	128648	280412

Table 13.3.4. Plaice in Subarea 4 and Subdivision 20: Stock summary table.

year	recruits	ssb	catch	landings	discards	fbar2-6	fbar hc2-6	fbar dis2-3	Y/ssb
1957	1777447	807543.9	78442.19	70562.83	7881	0.11	0.09	0.046	0.09
1958	2574779	805718.9	88161.52	73353.77	14837	0.128	0.093	0.078	0.09
1959	3051492	799447.3	109179.6	79300.54	29863	0.145	0.093	0.097	0.1
1960	2704808	824895.7	117346.5	87540.78	29793	0.149	0.11	0.091	0.11
1961	2913510	829413.8	118369	85987.03	32489	0.148	0.101	0.114	0.1
1962	2094935	991852.8	125273.5	87473.77	37902	0.16	0.101	0.124	0.09
1963	2463849	895708.2	148439.1	107120.2	41257	0.182	0.116	0.152	0.12
1964	6266903	882605.3	147596.7	110542.2	37030	0.188	0.121	0.128	0.13
1965	2422182	779390	140210.2	97139.8	43081	0.17	0.12	0.117	0.12
1966	1901768	833997.6	166490.3	101832.6	64719	0.182	0.111	0.151	0.12
1967	1281557	957752.2	163517.5	108815.2	54548	0.184	0.103	0.143	0.11
1968	1314378	900101.2	139497.2	111534	27987	0.166	0.103	0.107	0.12
1969	1882310	800516.4	142811.3	121649.7	21169	0.177	0.13	0.084	0.15
1970	1739388	737568	159923.3	130342	29639	0.227	0.168	0.129	0.18
1971	1144435	676347.5	136964.2	113945.8	22994	0.205	0.157	0.112	0.17
1972	1010330	660542.1	142441.6	122843.4	19632	0.222	0.179	0.094	0.19
1973	3345467	543346.7	143711.4	130432.2	13353	0.25	0.22	0.07	0.24
1974	2586583	535510.7	157427	112539.3	44945	0.27	0.222	0.116	0.21
1975	1836871	541835.2	195348.7	108534.9	86699	0.307	0.201	0.242	0.2
1976	1504720	559398.8	166997.2	113673.2	53245	0.256	0.183	0.157	0.2
1977	2157308	561052	176622.9	119189	57500	0.29	0.188	0.185	0.21
1978	1930926	534593.2	159539.4	113976.7	45658	0.279	0.211	0.138	0.21
1979	1865315	511239.1	213145.3	145349.4	67935	0.383	0.277	0.203	0.28
1980	2705160	497570.7	171852.5	140762.4	31081	0.33	0.29	0.096	0.28
1981	2130023	467552.3	174140.4	141234.5	33030	0.33	0.29	0.097	0.3
1982	4597953	450553.9	205328.7	156154.8	49125	0.358	0.304	0.131	0.35
1983	3084917	544782.4	220537.4	145780.6	74482	0.347	0.281	0.157	0.27
1984	2924046	561149.1	236422.1	165776.3	70813	0.359	0.27	0.158	0.3
1985	3695236	598279.6	232240.5	171840.7	60547	0.342	0.283	0.143	0.29
1986	9413689	624663.1	308262.5	178880.9	129952	0.421	0.32	0.204	0.29
1987	4262104	746710.3	358749	168738.1	190533	0.457	0.328	0.313	0.23
1988	4221792	647359.9	324771.9	168556.6	156421	0.441	0.274	0.314	0.26
1989	2878911	701085	286703.7	178891.3	107793	0.384	0.247	0.262	0.26
1990	2543192	629991.6	240832.1	169454.6	71224	0.361	0.25	0.235	0.27
1991	2405496	580727.7	237985.9	157282.6	80932	0.399	0.269	0.256	0.27
1992	2100116	495074.4	193692	136727.8	57048	0.392	0.273	0.219	0.28
1993	1348263	445227.3	163523.9	128502.3	35018	0.361	0.287	0.154	0.29
1994	1164663	389445.9	145744.6	121925	23785	0.361	0.304	0.136	0.31
1995	2471067	370771.8	131248	109349	21827	0.376	0.321	0.13	0.29
1996	2764040	348524.5	143394.4	91386.93	52048	0.4	0.309	0.209	0.26

year	recruits	ssb	catch	landings	discards	fbar2-6	fbar hc2-6	fbar dis2-3	Y/ssb
1997	5114056	376501	192968.8	92949.32	100149	0.457	0.312	0.357	0.25
1998	2076286	420274.6	183654.5	79810.38	103751	0.402	0.228	0.322	0.19
1999	1999642	389501.2	160881.1	89722.74	70978	0.375	0.222	0.258	0.23
2000	2459946	410553.9	135014.5	90751.62	44312	0.297	0.196	0.193	0.22
2001	1708452	460560.4	193367.5	92904.83	100313	0.396	0.184	0.323	0.2
2002	4842997	401319.1	134404.4	79176.87	55099	0.325	0.213	0.232	0.2
2003	1817149	476195.2	154023.1	74728.11	79273	0.308	0.192	0.224	0.16
2004	3461146	465976	127824	70507.74	57479	0.229	0.141	0.182	0.15
2005	2682394	531536.8	118885	62795.21	56250	0.209	0.109	0.178	0.12
2006	3160040	597792.7	131169	67142.61	64159	0.18	0.107	0.156	0.11
2007	4538757	624279.9	101028.6	58573.28	42373	0.143	0.08	0.124	0.09
2008	4055831	798229.7	105288.9	58334.77	46993	0.113	0.075	0.085	0.07
2009	3987082	930373.1	108298.9	62359.19	45903	0.102	0.064	0.081	0.07
2010	4333843	1076306	116971.5	70342.18	46569	0.101	0.061	0.076	0.07
2011	6119852	1057917	118106.1	76502.28	41595	0.104	0.058	0.076	0.07
2012	3755868	1101077	141842.4	82016.79	59914	0.111	0.061	0.09	0.07
2013	4414532	1144205	126359.8	86217.84	40027	0.104	0.064	0.081	0.08
2014	5410268	1219831	133664.5	80683.88	53012	0.111	0.055	0.092	0.07
2015	2704338	1082277	134577.4	85357.64	49226	0.118	0.062	0.101	0.08
2016	3026454	1042356	136930.5	92744.85	44251	0.134	0.067	0.111	0.09
2017	4726987	980394.1	114281.1	74928.9	39372	0.125	0.061	0.103	0.08
2018	2840331	825079.2	105953.7	57798.71	48001	0.132	0.058	0.113	0.07
2019	6543052	742891.3	86015.41	48744.33	37376	0.109	0.047	0.086	0.07
2020	4155293	774883.5	79078.72	40888.65	38269	0.095	0.041	0.075	0.05
2021	3599961	834755.3	73349.59	35930.74	37522	0.08	0.032	0.068	0.04

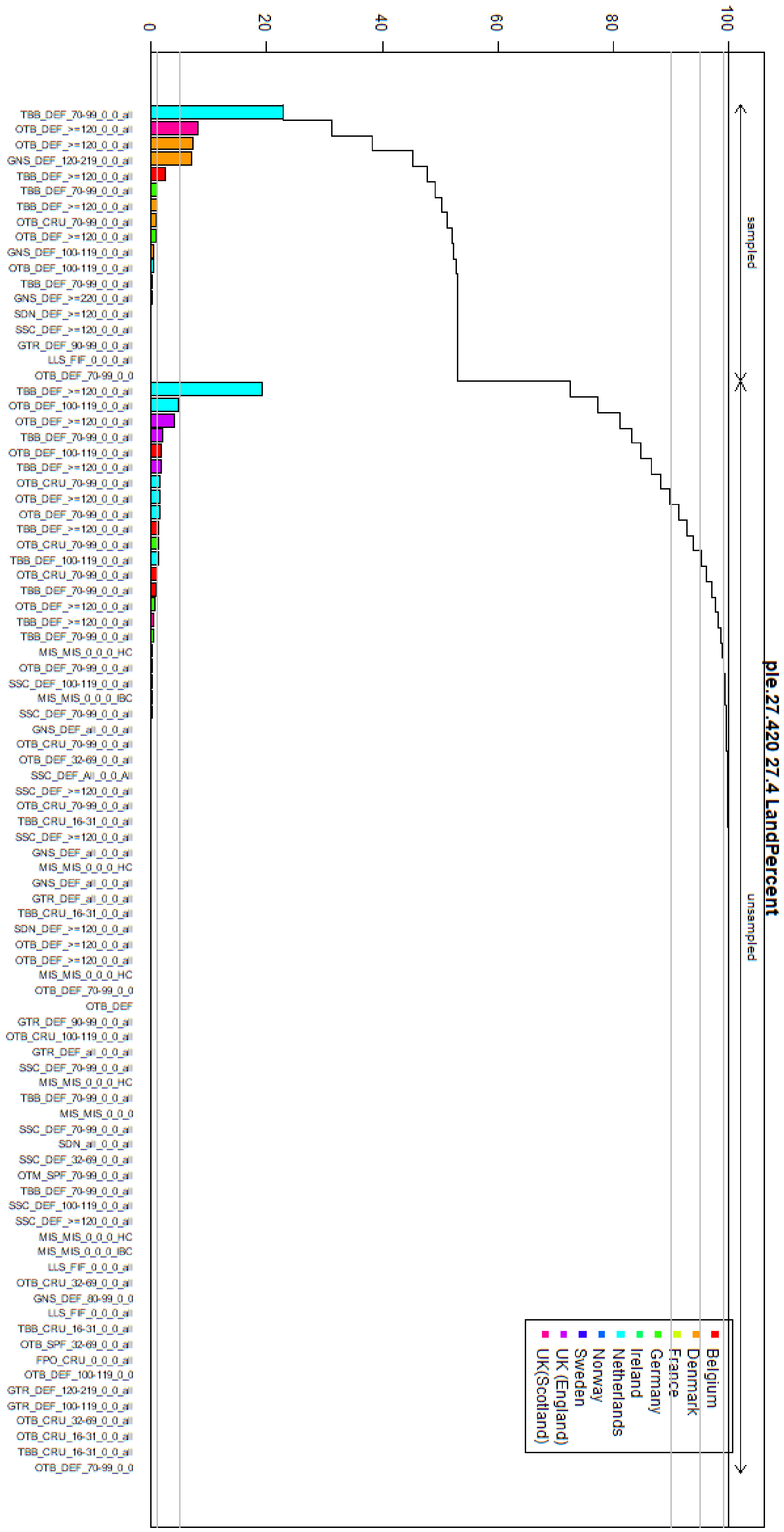
Table 13.5.1. Plaice in Subarea 4 and Subdivision 20: Results from the short-term forecast assuming $F_{2022} = F_{-status\ quo}$.

Basis	Total catch (2023)	Projected landings * (2023)	Projected discards ** (2023)	F_{total} ages 2–6 ^^^ (2023)	$F_{projected\ landings}$ ages 2–6 (2023)	$F_{projected\ discards}$ ages 2–3 (2023)	SSB (2024)	% SSB change ***	% advice change ^^
ICES advice basis									
MSY approach: F_{MSY}	150705	89647	61058	0.152	0.064	0.088	939221	-3.9	5.8
Other scenarios									
F =$F_{MSY\ upper}$	178156	105971	72185	0.182	0.077	0.105	916347	-6.3	25
F = $F_{MSY\ lower}$	117767	70047	47720	0.117	0.049	0.068	966970	-1.08	-17.4
F = 0	0	0	0	0	0	0	1065304	9	-100
F_{pa}	178156	105971	72185	0.182	0.077	0.105	916347	-6.3	25
SSB (2023) = B_{lim}	910260	538461	371799	1.53	0.64	0.88	341003	-65	540
SSB (2023) = B_{pa}	730460	432732	297728	1.04	0.44	0.60	473850	-52	410
SSB (2023) = MSY $B_{trigger}$	730460	432732	297728	1.04	0.44	0.60	473850	-52	410
Rollover advice	142508	85173	57335	0.144	0.061	0.083	945389	-3.3	0
$F_{2023} = F_{2022}$	81350	48410	32940	0.080	0.034	0.046	997551	2.1	-43

*** "projected" landing and discards are used to describe fish that would be landed and discarded in the absence of the EU landing obligation, based on average discard rate estimates for 2019–2021. Both projected landing and projected discards refer to Subarea 4 and Subdivision 20, calculated as the projected total stock catch (including Division 7.d) deducted by the catch of plaice from Subarea 4 taken in Division 7.d in 2022. The subtracted value (278 t of projected landing and 326 t of projected discards) is estimated based on the plaice catch advice for Division 7.d for 2023.**

*** Marketable landings.**

(a)


ple.27.420 27.4 LandPercent
sampled
unsampled
0
20
40
60
80
100
Belgium
Denmark
France
Germany
Ireland
Netherlands
Norway
Sweden
UK (England)
UK(Scotland)

(b)

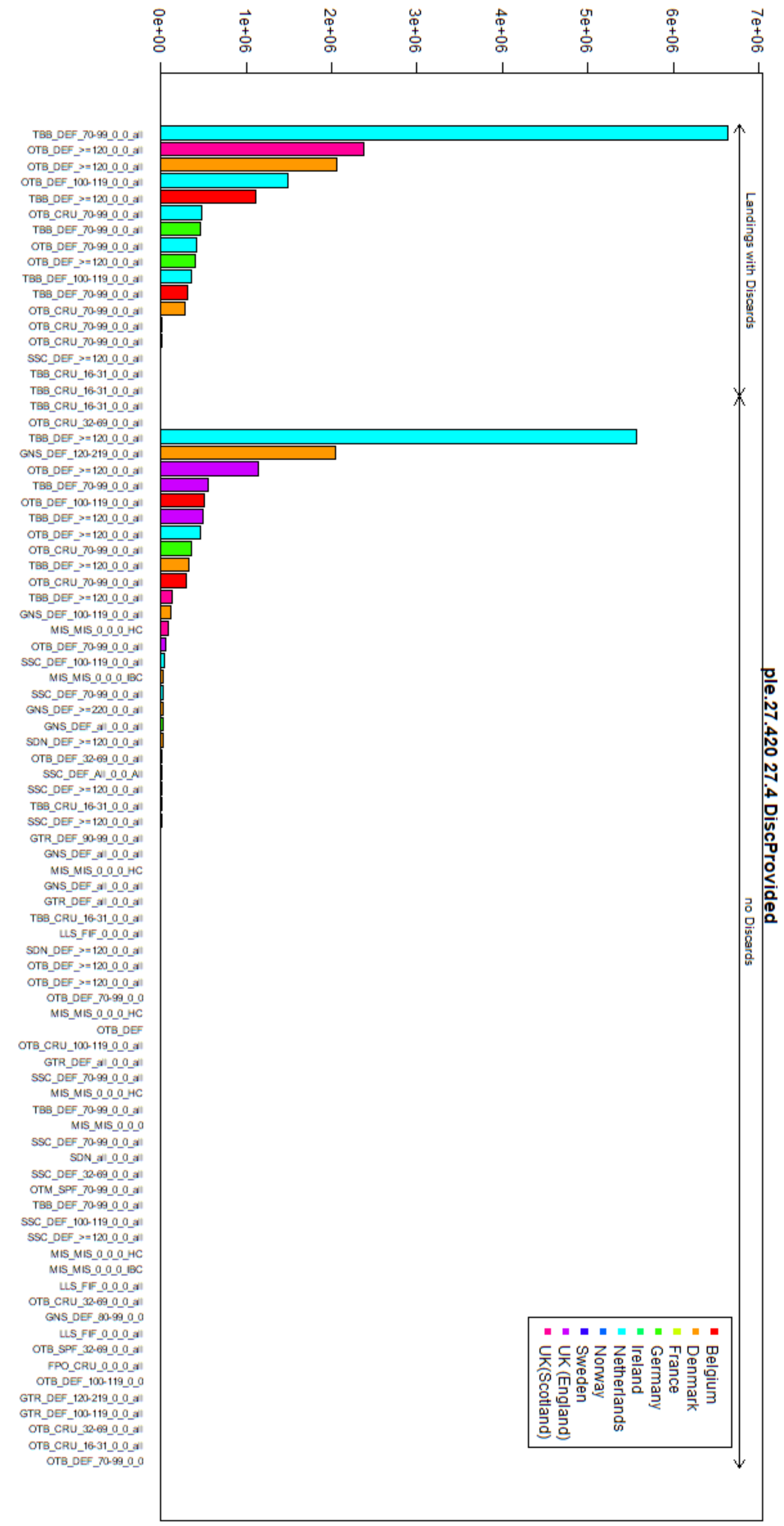
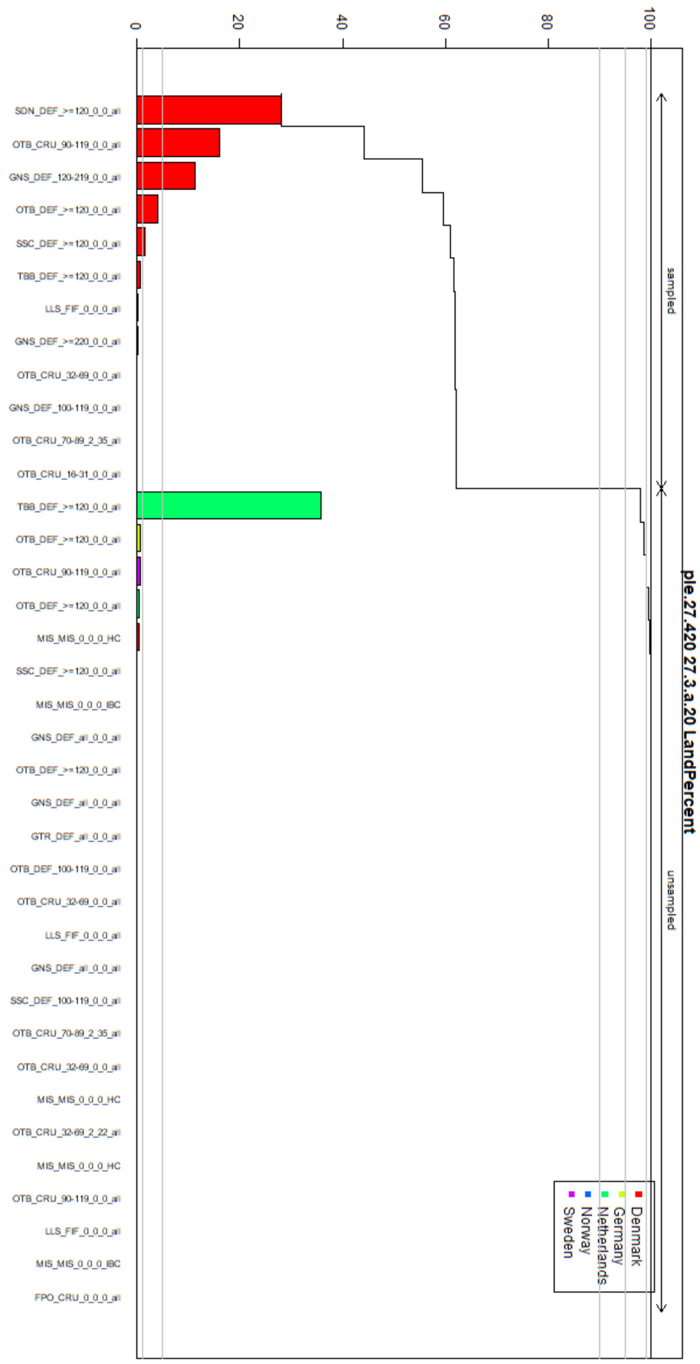


Figure 13.2.1. Summary of data upload in Intercatch for Subarea 4: (a) Percentage of landings. Sampled and unsampled refers to availability of age-composition information. (b) Percentage of landings provided with discards, by country by métier.

(a)


ple.27.420 27.3.a.20 LandPercent
sampled
unsampled
0
20
40
60
80
100
Denmark
Germany
Netherlands
Norway
Sweden
SDN_DEF_>=120_0_0_all
OTB_CRU_90-119_0_0_all
GNS_DEF_120-219_0_0_all
OTB_DEF_>=120_0_0_all
SSC_DEF_>=120_0_0_all
TBB_DEF_>=120_0_0_all
LLS_FIF_0_0_0_all
GNS_DEF_>=220_0_0_all
OTB_CRU_32-69_0_0_all
GNS_DEF_100-119_0_0_all
OTB_CRU_70-89_2_35_all
OTB_CRU_16-31_0_0_all
TBB_DEF_>=120_0_0_all
OTB_DEF_>=120_0_0_all
OTB_CRU_90-119_0_0_all
OTB_DEF_>=120_0_0_all
MIS_MIS_0_0_0_HC
SSC_DEF_>=120_0_0_all
MIS_MIS_0_0_0_IBC
GNS_DEF_all_0_0_all
OTB_DEF_>=120_0_0_all
GNS_DEF_all_0_0_all
GTR_DEF_all_0_0_all
OTB_DEF_100-119_0_0_all
OTB_CRU_32-69_0_0_all
LLS_FIF_0_0_0_all
GNS_DEF_all_0_0_all
SSC_DEF_100-119_0_0_all
OTB_CRU_70-89_2_35_all
OTB_CRU_32-69_0_0_all
MIS_MIS_0_0_0_HC
OTB_CRU_32-69_2_22_all
MIS_MIS_0_0_0_HC
OTB_CRU_90-119_0_0_all
LLS_FIF_0_0_0_all
MIS_MIS_0_0_0_IBC
FPO_CRU_0_0_0_all

(b)

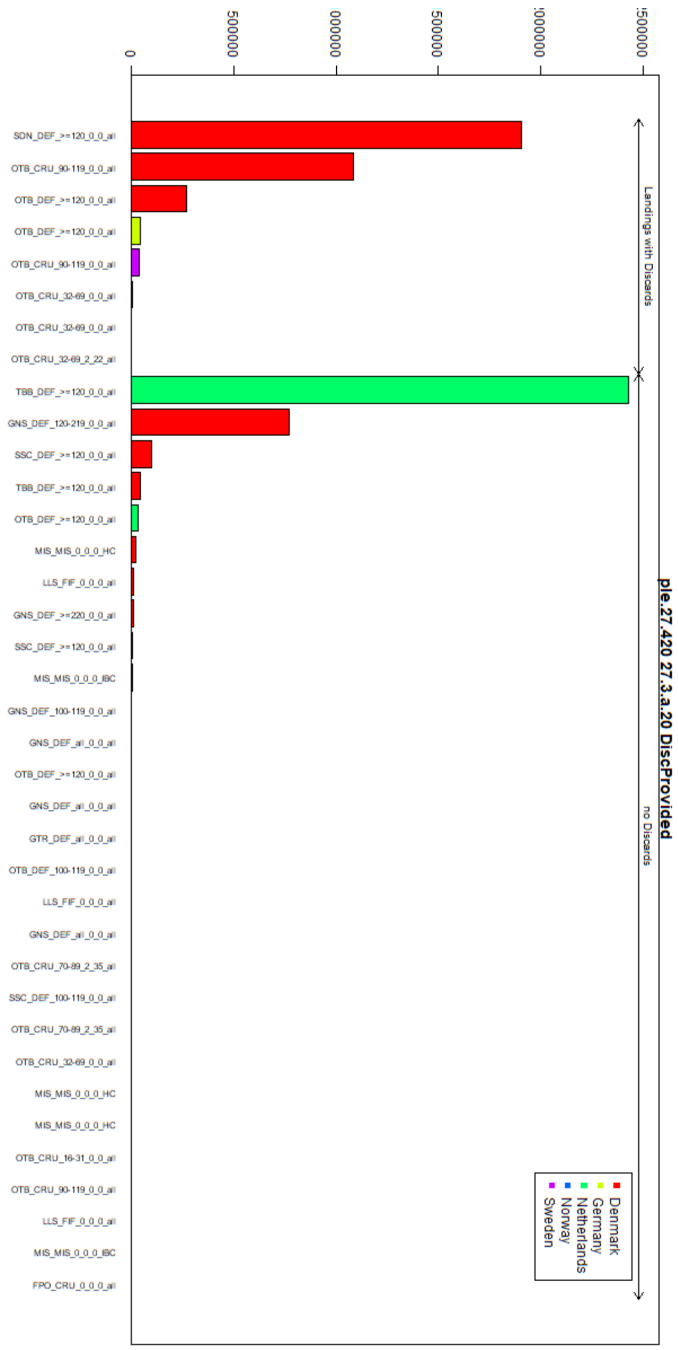


Figure 13.2.2. Summary of data upload in Intercatch for Subdivision 20: (a) Percentage of landings. Sampled and unsampled refers to availability of age-composition information. (b) Percentage of landings provided with discards, by country by métier.

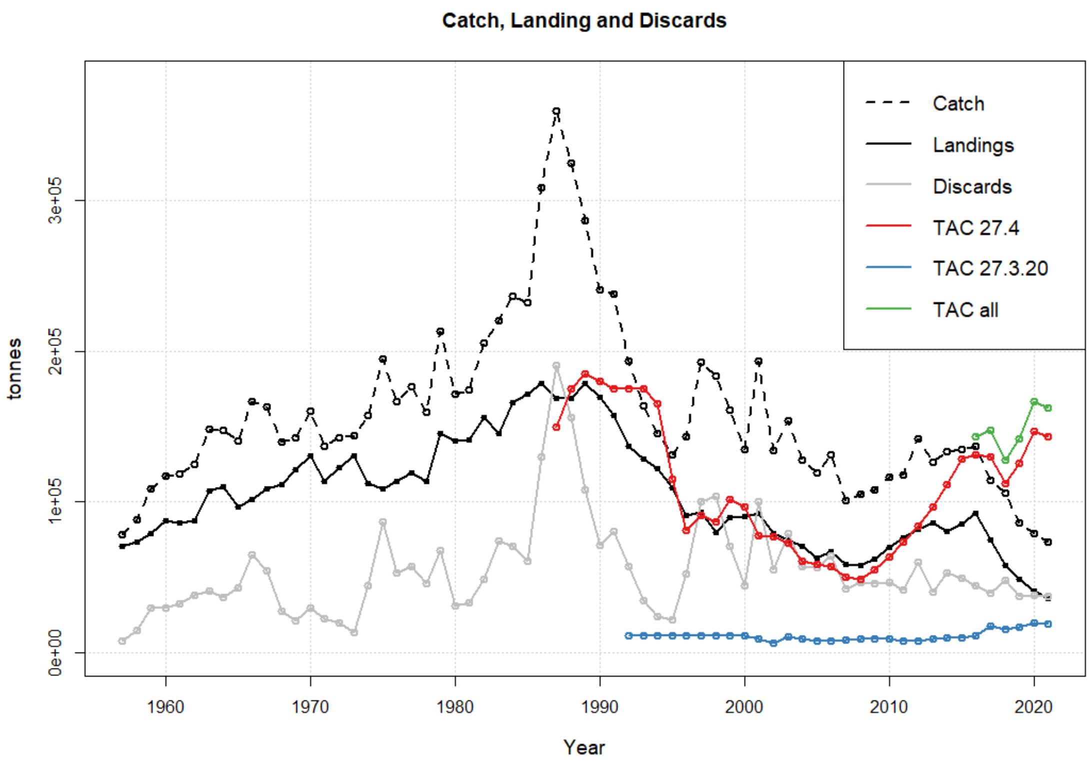


Figure 13.2.3. Plaice in Subarea 4 (including Subdivision 20 and 7.d Q1): Time series of catch (dashed line), landings (solid black line) and discards (gray line) estimates. TAC for Subarea 4 (red) , Subdivision 20 (blue) and combined area (green) are also plotted,. Discards before 2000 were reconstructed using a model-based method. Landing TAC was given before 2019 and catch TAC was given since 2019.

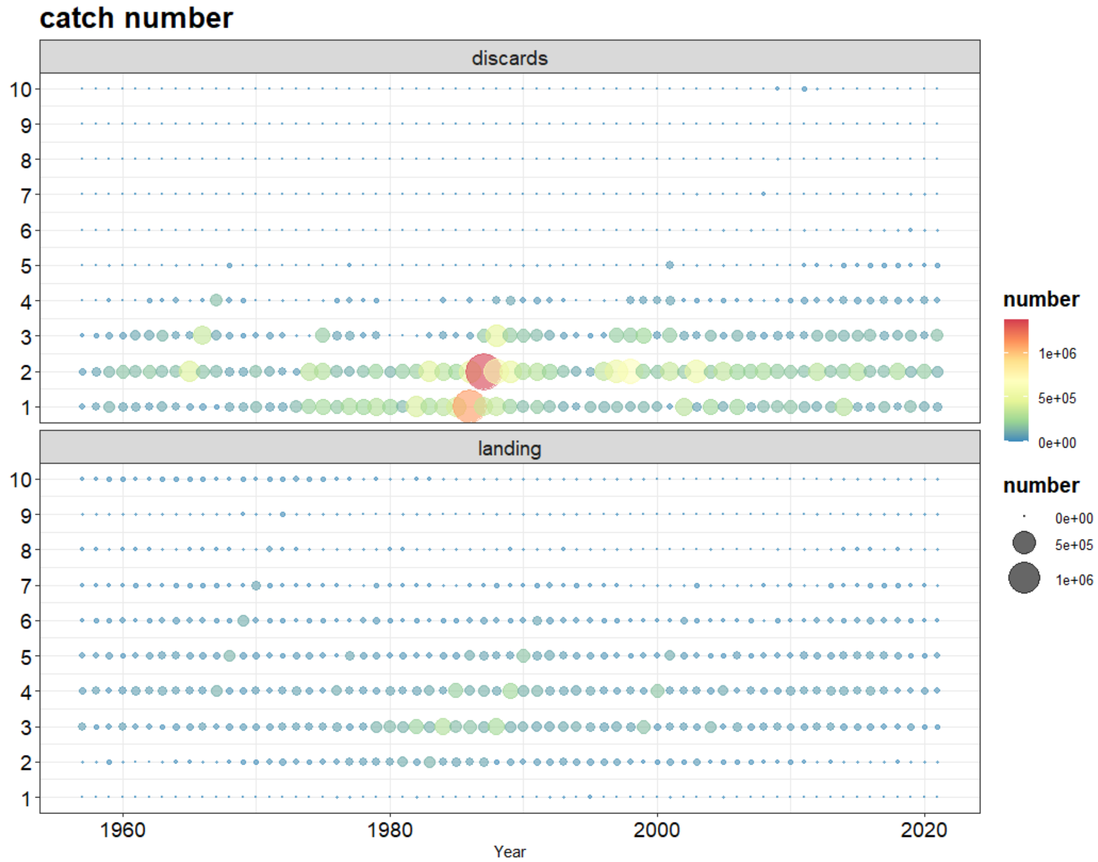


Figure 13.2.4. Plaice in Subarea 4 and Subdivision 20: Discards numbers-at-age (top) and landings numbers-at-age (down). Discards before 2000 were reconstructed using a model-based method.

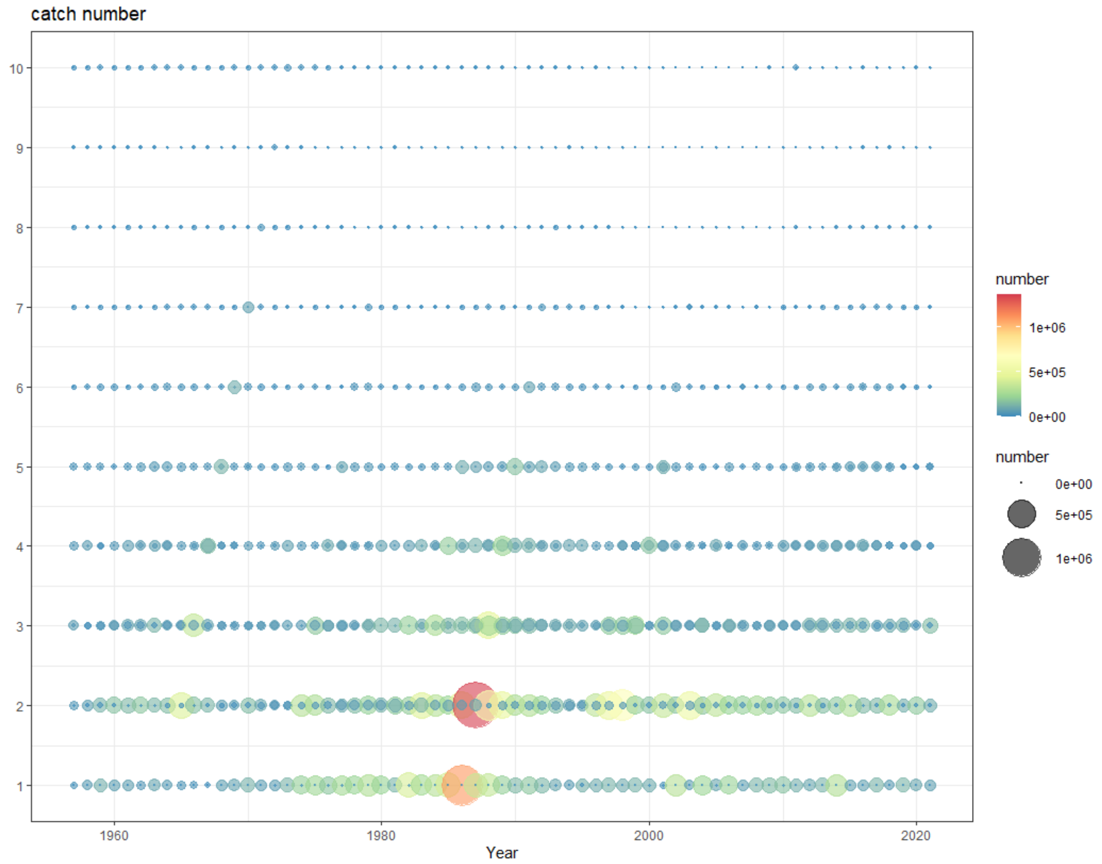


Figure 13.2.5. Plaice in Subarea 4 and Subdivision 20. Catch numbers-at-age: Discards before 2000 were reconstructed using a model-based method.

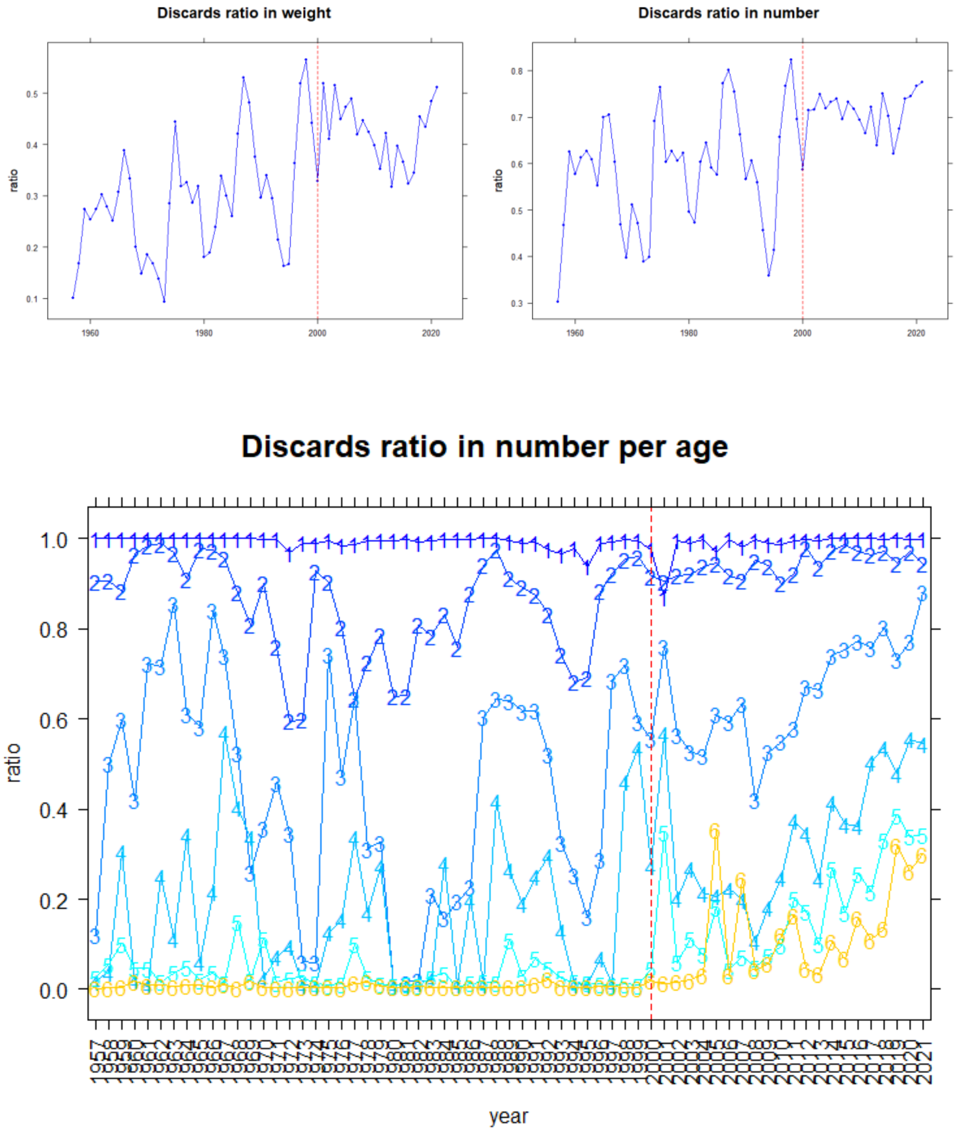


Figure 13.2.6. Discards ratio. Discards before 2000 were reconstructed using a model-based method.

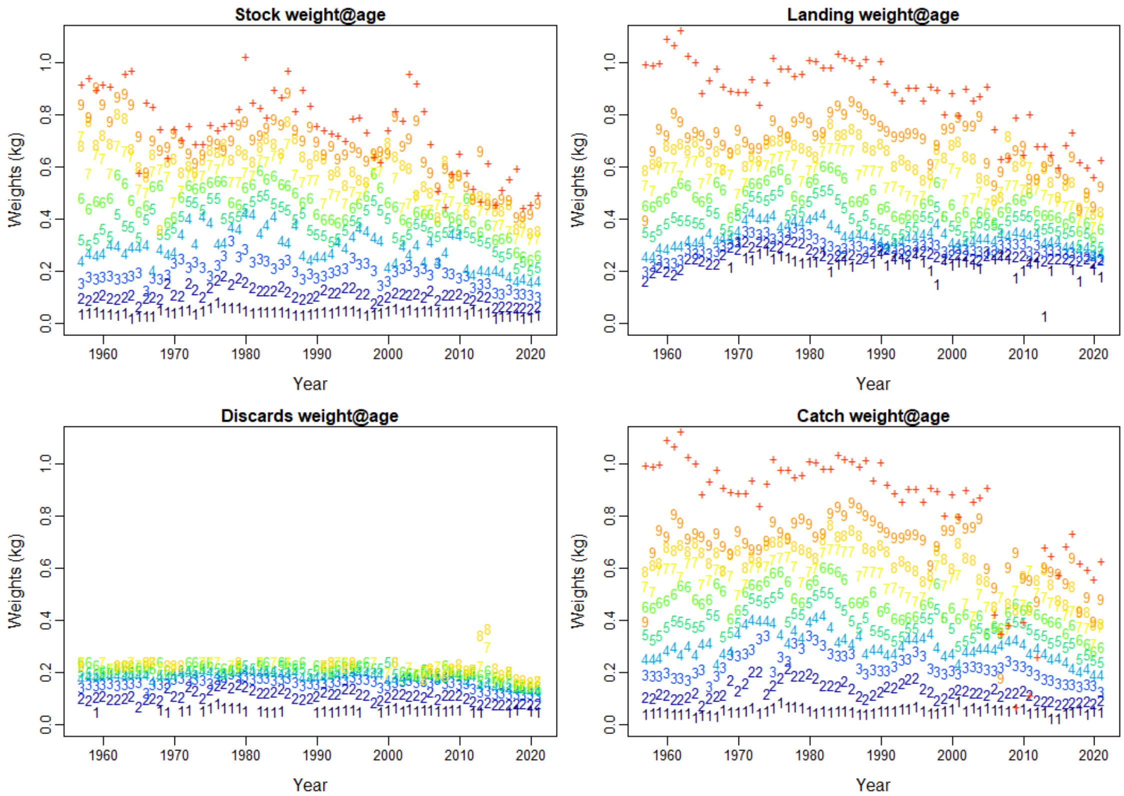


Figure 13.2.7. Plaice in Subarea 4 and Subdivision 20: Stock weight-at-age (top left), landings weight-at-age (top right), discards weight-at-age (bottom left) and catch weight-at-age (bottom right).

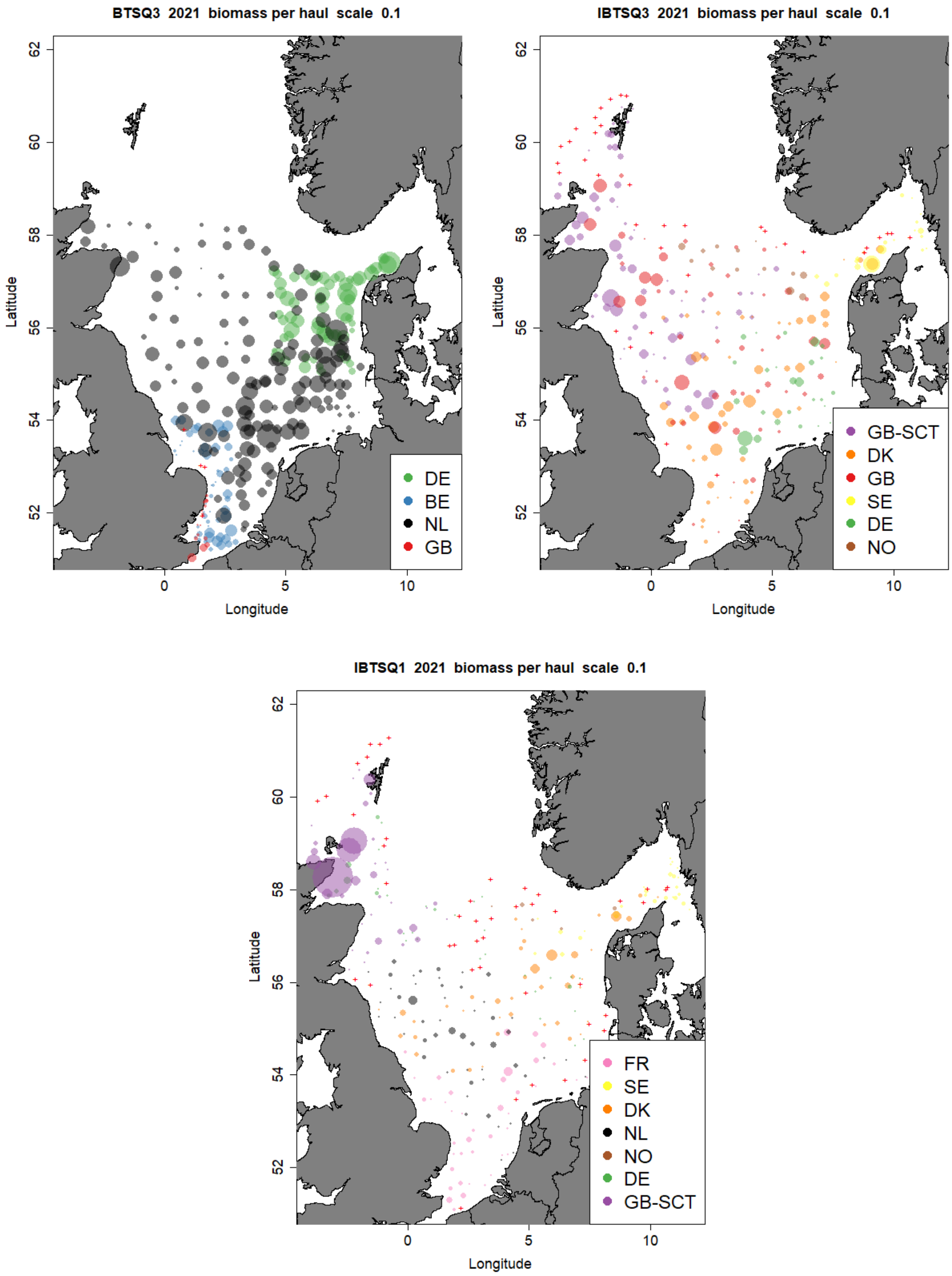
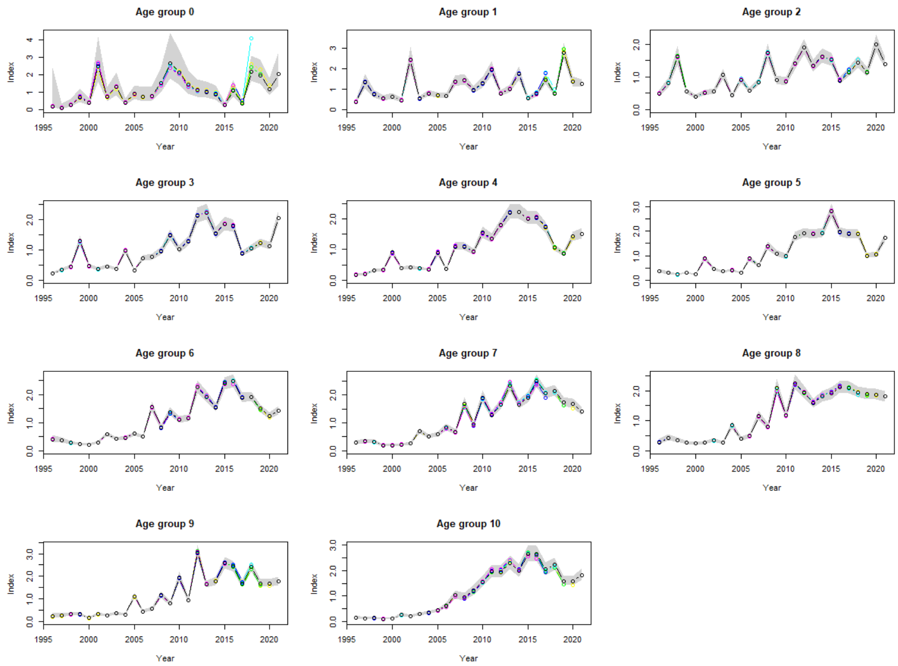


Figure 13.2.8. Spatial distribution of biomass per haul for BTS-Q3, IBTS-Q3 and IBTS-Q1 surveys in 2021. The age length key was estimated annually using GAM including spatial effects. Samples in grey area were excluded due to low coverage.

(a) BTS-IBTS Q3



(b) IBTS Q1

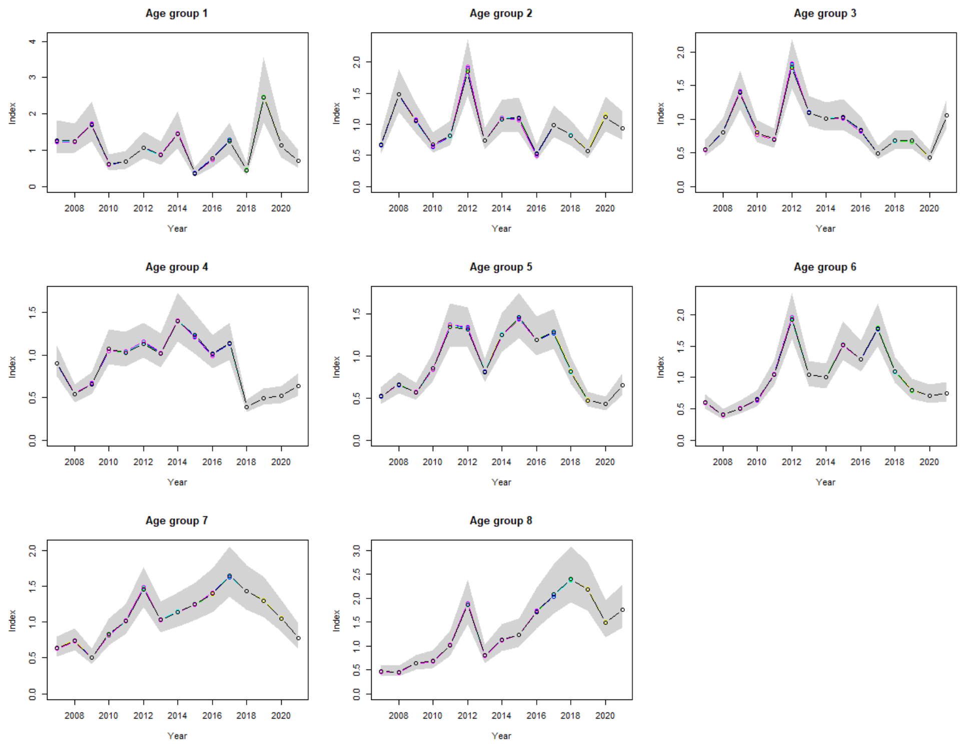
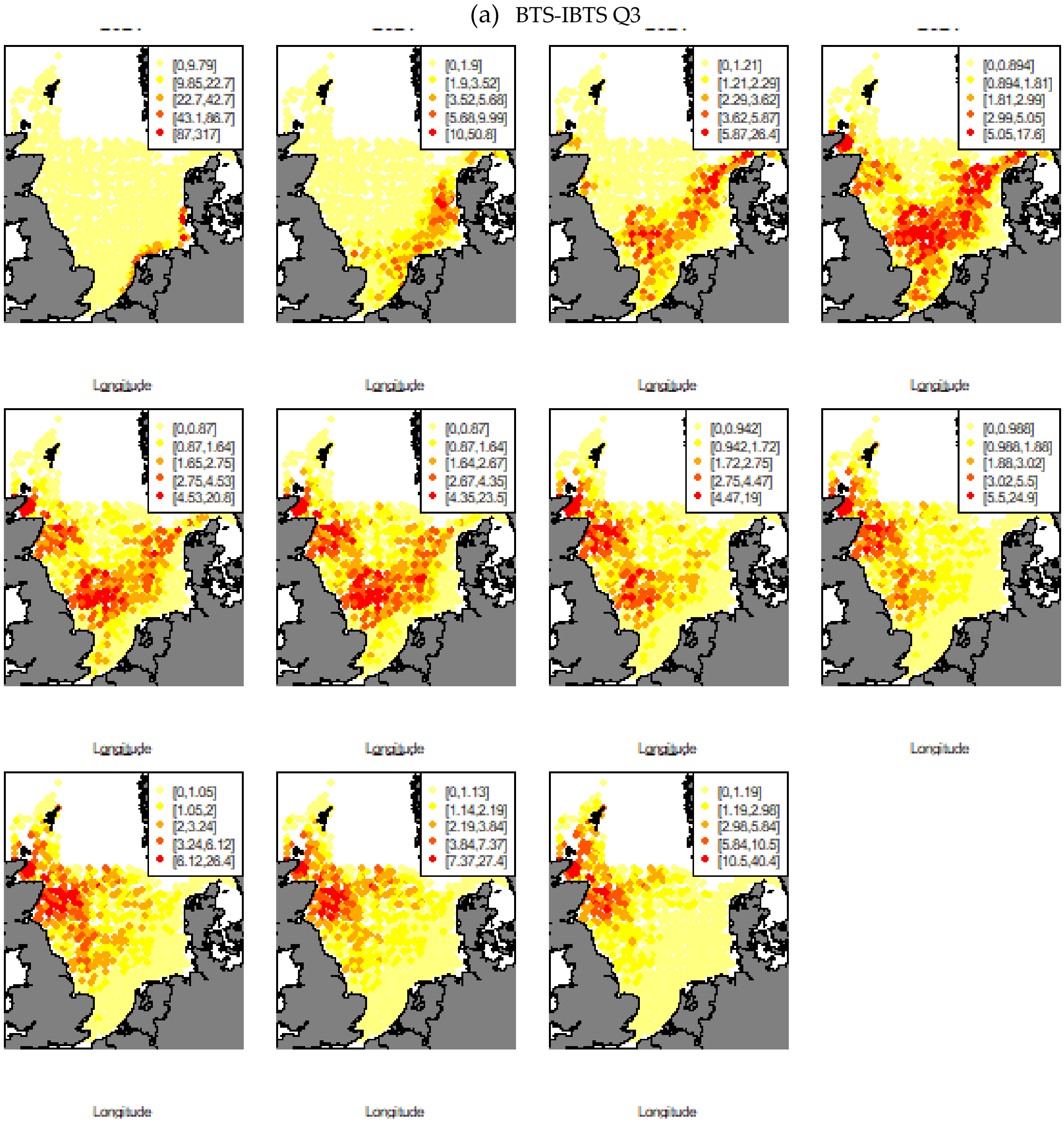


Figure 13.2.9. Retrospective analysis of (a) BTS-IBTS Q3 and (b) IBTS Q1. All Mohn's rho values are low (<<0.2).

(a) BTS-IBTS Q3


[0,9.79]
[9.85,22.7]
[22.7,42.7]
[43.1,86.7]
[87,317]
[0,1.9]
[1.9,3.52]
[3.52,5.68]
[5.68,9.99]
[10,50.8]
[0,1.21]
[1.21,2.29]
[2.29,3.62]
[3.62,5.87]
[5.87,26.4]
[0,0.894]
[0.894,1.81]
[1.81,2.99]
[2.99,5.05]
[5.05,17.6]
[0,0.87]
[0.87,1.64]
[1.65,2.75]
[2.75,4.53]
[4.53,20.8]
[0,0.87]
[0.87,1.64]
[1.64,2.67]
[2.67,4.35]
[4.35,23.5]
[0,0.942]
[0.942,1.72]
[1.72,2.75]
[2.75,4.47]
[4.47,19]
[0,0.968]
[0.968,1.88]
[1.88,3.02]
[3.02,5.5]
[5.5,24.9]
[0,1.05]
[1.05,2]
[2,3.24]
[3.24,8.12]
[8.12,26.4]
[0,1.13]
[1.14,2.19]
[2.19,3.84]
[3.84,7.37]
[7.37,27.4]
[0,1.19]
[1.19,2.98]
[2.98,5.84]
[5.84,10.5]
[10.5,40.4]
Longitude

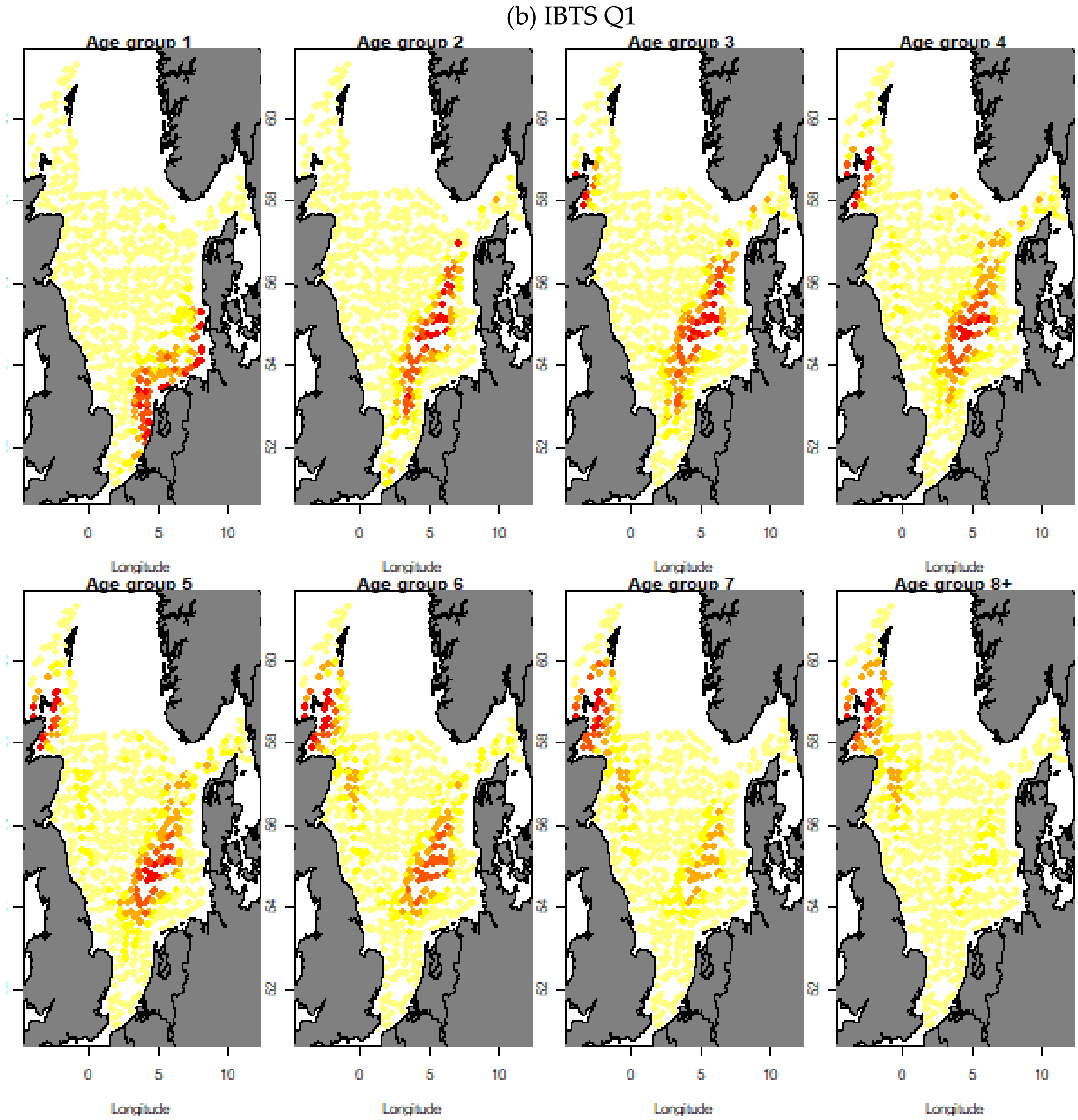


Figure 13.2.10. The abundance map per age for (a) BTS-IBTS Q3, (b) IBTS-Q1, estimated using delta-GAM method. BTS-IBTS Q3 includes age 0-10+. IBTS Q1 inclues age 1-8+. Abundance decreasing from red to white colour.

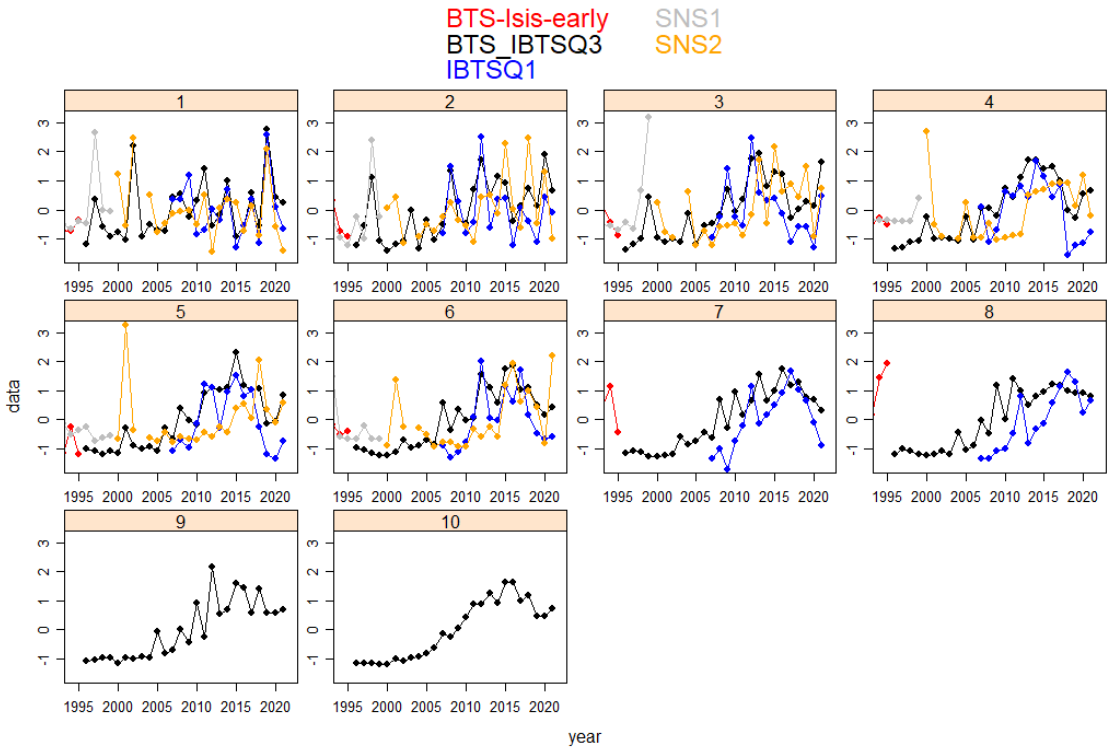


Figure 13.2.11. Plaice in Subarea 4 and Subdivision 20. Standardized survey tuning indices used for tuning stock assessment model: BTS–IBTS Q3 combined (1996–2021, black), BTS–Isis-early (1985–1995, red), IBTS Q1 (2007-2021, blue), SNS–1 (1970–1999, gray), and SNS–2 (2000–2021, yellow). Note: only ages used in the assessment are presented.

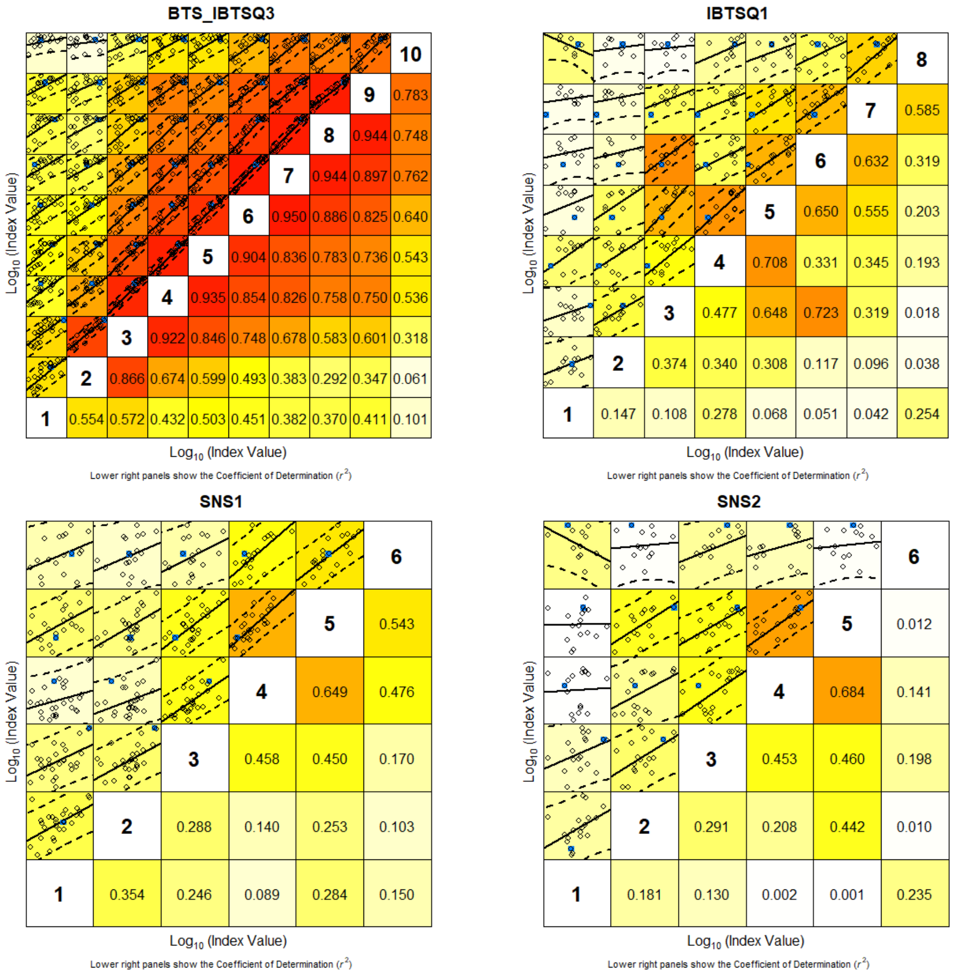


Figure 13.2.12. Plaice in Subarea 4 and Subdivision 20: Internal consistency plot for surveys.

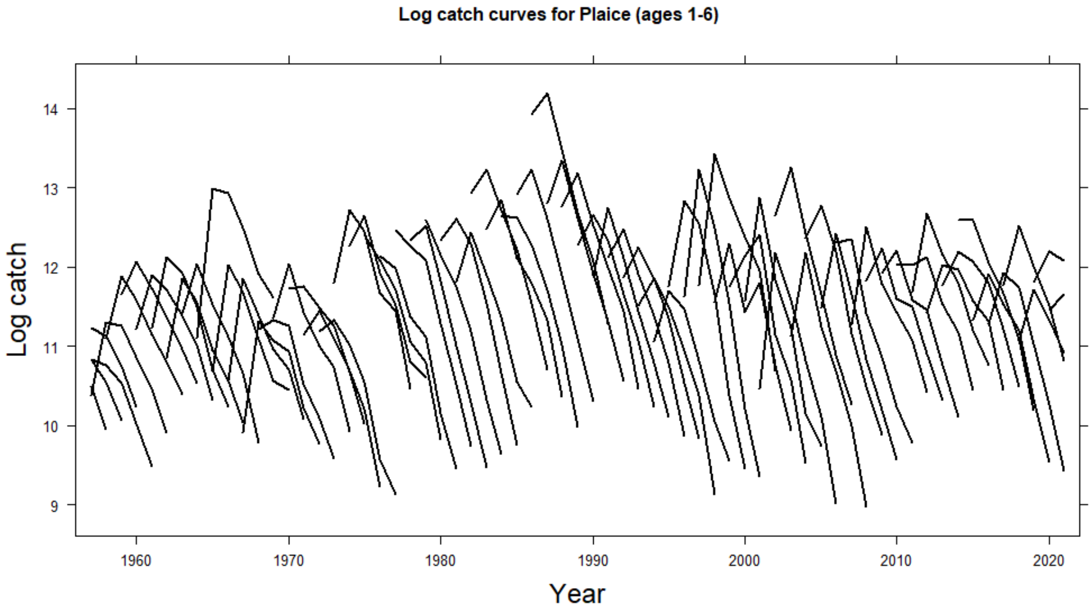


Figure 13.2.13. Catch curves for catches in age 1–6.

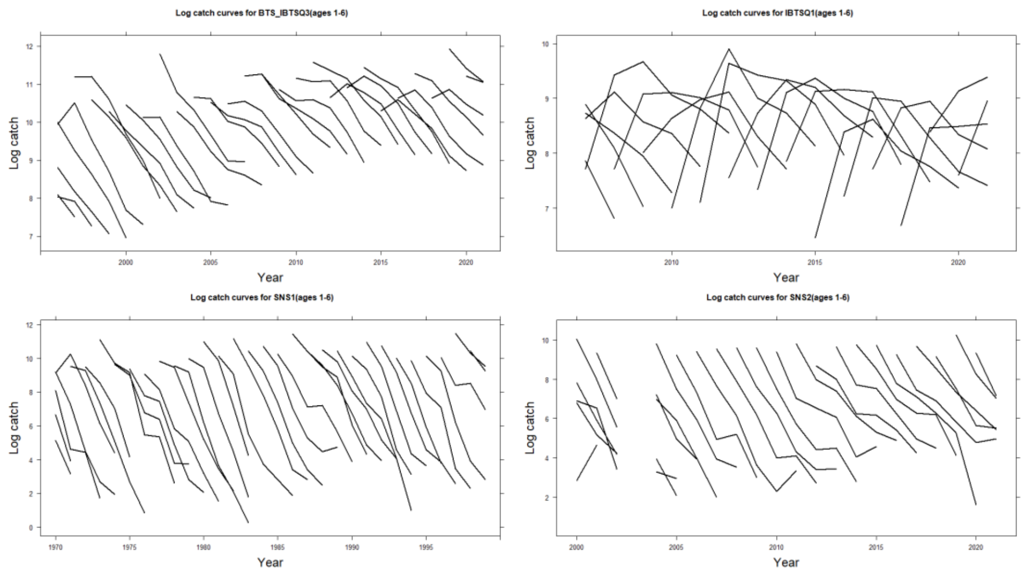
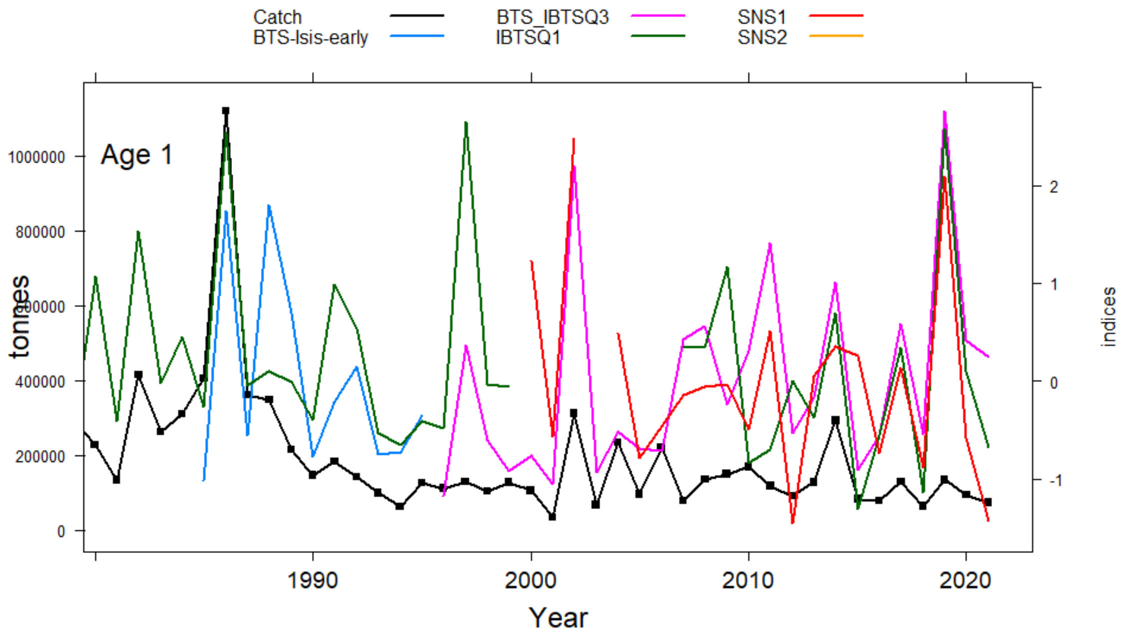
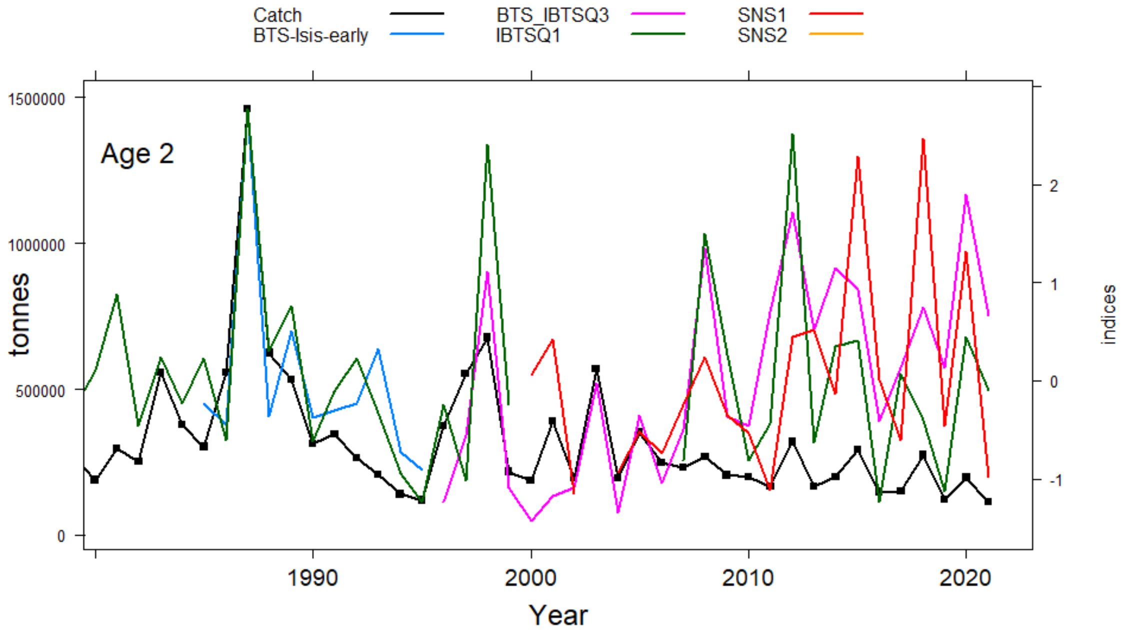
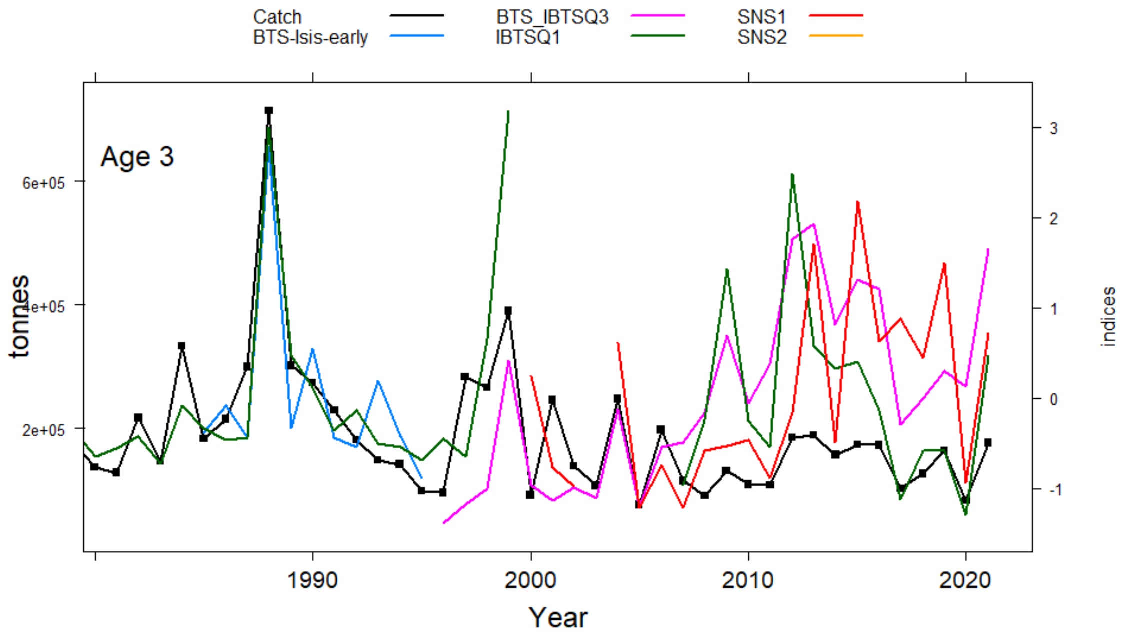
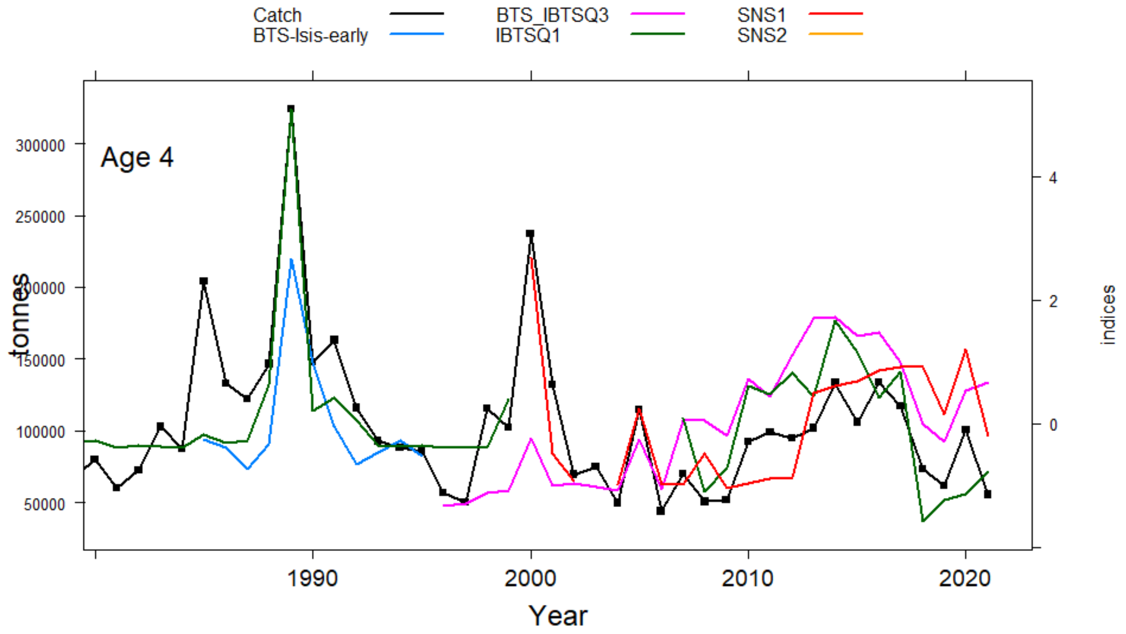


Figure 13.2.14. Catch curves for Surveys in age 1–6.


Catch
BTS-Isis-early
BTS_IBTSQ3
IBTSQ1
SNS1
SNS2
Age 1
tonnes
indices
Year
1990
2000
2010
2020
0
200000
400000
800000
1000000
-1
0
1
2


Catch
BTS-Isis-early
BTS_IBTSQ3
IBTSQ1
SNS1
SNS2
Age 2
tonnes
indices
Year
1990
2000
2010
2020
0
500000
1000000
1500000
-1
0
1
2


Catch
BTS-Isis-early
BTS_IBTSQ3
IBTSQ1
SNS1
SNS2
Age 3
tonnes
indices
Year


Catch
BTS-Isis-early
BTS_IBTSQ3
IBTSQ1
SNS1
SNS2
Age 4
tonnes
indices
Year

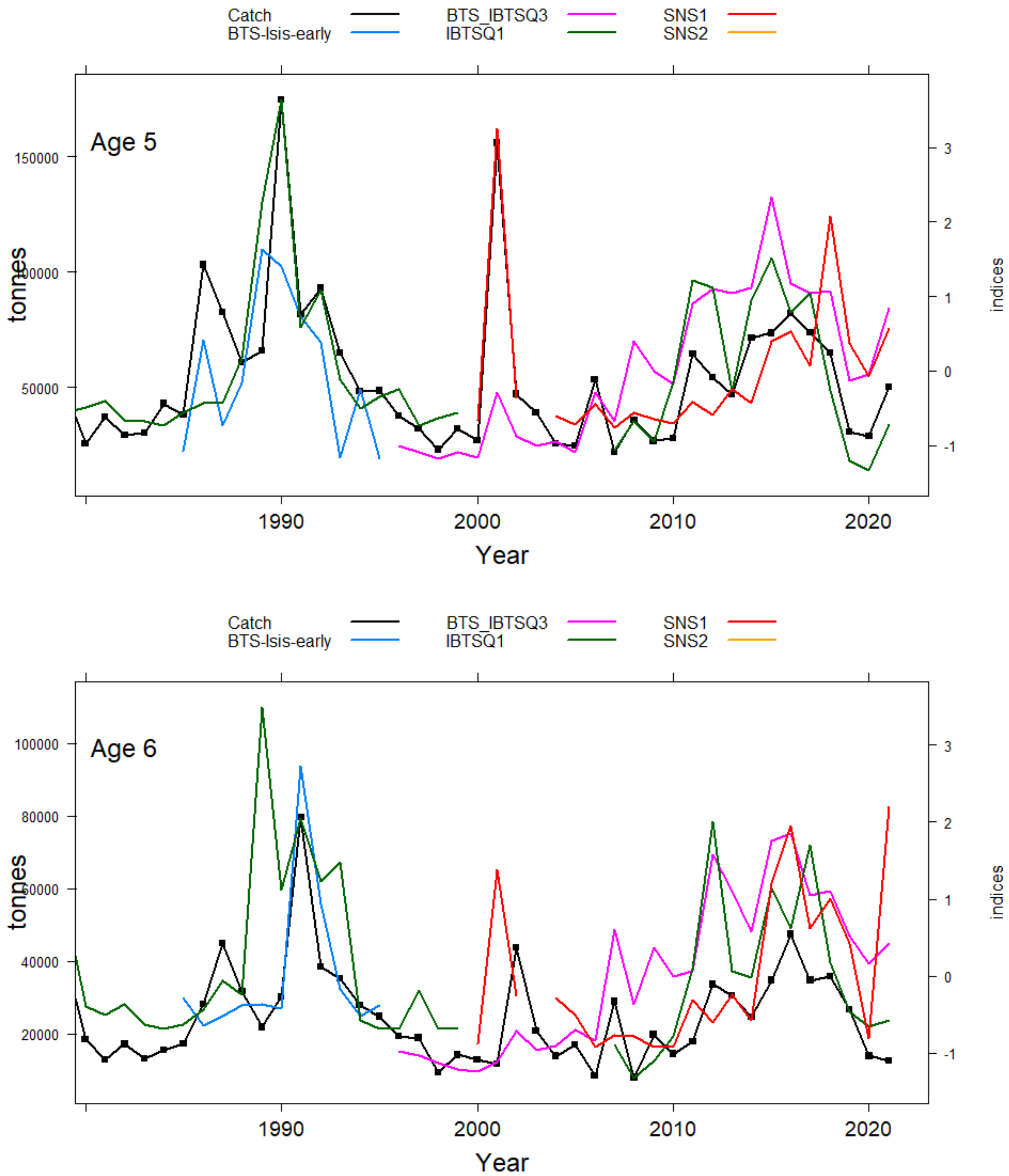


Figure 13.2.15. Catches vs. standardized survey indices by age (1–6). Figures are plotted since 1979 for better visualization of recent years.

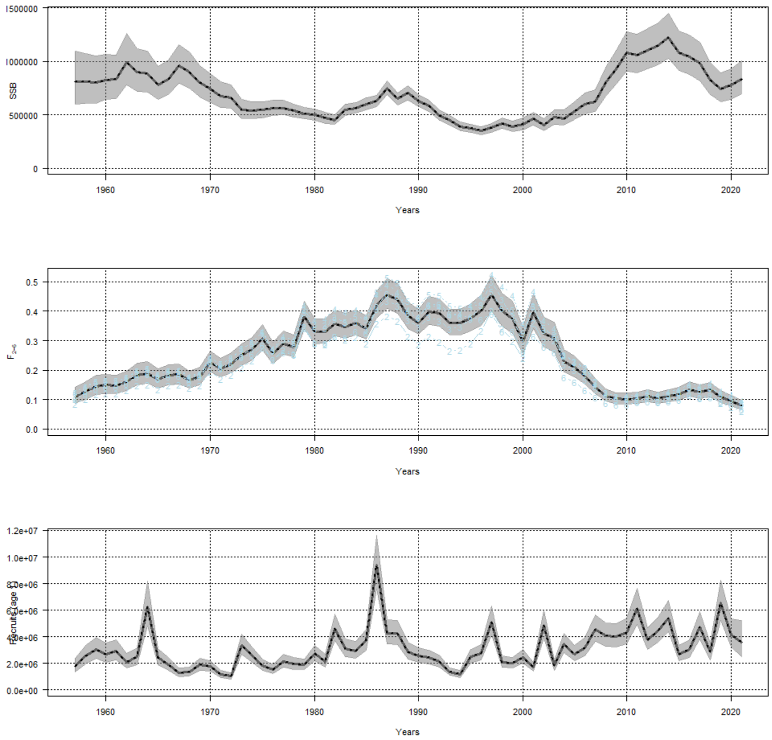


Figure 13.3.1. Stock assessment output for ple.27.420. SSB (top left), fishing mortality (top right), recruitment (bottom left) estimates of the assessment and the observed discards fraction (bottom right).

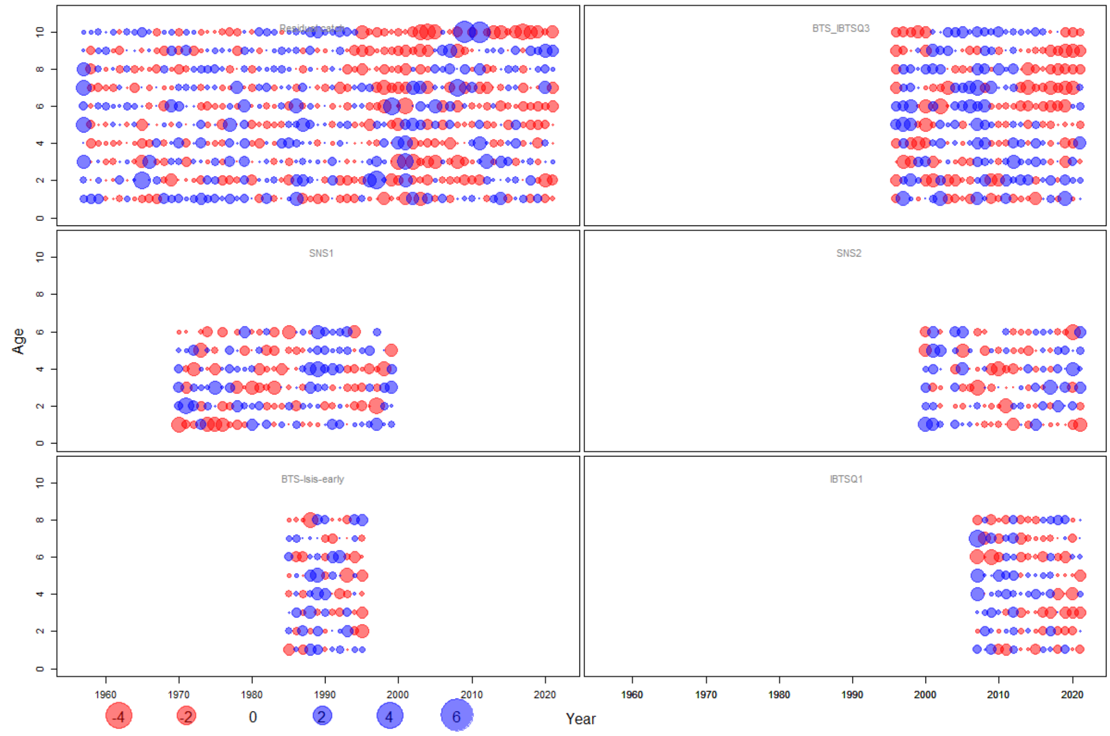


Figure 13.3.2. Standardized one step ahead observation residuals for catch and survey indices. Positive values are in blue and negative values are in red.

Figure 13.3.3. Process error for logN and logF. Positive values are in blue and negative values are in red.

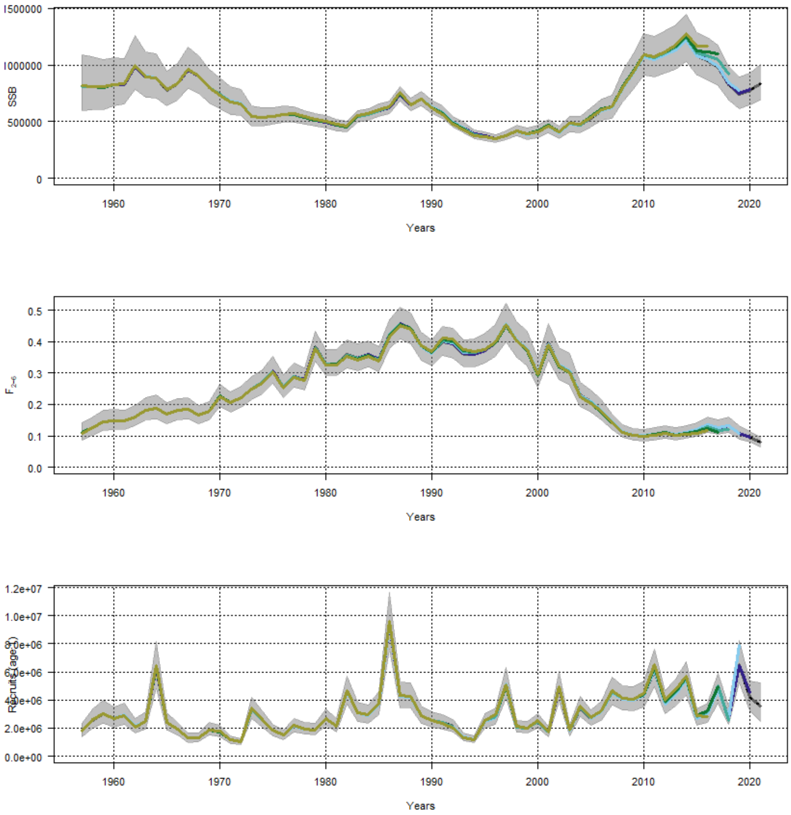


Figure 13.3.4. Retrospective analysis for SSB (Mohn's rho=0.081), recruitment (Mohn's rho=0.029) and F (Mohn's rho=-0.061).

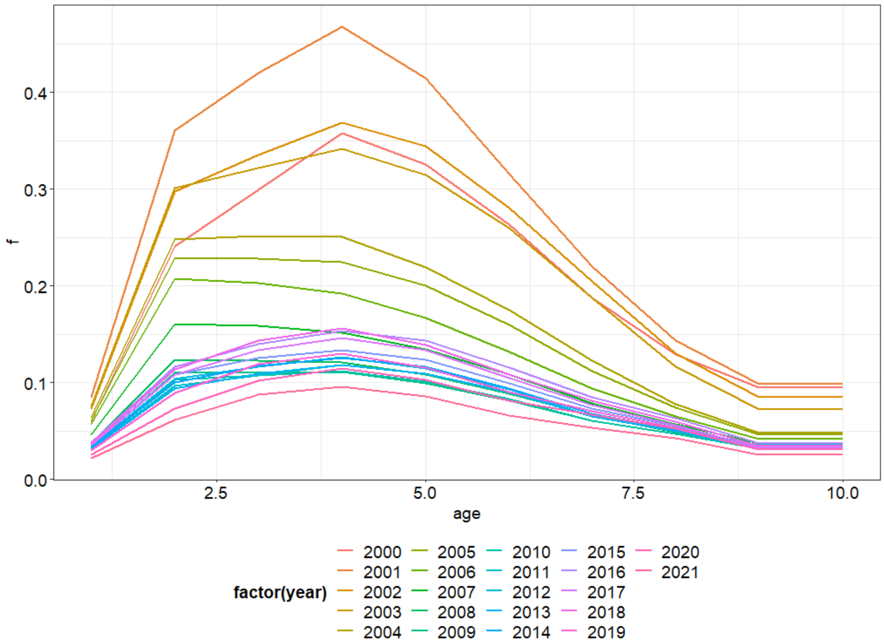


Figure 13.3.5. Estimated fishing mortality by age since 2000.

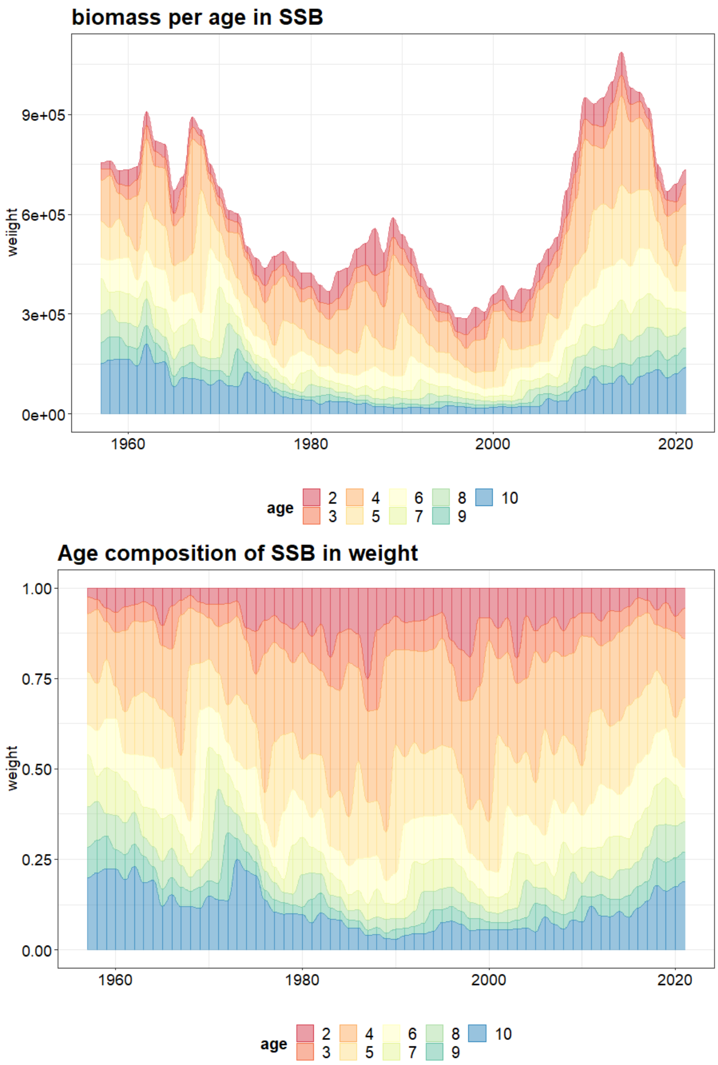


Figure 13.3.6. Age compositions in the estimated SSB.

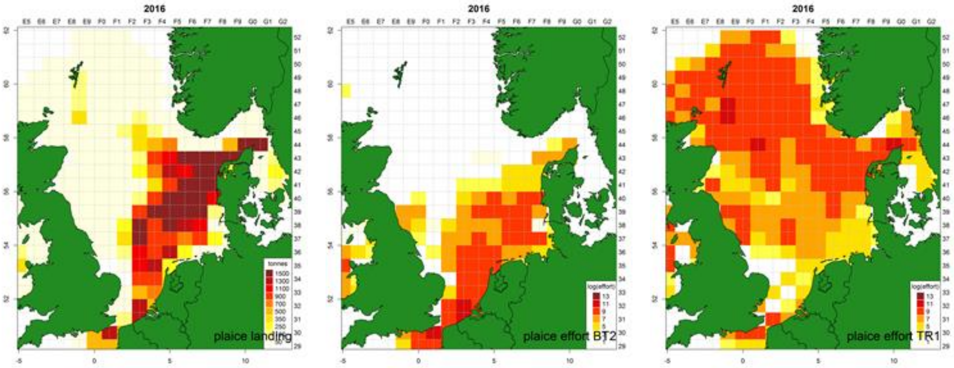


Figure 13.3.7. (a) Spatial distribution (by ICES rectangle) of landed plaice in 2016; (b) Spatial distribution of log-transformed TB2 fishing effort in 2016; (c) Spatial distribution of log-transformed TR1 fishing effort in 2016. Data were extracted from STECF FDI dataset. TB2 and TR1 are the two major gears in catching plaice in North Sea.

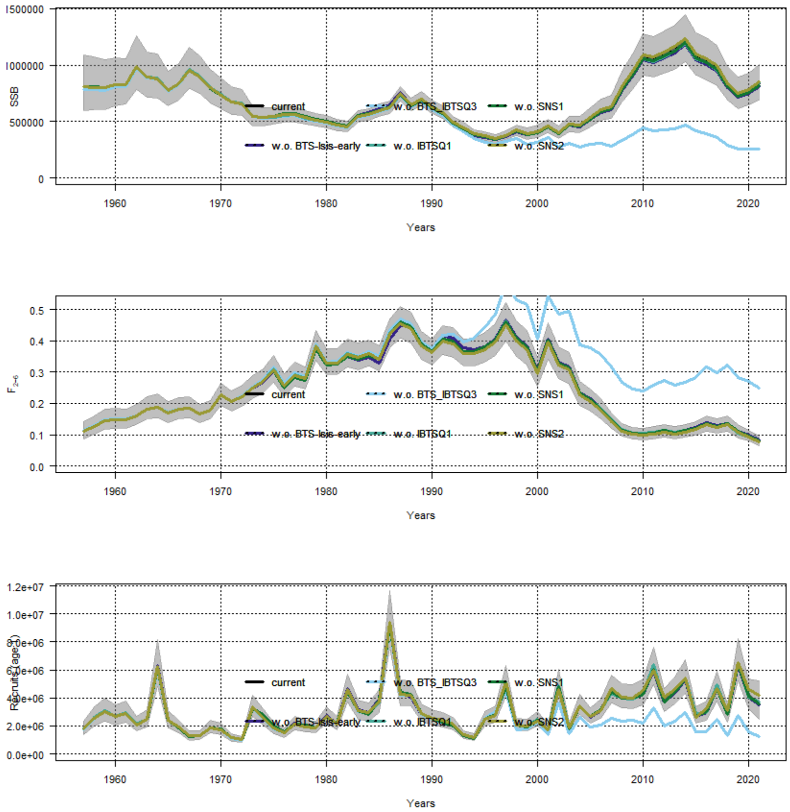


Figure 13.3.8. Leave one out runs.

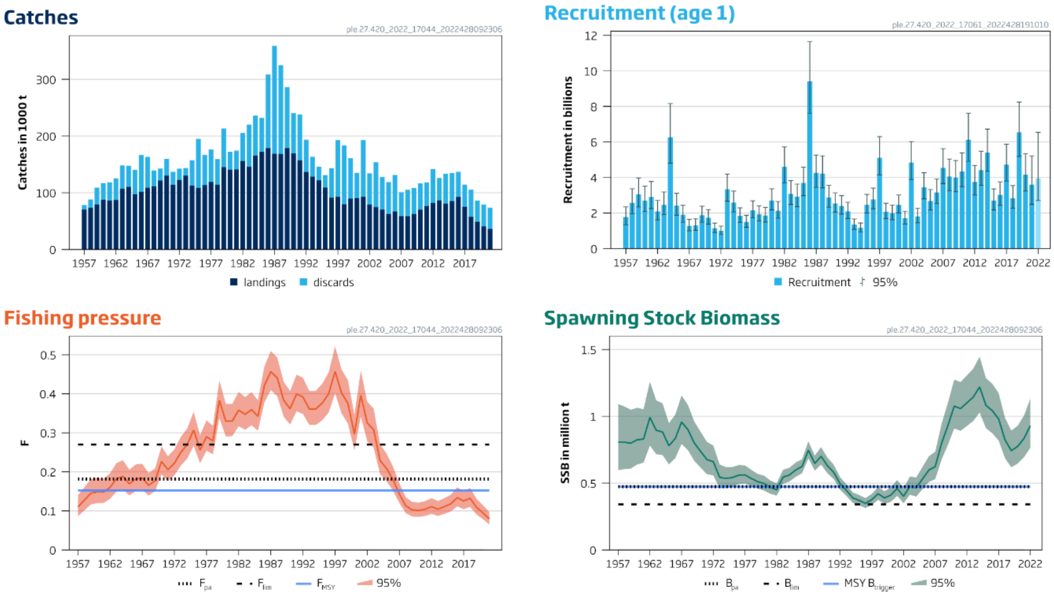


Figure 13.3.9. Stock development over time.

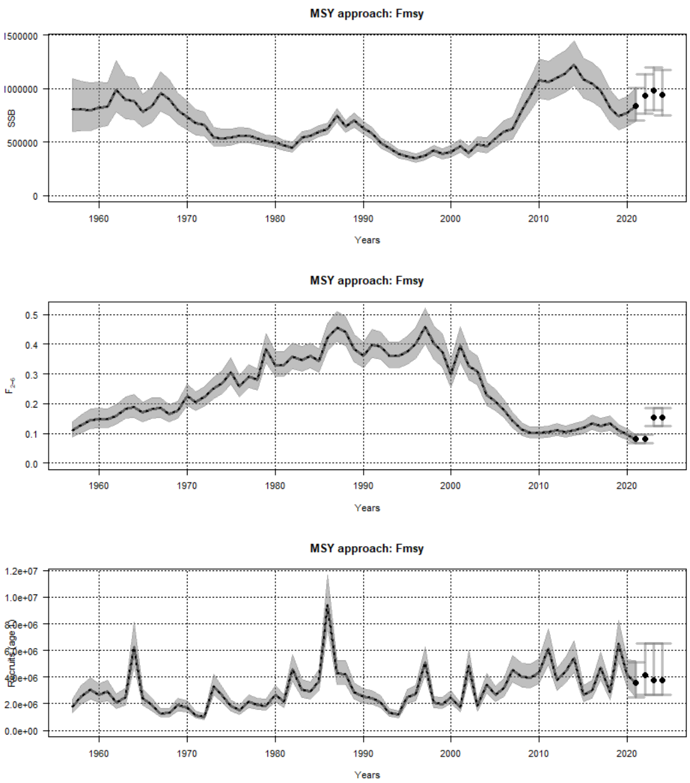


Figure 13.4.1. Stock short term forecast uner Fmsy optioin.

14 Plaice in Division 7.d

This stock is in category 1. This year, the assessment of plaice in Division 7.d was made following methodological information described in the Stock Annex revised during ICES WKPLE (2015) and WGNSSK (2015). After the update of the FR CGFS Index in 2022, a new set of reference points were calculated for this stock. This calculation was carried out following the procedures set in ICES (2021).

14.1 General

14.1.1 Stock definition

A summary of available information can be found in the stock annex.

14.1.2 Ecosystem aspects

No new information on ecosystem aspects was presented at the working group in 2022. All available information on ecological aspects can be found in the Stock Annex.

14.1.3 Fisheries

Plaice is mainly caught in two offshore fisheries, i.e. the beam trawl fishery for sole and the mixed demersal fishery using otter trawls. There is also a directed fishery during parts of the year by inshore trawlers and netters on the English and French coasts. All available information on the fisheries can be found in the Stock Annex.

14.1.4 ICES advices for previous years

2020 advice: ICES advises that when the EU multiannual plan (MAP) for the Western Waters is applied, catches from the Division 7.d plaice stock in 2021 that correspond to the F ranges are between 6066 tonnes and 11 130 tonnes. According to the MAP, catches higher than those corresponding to FMSY (8402 tonnes) can only be taken under conditions specified in the MAP, whilst the entire range is considered precautionary when applying the ICES advice rule.

2021 advice: ICES advises that when the MSY approach is applied, catches from the Division 7.d plaice stock in 2022 should be no more than 6365 tonnes. This corresponds to catches of plaice in Division 7.d of no more than 7566 tonnes in 2022, assuming the same proportion of the Division 7.e and Subarea 4 plaice stocks is taken in Division 7.d as was estimated during 2003–2020.

14.1.5 Management

There are no explicit management objectives for this stock.

The TACs have been set to for **the combined ICES divisions 7.d and 7.e**.

The minimum landing size for plaice is 27 cm, which is not in accordance with the minimum mesh size of 80 mm, permitted for catching plaice by beam and otter trawling. Fixed nets are required to use 90 mm mesh as an absolute minimum.

Demersal fisheries in the area are mixed fisheries, with many stocks exploited together in various combinations in the various fisheries. In these cases, management advice must consider both the state of individual stocks and their simultaneous exploitation in demersal fisheries. Stocks in the poorest condition, particularly those which suffer from reduced reproductive capacity, become the overriding concern for the management of mixed fisheries, where these stocks are exploited either as a targeted species or as a bycatch.

14.2 Data available

14.2.1 Catch

Landings data as reported to ICES are shown in Figure 14.2.1.1, Figure 14.2.1.2 as well as in Table 14.2.1.1 together with the total landings estimated by the Working Group. The 2021 landings of 1774 tonnes are below the catch level of the past 10 years (between 2000 and 5000 tonnes). France and Belgium are the highest contributors to the total 7.d landings in 2021, each country for 40% and UK contributing for 16%. The Belgian TBB and the French OTB recorded the highest landings.

Routine discard monitoring began following the introduction of the EU data collection regulations. Based on the sampling intensity (ICES WKPLE, 2015), a discards time series starting in 2006 has been included in the assessment. In 2021, the discard number increased by 47% (from 18 196 800 in 2020 to 26 786 500 in 2021) to be of the same order of magnitude as for the period 2010–2017.

Following the ICES WKFLAT 2010 and WKPLE 2015 conclusions, 65% of the first quarter catches were removed. These 65% were estimated during ICES WKFLAT 2010, based on published tagging results and some previous studies (e.g. Burt *et al.*, 2006; Hunter *et al.*, 2004; Kell *et al.*, 2004) showing that 50% of the fish caught during the first quarter are fish coming from area 4 to spawn. The same study also shown that 15% of the fish caught during the first quarter were fishes from area 7.e. Following the ICES WKPLE 2015 conclusions, only mature individuals are removed, both from landings and discards. Table 14.2.1.2 shows the Quarter 1 landings and discards and the corresponding removals. Removing this part of the catches allows for assessing the stock resident biomass**.** All the following figures will take into account this Quarter 1 removal.

14.2.2 InterCatch

UK, France, the Netherlands and Belgium have been providing landings data under the ICES InterCatch format since 2011, and InterCatch was used to produce the input data. Age distributions were provided by France, Belgium and England, accounting for 75% of the landings (Figure 14.2.2.1). Belgium has not always been able to provide landings data per quarter: for 2004, 2005, 2006, 2011, catch data were provided per semester or year. Since 2013, they were provided per year for the TBB fleet with at least quarter 1 landings data on a separate excel spreadsheet. For 2021, Belgium landings data were transmitted per quarter except for the TBB fleet which was submitted per year. Allocations to calculate age structures for the remaining landings were done per quarter, using the groups below:

Unsampled fleet*	Sampled fleet**
All nets	All nets
All OTB, OTT, TBB and Seines	All OTB, OTT and TBB
Others (MIS, OTM, DRB, FPO and LLS)	All métiers

*** Unsampled fleet are those fleets for which no age structure is known.**

**** Sampled fleet are those fleets for which the age structure is known.**

Discards data have also been provided under the ICES InterCatch format by France, Belgium, and the UK since WKPLE (ICES, 2015). In 2021, 60 % of landings had associated discards data imported to InterCatch. The discard volumes of the remaining strata have been raised using the grouping below (all quarters were pooled). As a result, the raised discards account for 42% of the total discards. Allocations to calculate age structures of discards were done per quarter, using the groups below:

Unsampled fleet*	Sampled fleet**
All nets	All Nets
OTB, OTT, TBB and Seines	OTB, OTT and TBB
Others (MIS, OTM, DRB, FPO and LLS)	All métiers

*** Unsampled fleet are those fleets for which no discards data have been provided.**

**** Sampled fleet are those fleets for which the discards volumes are known.**

Age distributions were provided by France, Belgium and England, accounting for 57% of the total discards (imported + raised).

Due to a lack of samples, a different approach was used to calculate age structures for the remaining discards for the following quarters: i) Q1_OTT-OTB-TBB-Seines discards were raised by OTT-OTB-TBB-Seines samples from Q1 and Q2, ii) Q4_OTT-OTB-TBB-Seines discards were raised by OTT-OTB-TBB-Seines samples from Q1, Q3 and Y2021, and iii) Q2_GNS-GTR landings were raised by GNS-GTR samples from Q1, Q2 and Q3.

14.2.3 Age compositions

Age compositions of the landings and of the discards are presented in Table 14.2.3.1 and Figure 14.2.3.1, and Table 14.2.3.2 and Figure 14.2.3.2 respectively.

Figures 14.2.3.3 and 14.2.3.4 present the discards at age ratios (i.e. discards numbers / landings numbers) per age and through time over the sampled period 2006–2021. Since 2013, the ratio is higher for the ages 4 and 5. The ratio for ages 1 to 3 remains stable between 2019 and 2021.

14.2.4 Weight-at-age

Weights at age in the landings, discards and stock are presented in tables 14.2.4.1, 14.2.4.2 and 14.2.4.3, respectively and in Figure 14.2.4.1. Stock weights are assumed to be the Q2 landings weights. These weights at age do not show specific trends, apart from a general decrease in landing weights in 2013–2021 for ages 5, 6 and 7.

14.2.5 Maturity and natural mortality

The maturity ogive used in the assessment is given in the table below.

Age	1	2	3	4	5	6	7
Proportion of mature	0	0.15	0.53	0.96	1	1	1

Age-specific natural mortality rates have been estimated from Peterson and Wroblewski's relationship during the 2015 WKPLE benchmark, as detailed in the Stock Annex.

Age	1	2	3	4	5	6	7
Natural mortality	0.3531	0.3132	0.292	0.2749	0.2594	0.2474	0.2329

14.2.6 Surveys

The survey series used in the assessment are the French Ground Fish Survey (FR GFS) (G3425), 1993–present and the UK beam trawl survey (UK BTS) (B2453), 1989–present (Figure 14.2.6.1 and Table 14.2.6.1). The International Young Fish Survey is also presented, although not used in the assessment. They are fully described in the stock annex.

Both time series were re-calculated in 2016 and the impact of those changes were assessed during 2016 WGNSSK meeting (ICES, 2016).

In 2020, due to the COVID-19 pandemic, only the French waters of the English Channel were sampled during the CGFS survey which has an impact on the FR GFS index used in the assessment. In addition, issues in the calculation of the FR GFS index were reported (some hauls with no catch were dropped in the calculation of the index). The effect of those issues have been investigated during 2020 WGNSSK meeting by i) testing the impact of removing UK sampling stations in the calculation of the index, and ii) testing the impact of removing the FR GFS index in 2020. The results did not show significant impacts on assessment outputs.

A new delta-GAMM index was presented during 2022 WGNSSK meeting (Figure 14.2.6.1). The difference between the former and the delta-GAMM index is illustrated in the Figure 14.2.6.2. The use of the new index was followed by an estimation of new reference points based on the latest selectivity and biological patterns (WD in Annex 8). New reference points can be found in the updated Stock Annex and in the table below.

Plaice in Division 7.d. Values of previous and new reference points.

Reference point	Previous reference points	New reference points
MSY $B_{trigger}$	25826	37761
F_{MSY}	0.25	0.156
B_{lim}	18447	27174
B_{pa}	25826	37761
F_{lim}	0.5	0.381
F_{pa}	0.418	0.238
F_{lower}	0.175	0.113
F_{upper}	0.344	0.224

The consistencies between ages are good for the UK-BTS survey, and correct for ages 2 to 6 (Figure 14.2.6.3). However, for the FR GFS survey the consistencies between ages is less robust in comparison to UK-BTS survey.

14.3 Assessment

The model used is the Aarts and Poos model (AAP, Aarts and Poos, 2009, for more details please refer to the Stock Annex).

Year of assessment:		2022
Assessment model:		AAP
Assessment software		FLR/ADMB
Fleets:		
UK Beam Trawl Survey	Age range	1–6
	Year range	1989 onwards
FR Ground Fish Survey	Age range	1–6
	Year range	1993 onwards
Catch/Landings		
Age range:		1–7+
Landings data:		1980–2021
Discards data		2006–2021
Model settings		
Fbar:		3–6
Age from which F is constant (qplat.Fmatrix)		6
Dimension of the F matrix (Fage.knots)		4
Ftime.knots		14
Wtime.knots		5
Age from which q is constant (qplat.surveys)		5

14.3.1 Results

The landings and discards estimated by the model are presented in Figure 14.3.1.1 and the residuals in tables 14.3.1.1 and 14.3.1.2. Given the observed trend in the discard at age ratio (see Section 14.2.3), the average discard at age ratio over 2006–2011 is used to estimate the discards prior to 2006; while the actual discard at age ratios are used in the assessment to estimate the discards since 2012.

The survey residuals are shown in Figure 14.3.1.2 and Table 14.3.1.3 for the two surveys. There are opposite trends in the residuals of the UK BTS and French GFS (the two surveys covering the entire geographical area of the stock) appearing in the most recent years for ages 1 to 3. Since 2014, the model tend to overestimate the French GFS survey for all ages, the vessel used during this survey has changed in 2015, moving from the R/V Gwen Drez to the R/V Thalassa. Even if the inter-calibration between the two vessels realised in 2015 showed no significant effect on plaice catches (Auber *et al.*, 2015) and no correction coefficients were applied to calculate plaice survey indices (Travers-Trolet *et al*., 2016), further investigation is needed.

The final outputs are given in Table 14.3.1.4 (fishing mortalities) and Table 14.3.1.5 (stock numbers). A summary of the assessment results is given in Table 14.3.1.6 and trends in fishing mortality, recruitment, spawning stock and total catches are shown in Figure 14.3.1.3. Retrospective patterns for the final run are shown in Figure 14.3.1.4 with their associate Mohn's Rho value.

The 1986 year class dominated the history of this stock until the late 2000s (Figure 14.3.1.5 and 14.3.1.3). A second peak occurred with the 1997 year class, although estimated to be at 75% of the 1986 year class. The ephemeral peak of SSB in 1999 has been followed by years of stability at a low level. From 2006 onwards, a series of high recruitments occurred, reaching a maximum in 2011, which caused the biomass to increase until 2014 then stabilize and decrease in 2016–2019 (Figure 14.3.1.3). After the decline in recruitment in 2016-2017, the recruitment in 2018 and 2019 is increasing. After a large drop in 2020, the recruitment increased in 2021 (163630) to be at the same order of magnitude as 2018 and 2019.

14.4 Biological reference points

A new FR CGFS index is used in 2022 assessment to fix the reported issues in 2021 assessment (WGNSSK 2021). Following the benchmark guidelines, a new set of reference points were calculated for plaice 7.d stock and presented during WGNSSK 2022 meeting. This calculation carried out following the procedures set in ICES (2021) for a category 1 stock, and using the EqSim method from the msy R package (more details could be found in the working document in the Annex).

14.5 Short-term forecasts

Weight-at-age in the stock and in the catch were taken to be the average estimated weights over the last 3 years. The exploitation pattern, as well as the discards/landings numbers ratio, were taken to be the mean value of the last three years. Population numbers at age 2 and older in 2022 are AAP survivors estimates.

14.5.1 Recruitment estimates

Considering the retrospective patterns observed, the recruitment is assumed to be poorly estimated. Following the stock annex, the recruitment of 2021 and the previsions (2022, 2023 and 2024) was calculated as the geometric mean recruitment over the period 2016-2020 (Figure 14.5.1.2).

14.5.2 Calculation of the 7.d resident stock

This year, F for the intermediate year is set as equal to the average F for the period 2019-2021. Plaice in 7.d are under landing obligation since the 1st January 2019. To assess if the TAC in 2022 will be fully taken, we compared ICES catches of resident plaice in 7.d in 2021 to the proportion of the 2021 TAC corresponding to resident plaice in 7.d (5646 t) (dark green dot in Figure 14.5.2.1). Using first the average official landing proportion between 7.e and 7.d.e over the period 2003-2021 (Figure (14.5.2.2) we obtained the TAC in 7.d. Then the Q1 removal ratio was applied over the same period to account for migration of mature individuals of plaice from the 7.e and 4.c during Q1 (Figure 14.5.2.3). ICES catches were compared to 2021 TAC corresponding to resident plaice in 7.d by taking into account survivability exemption applied to OTB, OTT, OTM, GTR, TBB and SDN (EU, 2021) landings. ICES catches under landings obligation are significantly lower than the TAC (Figure 14.5.2.1), leading to the decision that the fully taken TAC assumption was inappropriate.

14.5.3 Management options tested

14.5.3.1 Calculation of STF

Potential TACs for 2023 were calculated using the MSY approach Alternative options (e.g. $F_{MSY\ lower}$ and $F_{MSY\ upper}$) were also tested. Results are presented in Table 14.5.3.1.1 for the resident stock.

Following the MSY approach catches from the Division 7.d plaice stock in 2022 should be no more than 4738 tonnes. Assuming the same proportion of the Division 7.e and Subarea 4 plaice stocks is taken in Division 7.d as during 2003–2021, this will correspond to catches of plaice in Division 7.d in 2022 of no more than 5671 tonnes.

14.6 Quality of the assessment

The sampling for plaice in 7.d are considered to be at a reasonable level. The quality of the assessment is considered to have improved in 2015 following the change of assessment model and the inclusion of discards.

A fishery on the spawners takes place during the first quarter of the year, yielding an age distribution different from the rest of the year. It is unknown whether there is major inter-annual variability in the immigration from the North Sea to these spawning grounds, which could distort any catch-based analysis. Any migration events taking place in the first quarter cannot be represented in the surveys in the second semester.

Landings-at-age information are highly dependent on the accuracy of the spatial declaration of the fishing activity as an important component of the fisheries operates on the borderline to ICES Subdivision 4.c.

The use of FR GFS survey during the assessment needs to be further investigated. In the recent years, this index has always been overestimated by the model.

14.7 Status of the stock

ICES assesses that Fishing pressure on the stock is above F_{MSY}, and under F_{pa} and F_{lim}. ICES assess that the spawning-stock size is above MSY $B_{trigger}$, B_{pa}, and B_{lim} (Figure 14.3.1.3).

	Fishing pressure					Stock size				
		2019	2020	2021			2020	2021	2022	
Maximum sustainable yield	F_{MSY}	✗	✗	✗	Above	MSY $B_{trigger}$	✗	✗	✓	Above trigger
Precautionary approach	F_{pa},F_{lim}	o	✓	✓	Harvested sustainably	B_{pa},B_{lim}	o	o	✓	Full reproductive capacity
Management plan	F_{MGT}	–	–	–	Above	B_{MGT}	–	–	–	Above

14.8 Management considerations

The stock identity of plaice in the Channel is unclear and may raise some issues.

The TAC is combined for divisions 7.d and 7.e. Plaice in 7.e is considered at risk of being harvested unsustainably (F above F_{MSY}).

The plaice stock in 7.d is mostly harvested in a mixed fishery with sole in 7.d.

Due to the minimum mesh size (80 mm) in the mixed beam and otter trawl fisheries, a large number of undersized plaice are discarded. The 80 mm mesh size is not matched to the minimum landing size of plaice (27 cm). Measures taken specifically to control sole fisheries will impact the plaice fisheries.

14.9 Issue for future benchmarks

14.9.1 Data

The vessel used for FR GFS survey was changed in 2014, moving from the R/V Gwen Drez to the R/V Thalassa. Even if the inter-calibration between the two vessels realised in 2015 showed no significant effect on plaice catches (Auber *et al*., 2015) and no correction coefficients were applied to calculate plaice survey indices (Travers-Trolet *et al*., 2016). Further investigations are needed to evaluate if a vessel effect is significant in the data and test the possibility of splitting the FR GFS time series.

Ifremer has started a new young fish surveys (YFS) in the Channel since 2016 (Bay of Canche-Authie, and Bay of Seine) in addition to the YFS in the Bay of Somme used in sole.27.7d assessment. Further investigation is needed to evaluate if recruitment indices could be produced from those surveys.

Data is available from FR GFS to calculate new maturity ogive and test them. The one currently used is based on ICES WKFLAT 2010.

Migration data is required to update the Q1 migration proportion.

14.9.2 Assessment

Residual patterns in the FR GFS residuals and the year effect (from 2016) in landings residuals could be corrected by the use of a new survey index for FR GFS. In addition, parameters settings might improve the fitting of the model.

14.9.3 Short-term forecast

If FR YFS indices are available, the use of RCT3 to estimate recruitment could be investigated. New information for age 0 could be introduced from YFS.

14.10 References

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Table 14.2.1.1. Plaice in 7.d: Nominal landings (tonnes) as officially reported to ICES, 1976–2021.

Year	BEL	FRA	UK(E+W)	Others	Tot Off. Land.	Unalloc.	Tot. Land. 7.d (1)	Estim.discards 7.d (2)	Tot. land. rep. in 7.e (3)	Agreed TAC (4)
1976	147	1439	376		1962	1	1963		640	
1977	149	1714	302		2165	81	2246		702	
1978	161	1810	349		2320	156	2476		784	
1979	217	2094	278		2589	28	2617		977	
1980	435	2905	304		3644	-994	2650		1178	
1981	815	3431	489		4735	34	4769		1676	
1982	738	3504	541	22	4805	60	4865		1878	
1983	1013	3119	548		4680	363	5043		1714	
1984	947	2844	640		4431	730	5161		1758	
1985	1148	3943	866		5957	65	6022		1677	
1986	1158	3288	828		5274	1560	6834		2078	
1987	1807	4768	1292		7867	499	8366		2272	8300
1988	2165	5688	1250		9103	1317	10420		2835	9960
1989	2019	3713	1383		7115	1643	8758		2742	11700
1990	2149	4739	1479		8367	680	9047		2985	10700
1991	2265	4082	1566		7913	-100	7813		2183	10700
1992	1560	3099	1572	1	6232	105	6337		1882	9600
1993	877	2792	1102		4771	560	5331		1614	8500
1994	1418	3199	1007	9	5633	488	6121		1404	9100
1995	1157	2598	814		4569	561	5130		1247	8000
1996	1112	2630	856		4598	795	5393		1266	7530
1997	1161	3077	1078		5316	991	6307		1583	7090
1998	854	3276	700		4830	932	5762		1346	5700
1999	1306	3388	743		5437	889	6326		1543	7400
2000	1298	3183	754		5235	779	6014		1625	6500

Year	BEL	FRA	UK(E+W)	Others	Tot Off. Land.	Unalloc.	Tot. Land. 7.d (1)	Estim.discards 7.d (2)	Tot. land. rep. in 7.e (3)	Agreed TAC (4)
2001	1346	2962	660		4968	298	5266		1310	6000
2002	1204	3450	841	1	5496	281	5777		1472	6700
2003	998	2893	756	3	4650	-564	4086		1387	5970
2004	954	2766	582	10	4312	438	4750		1337	6060
2005	832	2432	421	21	3706	285	3991		1319	5150
2006	1024	1935	550	16	3525	121	3646	749	1411	5151
2007	1355	2017	463	10	3845	156	4001	1252	1146	5050
2008	1386	1740	471	12	3609	255	3864	936	1112	5050
2009	1002	1892	612	16	3522	38	3560	1528	1024	4646
2010	1123	2190	517	62	3892	519	4411	2511	1208	4274
2011	1067	1994	472	60	3593	56	3649	2025	1417	4665
2012	1045	1962	542	63	3612	111	3723	3336	1492	5062
2013	1295	2159	641	87	4182	-55	4127	2955	1472	6400
2014	1389	2229	633	76	4327	-7	4320	3886	1490	5322
2015	1600	1702	392	54	3748	-21	3727	2821	1424	6223
2016	2247	1557	795	60	4659	-21	4638	3603	2013	12446
2017	2189	1487	814	86	4576	37	4613	5065	2128	10022
2018	1876	2171	832	98	4977	27	4999	6215	1644	10360
2019	1277	1688	628	87	3681	40	3721	7064	1520	10354
2020	750	1007	342	52	2120	32	2152	2191	1276	9154
2021	663	769	284	53	1774	-4	1170	3672	1328	11920

(1) As provided to ICES through InterCatch

(2) Raised with InterCatch from BE, UK and FR estimated discards data.

(3) As officially reported to ICES

(4) TAC´s for Divisions 7.d, e. Since 2016, a catch advice is given rather than a landing advice.

Table 14.2.1.2. Plaice in 7.d: Nominal landings, estimated discards, and quarter 1 removals.

Year	Total Landings	Q1 Remov.	Landings as used by WG (1)	Estim. discards	Discards Q1 remov.	Discards as used by WG (1)
1980	2650	427	2223			
1981	4769	760	4009			
1982	4865	825	4040			
1983	5043	950	4093			
1984	5161	912	4249			
1985	6022	1022	5000			
1986	6834	1161	5673			
1987	8366	1360	7006			
1988	10420	1635	8785			
1989	8758	1665	7093			
1990	9047	1698	7349			
1991	7813	1451	6362			
1992	6337	1118	5219			
1993	5331	852	4479			
1994	6121	1074	5047			
1995	5130	934	4196			
1996	5393	963	4430			
1997	6307	1127	5180			
1998	5762	931	4831			
1999	6326	1058	5268			
2000	6015	1494	4521			
2001	5266	886	4380			
2002	5777	931	4846			
2003	4086	476	3610			
2004	4750	544	4206			
2005	3991	506	3485			
2006	3646	421	3225	749	21	727
2007	4001	620	3381	1252	32	1220
2008	3864	586	3278	936	48	888
2009	3560	436	3124	1528	56	1473
2010	4411	501	3910	2511	99	2412
2011	3649	358	3291	2025	99	1926
2012	3723	544	3178	3336	293	3043
2013	4127	523	3604	2955	260	2696
2014	4320	645	3675	3886	561	3325
2015	3727	771	2956	2821	453	2368
2016	4638	1020	3617	3603	514	3090
2017	4613	924	3689	5065	990	4075

Year	Total Landings	Q1 Remov.	Landings as used by WG (1)	Estim. discards	Discards Q1 remov.	Discards as used by WG (1)
2018	4999	1024	3975	6215	1255	4960
2019	3721	885	2836	7064	854	6210
2020	2152	424	1727	2191	290	1901
2021	1174	313	1456	3672	411	3261

(1) Takes into account the removal of 65% of the Quarter 1 landings or discards.

Table 14.2.3.1. Plaice in 7.d: Landings in numbers (thousands) as used in the assessment, taking into account the first quarter removal.

	age						
year	1	2	3	4	5	6	7+
1980	53	2598	1253	370	324	50	133
1981	16	2403	5866	1643	192	106	238
1982	265	1369	5964	2262	505	138	179
1983	92	2977	2761	4048	617	151	214
1984	350	1838	6310	1928	1242	356	312
1985	142	5614	5347	3346	274	409	300
1986	679	4799	6072	2510	965	375	247
1987	25	8350	6481	2379	833	287	512
1988	16	4923	16239	3357	741	362	561
1989	826	3574	6238	6477	1770	392	497
1990	1632	2581	7550	4099	2386	535	572
1991	1542	5758	4700	3099	1614	1123	429
1992	1665	6085	3841	1183	786	697	745
1993	740	7473	3295	863	359	313	581
1994	1242	3570	6015	2131	563	280	781
1995	2592	4264	2532	2006	611	152	591
1996	1119	4762	3113	1060	951	326	585
1997	550	4168	6184	2382	724	506	722
1998	464	4323	7467	2335	360	94	289
1999	741	1737	10493	4583	696	121	223
2000	1383	6177	3432	3992	752	150	142
2001	2682	4070	3589	1385	1253	203	145
2002	902	6876	4553	1390	1144	603	288
2003	0	3597	2103	1380	350	356	758
2004	922	2718	4573	760	400	219	527
2005	86	2602	2153	1975	449	245	508
2006	191	2801	3081	1626	987	166	379
2007	529	2986	2379	1237	534	395	274
2008	293	3844	2512	1125	584	218	258
2009	491	2975	3112	848	402	242	240

year	age						
	1	2	3	4	5	6	7+
2010	530	4238	3367	1465	392	278	287
2011	93	4436	3557	964	316	59	119
2012	18	1266	3780	1845	524	195	171
2013	9	756	3666	3294	1158	247	156
2014	76	759	2015	3731	1848	468	202
2015	3	600	1523	1483	1933	940	642
2016	12	233	2115	2220	1431	1719	1028
2017	3	120	1370	2772	1753	987	1645
2018	18	217	1045	2852	2482	1316	2410
2019	41	233	1506	1256	1681	1462	1424
2020	14	459	499	855	768	822	1229
2021	8	170	1206	959	653	666	938

Table 14.2.3.2. Plaice in 7.d. Discards in numbers (thousands) as used in the assessment, taking into account the first quarter removal.

year	1	2	3	4	5	6	7+
2006	553	2541	1826	70	10	1	0
2007	1227	5531	1776	278	0	2	0
2008	2368	2893	631	163	38	8	1
2009	2032	5679	1988	114	17	26	3
2010	2023	11797	3243	336	28	3	2
2011	2480	8872	1559	155	14	19	1
2012	1423	10296	7943	1235	52	0	0
2013	2040	5395	9367	1818	89	9	1
2014	4380	6222	8481	3445	493	79	10
2015	4420	8316	4958	1478	761	276	40
2016	1767	6524	7917	1801	589	227	27
2017	2045	7478	9758	4581	672	347	66
2018	4500	11034	12209	7137	2437	807	371
2019	8145	12050	13508	3940	2001	859	271
2020	162	7418	5098	3534	1250	512	222
2021	6610	4655	6725	4839	2537	1040	380

Table 14.2.4.1. Plaice in 7.d: Weights in the landings.

	1	2	3	4	5	6	7+
1980	0.314	0.317	0.508	0.638	0.801	1.159	1.439
1981	0.231	0.288	0.36	0.448	0.687	0.839	1.032
1982	0.237	0.263	0.342	0.418	0.62	0.77	1.193
1983	0.254	0.282	0.333	0.401	0.517	0.784	1.178
1984	0.211	0.267	0.304	0.364	0.46	0.624	0.852
1985	0.241	0.264	0.286	0.406	0.477	0.541	0.82
1986	0.231	0.312	0.338	0.414	0.557	0.496	0.823
1987	0.25	0.281	0.359	0.475	0.575	0.78	0.967
1988	0.279	0.256	0.307	0.413	0.536	0.629	0.926
1989	0.199	0.266	0.318	0.367	0.469	0.643	1.073
1990	0.209	0.266	0.338	0.392	0.501	0.633	1.091
1991	0.223	0.275	0.309	0.387	0.451	0.552	1.009
1992	0.181	0.276	0.35	0.427	0.506	0.582	0.791
1993	0.217	0.268	0.331	0.426	0.5	0.583	0.853
1994	0.248	0.276	0.294	0.364	0.476	0.588	0.996
1995	0.215	0.267	0.309	0.385	0.478	0.678	0.932
1996	0.228	0.31	0.299	0.409	0.49	0.664	1.115
1997	0.201	0.254	0.3	0.335	0.446	0.582	1.024
1998	0.167	0.257	0.281	0.401	0.529	0.803	1.175
1999	0.204	0.253	0.243	0.316	0.477	0.776	1.133
2000	0.217	0.256	0.273	0.296	0.392	0.603	0.953
2001	0.233	0.273	0.328	0.401	0.484	0.695	1.133
2002	0.246	0.248	0.299	0.364	0.424	0.545	0.819
2003	NA	0.286	0.376	0.485	0.643	0.654	0.872
2004	0.245	0.297	0.399	0.498	0.688	0.786	0.993
2005	0.29	0.318	0.351	0.452	0.568	0.666	1.109
2006	0.261	0.279	0.306	0.364	0.447	0.557	0.85
2007	0.182	0.318	0.398	0.477	0.546	0.613	0.959
2008	0.24	0.293	0.351	0.434	0.549	0.647	0.975
2009	0.24	0.291	0.35	0.498	0.526	0.66	1.073
2010	0.232	0.305	0.359	0.451	0.512	0.658	0.847
2011	0.159	0.264	0.354	0.487	0.637	0.82	1.076
2012	0.204	0.297	0.358	0.452	0.559	0.715	1.062
2013	0.145	0.263	0.321	0.395	0.498	0.738	1.077
2014	0.176	0.26	0.295	0.373	0.514	0.704	0.986
2015	0.126	0.227	0.303	0.346	0.413	0.538	0.842
2016	0.203	0.317	0.319	0.356	0.415	0.46	0.673

	1	2	3	4	5	6	7+
2017	0.276	0.272	0.301	0.344	0.417	0.468	0.667
2018	0.236	0.248	0.27	0.291	0.341	0.403	0.593
2019	0.244	0.264	0.285	0.316	0.337	0.386	0.567
2020	0.223	0.260	0.267	0.294	0.340	0.388	0.521
2021	0.225	0.257	0.263	0.274	0.301	0.311	0.455

Table 14.2.4.2. Plaice in 7.d. Weights in the discards.

year	1	2	3	4	5	6	7+
2006	0.100	0.138	0.166	0.206	0.259	0.566	NA
2007	0.103	0.139	0.157	0.163	0.284	0.214	NA
2008	0.118	0.153	0.188	0.222	0.219	0.383	NA
2009	0.125	0.138	0.169	0.450	0.731	1.302	0.268
2010	0.104	0.135	0.167	0.180	0.237	0.381	0.369
2011	0.096	0.155	0.174	0.216	0.215	0.228	1.352
2012	0.093	0.130	0.166	0.193	0.213	0.607	NA
2013	0.083	0.128	0.155	0.188	0.249	0.464	0.421
2014	0.090	0.123	0.137	0.232	0.247	0.302	0.385
2015	0.039	0.106	0.156	0.174	0.220	0.274	0.622
2016	0.171	0.165	0.155	0.175	0.181	0.203	0.403
2017	0.131	0.147	0.162	0.191	0.227	0.218	0.221
2018	0.126	0.118	0.119	0.141	0.157	0.179	0.18
2019	0.140	0.141	0.158	0.169	0.173	0.197	0.224
2020	0.113	0.08	0.107	0.125	0.143	0.155	NA
2021	0.100	0.128	0.130	0.121	0.132	0.142	NA

Table 14.2.4.3. Plaice in 7.d: Weights in the stock.

year	1	2	3	4	5	6	7+
1980	0.171	0.332	0.482	0.622	0.751	0.870	1.197
1981	0.110	0.216	0.317	0.414	0.506	0.594	0.924
1982	0.105	0.208	0.308	0.406	0.502	0.596	0.869
1983	0.097	0.192	0.286	0.379	0.470	0.560	0.854
1984	0.082	0.164	0.248	0.333	0.420	0.507	0.738
1985	0.084	0.171	0.259	0.348	0.440	0.533	0.778
1986	0.101	0.205	0.311	0.420	0.532	0.646	0.850
1987	0.122	0.242	0.361	0.479	0.596	0.712	0.929
1988	0.084	0.168	0.254	0.340	0.427	0.514	0.715
1989	0.079	0.162	0.250	0.342	0.439	0.541	0.855
1990	0.085	0.230	0.322	0.346	0.465	0.549	1.118
1991	0.143	0.219	0.275	0.335	0.375	0.472	0.958

year	1	2	3	4	5	6	7+
1992	0.088	0.241	0.336	0.421	0.477	0.521	0.725
1993	0.108	0.258	0.296	0.379	0.493	0.539	0.727
1994	0.165	0.198	0.276	0.331	0.383	0.493	0.866
1995	0.124	0.257	0.286	0.354	0.442	0.707	0.855
1996	0.178	0.229	0.263	0.347	0.354	0.474	0.934
1997	0.059	0.202	0.256	0.266	0.417	0.530	0.902
1998	0.072	0.203	0.273	0.361	0.530	0.670	0.873
1999	0.072	0.172	0.213	0.351	0.429	0.644	0.904
2000	0.068	0.184	0.204	0.246	0.355	0.554	0.928
2001	0.093	0.206	0.274	0.338	0.404	0.624	1.104
2002	0.102	0.206	0.281	0.379	0.467	0.558	0.809
2003	NA	0.306	0.403	0.528	0.673	0.592	0.961
2004	0.280	0.366	0.508	0.571	0.701	0.788	0.861
2005	0.174	0.299	0.377	0.489	0.672	0.683	1.010
2006	0.220	0.270	0.343	0.419	0.506	0.637	0.938
2007	0.063	0.247	0.391	0.543	0.579	0.656	0.825
2008	0.121	0.245	0.301	0.368	0.448	0.462	1.005
2009	NA	0.268	0.358	0.487	0.476	0.719	1.036
2010	NA	0.280	0.354	0.415	0.455	0.561	0.719
2011	0.189	0.238	0.402	0.535	0.737	0.791	0.908
2012	NA	0.253	0.298	0.424	0.517	0.629	0.938
2013	0.174	0.252	0.277	0.479	0.454	0.886	0.995
2014	0.157	0.256	0.243	0.381	0.518	0.756	1.042
2015	0.154	0.253	0.256	0.287	0.363	0.436	0.782
2016	0.258	0.294	0.326	0.368	0.481	0.516	0.719
2017	0.256	0.253	0.28	0.319	0.387	0.434	0.619
2018	0.174	0.201	0.244	0.256	0.308	0.386	0.519
2019	0.132	0.239	0.262	0.289	0.332	0.394	0.531
2020	NA	0.296	0.292	0.351	0.407	0.450	0.597
2021	0.198	0.270	0.248	0.281	0.384	0.307	0.491

Table 14.2.6.1. Plaice in 7.d: UK BTS tuning fleet.

UK BTS						
1989 2021						
1 1 0.5 0.75						
1 6						
1	3.8	15.8	28.9	31.7	4.0	1.7
1	9.2	9.4	11.1	11.7	12.6	1.5
1	16.8	14.5	11.5	8.7	8.6	4.6
1	22.4	21.3	6.6	6.6	7.2	5.4
1	4.6	20.2	8.0	2.8	2.9	2.4
1	9.4	8.5	10.1	6.0	2.0	0.6
1	14.5	6.2	3.8	5.7	2.2	0.8
1	22.1	17.3	1.7	1.0	2.0	1.3
1	48.2	28.6	11.0	1.3	1.6	0.5
1	30.6	37.9	12.1	5.0	0.6	0.6
1	12.8	10.7	28.8	4.6	1.6	0.3
1	19.5	30.2	18.8	20.5	5.0	1.3
1	27.9	20.3	14.1	9.8	14.8	2.7
1	37.9	25.9	12.5	5.5	2.6	5.3
1	10.6	39.7	9.8	4.4	2.3	1.1
1	52.9	22.5	20.7	4.8	1.2	0.3
1	15.6	36.2	12.8	10.0	3.2	1.1
1	30.1	28.9	16.8	5.9	4.3	1.3
1	53.1	28.9	12.2	6.2	3.2	2.9
1	39.6	40.6	10.5	4.3	3.8	1.8
1	77.7	39.5	20.9	5.9	3.2	2.3
1	64.2	64.7	17.7	9.2	3.1	1.7
1	115.1	112.2	39.6	10.3	7.0	2.9
1	24.7	81.1	56.0	18.7	4.2	3.3
1	32.3	61.0	88.2	45.0	10.2	3.4
1	145.3	156.5	50.7	62.1	26.8	9.0
1	38	178.7	63.2	30.2	33.4	15.7
1	12.5	101.4	102.9	37.9	21.3	23.2
1	50.1	102.1	83.2	56.0	16.6	8.4
1	25.6	97	112.2	52.4	30.3	9.3
1	117.5	81.7	55.3	37.3	18.2	11.7
1	20.7	109.1	60.2	25.1	15.1	7.6
1	17.9	72	93.1	71.6	11.8	7.9

Table 14.2.6.1. (cont.) Plaice in 7.d: FR-CGFS tuning fleet.

FR GFS						
1993 2021						
1 1 0.75 1						
1 6						
1	232.043673	867.4287825	344.8955655	125.8471964	31.95775576	8.658407294
1	468.6873402	347.4850899	147.8813318	67.5869541	26.21535399	11.64864337
1	30.31109096	336.4829915	364.1256753	142.0631517	101.1338633	27.18601262
1	772.6475838	243.7542288	180.6639785	26.61287034	12.91243045	15.06717884
1	537.6705039	800.7359722	267.0910349	245.8189993	20.77554292	8.553243504
1	551.307581	415.3329629	406.1840569	93.73531388	29.25984548	0
1	65.41411891	512.8589304	267.1271748	394.6057679	77.12348897	13.05384032
1	2347.630256	653.6328317	655.4144392	201.1331868	192.5795542	50.44978408
1	62.33445568	263.161174	165.1964432	76.19582663	74.11093126	34.64615231
1	36.12946343	584.8509981	302.5781267	189.7086834	69.77828026	51.39798788
1	698.1159828	304.0046636	459.9872198	81.80794176	16.76415083	17.21206297
1	66.8932234	388.7334002	281.234191	137.0054922	39.95540279	4.34398821
1	105.131729	405.8614273	745.7793584	360.044779	114.1804689	32.06502689
1	2163.189914	684.3336833	447.4381101	152.028837	61.40122746	32.68785509
1	46.64407072	445.9575528	395.4247952	237.1863746	105.1123537	33.51809664
1	120.2912548	234.9552745	641.5887634	140.1203905	46.78900437	12.22972261
1	47.3117318	294.3932769	223.6439548	94.70045489	27.56043019	6.586044723
1	36.46492103	745.4582853	466.6747533	109.5448009	28.93695151	7.33495924
1	732.3893274	1974.518458	2367.136577	734.3266772	116.8307926	12.95513885
1	209.9130527	534.9202819	1534.911582	1285.173056	260.2784159	97.47269651
1	307.2607583	714.1449665	566.2668478	1148.158737	288.3992466	88.07432429
1	84.34564158	610.4110658	487.3594779	550.5088041	716.3678313	172.8930777
1	4.177091265	96.75191687	682.9784779	556.4846423	152.7571172	173.2270411
1	10.39528571	44.89772007	243.1237972	366.9978593	136.9087407	93.36947263
1	8.284571051	53.61083598	108.5638843	147.1079297	142.4390629	44.54717216
1	42.3950563	84.02162512	241.8083385	119.6310024	170.2295721	52.42852369
1	16.48445649	616.7568248	407.318741	315.5103249	127.8535144	187.8649014
1	171.979878	114.34103	276.8715	99.65671	51.78743	26.829016
1	66.99206784	355.9093299	676.1071729	572.4003641	78.29827268	52.62154812

Table 14.3.1.1. Plaice in 7.d: Landings residuals.

age	1	2	3	4	5	6	7+
1980	-0.558871596	0.877083487	-0.425393361	-0.304742107	0.184887798	-0.034474877	-0.146745308
1981	-1.485383488	0.113284389	0.370143114	0.33829389	-0.076096438	-0.179803251	0.315425038
1982	0.261106034	0.05474703	-0.141146557	-0.032472011	0.083155902	0.377406249	-0.260662457
1983	-0.744397194	0.061726234	-0.270771474	0.121463926	-0.312080641	-0.255776753	-0.030687507
1984	0.769290095	-0.277534736	-0.140882357	0.164999464	0.092111406	0.100999626	0.246793711
1985	-0.092948844	0.868126345	-0.180624433	0.172688052	-0.542622452	-0.045480847	-0.038495062
1986	0.911954558	0.459766578	-0.077978049	0.113734049	0.163754238	0.645239076	-0.542601275
1987	-2.038048471	0.264415926	-0.272192892	0.031444862	0.125095563	-0.342303416	0.249643799
1988	-2.546333718	0.176384216	-0.017079624	0.000387751	-0.156774497	-0.092352393	0.055094629
1989	1.095933896	0.19146705	-0.368399125	-0.14700616	0.276666989	-0.112283995	-0.086250411
1990	1.058167585	0.146259041	0.363478156	-0.050198832	-0.173218024	-0.057101629	0.218422919
1991	-0.062308233	0.719178444	0.421181217	0.300317329	0.086503797	0.061157069	0.015690679
1992	-0.575996073	0.119048486	0.275606679	0.02751265	0.023591434	0.190613181	0.127092937
1993	-0.661929446	0.040253463	-0.291670784	-0.134427218	-0.166842347	-0.146130629	-0.173554855
1994	0.322793888	0.140205393	0.108715048	0.329116785	0.283027966	0.142204403	0.042742838
1995	0.798644827	0.685873827	-0.030444993	-0.038283295	-0.131806698	-0.463049133	-0.210268722
1996	-0.038078234	0.358148832	0.347728552	-0.075267364	0.080256118	0.010050336	-0.05201483
1997	-1.214158503	0.092809051	0.416228975	0.781752056	0.559988719	0.537140081	0.409238479
1998	-0.663106908	-0.380196124	0.339356143	0.02158821	0.020899165	-0.148275185	-0.205811999
1999	-0.017886253	-0.612432639	0.073574285	0.380748702	0.01253628	0.344746142	0.040966132
2000	0.520455173	0.734050923	-0.400736752	-0.26687533	-0.170428911	-0.189566867	-0.04111169
2001	1.219657348	0.128784978	-0.168806544	-0.416104138	-0.144179389	-0.352763008	-0.187267185
2002	-0.105606333	0.623245233	0.069763839	0.071670124	0.637169689	-0.004723359	0.072363896
2003	-5.860854597	-0.294435572	-0.609118736	0.210863694	-0.180218513	0.122254691	0.345721333
2004	1.310974	0.327915921	-0.238805538	-0.410340033	-0.029753807	-0.091979686	-0.002789238
2005	-0.55052858	0.344253119	-0.386858741	-0.097295723	-0.011316715	0.062003799	0.109354133
2006	0.30444806	0.538548215	-0.266475782	0.164508302	0.161171273	-0.345784391	0.017602498
2007	0.685536037	0.479696852	-0.46546645	-0.277667214	0.085874058	-0.049595707	-0.110578339
2008	-0.0996161	0.176267984	-0.357870233	-0.102804119	0.091681451	-0.085242619	-0.301259522
2009	-0.02907193	-0.018531948	-0.452387208	-0.15488354	0.036361166	-0.014004727	-0.147459105
2010	-0.003598579	0.048852809	-0.24303157	0.070386736	0.249207461	0.548653657	0.118826285
2011	-1.491347367	0.006109226	-0.614658814	-0.407211796	-0.306160438	-0.641092876	-0.60712035
2012	0.017185686	0.141167854	-0.038744452	-0.013957833	0.154474955	0.237127926	-0.170016182
2013	0.04838073	0.216511806	0.058290293	-0.007458923	0.147126174	0.31050107	-0.463729783
2014	0.131361216	0.195674891	0.531394368	0.143727459	0.112222557	0.121875847	-0.480740589
2015	0.040948526	-0.089712206	-0.113912993	-0.203639725	-0.114515291	0.064355863	-0.003393238
2016	-0.538838128	-0.293822452	-0.263205536	-0.148058624	0.010015195	0.020376645	-0.363143789
2017	-0.305329023	-0.025436208	-0.130448997	-0.094636529	-0.067813892	0.011422598	-0.438933187
2018	0.584908799	0.383157205	0.217820959	0.352035556	0.159331724	0.276303302	0.033017911

age	1	2	3	4	5	6	7+
2019	0.755496407	0.501130676	0.450923216	-0.041498291	0.093639235	0.019701746	-0.38582538
2020	-2.082021	-0.203453891	-0.409261169	-0.156672155	-0.237233369	-0.180468149	-0.551296682
2021	0.613201959	0.611885189	-0.241999831	0.079528148	0.215592341	0.439069768	-0.470789272

Table 14.3.1.2. Plaice in 7.d: Discards residuals.

age	1	2	3	4	5	6	7+
2006	-0.415701664	0.013571149	0.136572354	-0.691103808	-0.702706388	0.115176724	0.548302876
2007	-0.255013464	0.668273231	0.168857858	0.5125031	-2.556852337	0.145900217	0.61401253
2008	0.207186586	-0.535330538	-0.811821047	0.25207144	1.009965663	1.754186998	1.079419179
2009	-0.392660272	0.200224284	0.025776402	0.127508115	0.58503146	2.794472934	2.079489779
2010	-0.44638193	0.644911134	0.645651869	0.88087208	1.267874256	1.350240636	2.032137133
2011	-0.003212269	0.271564458	-0.513142569	0.053000878	0.289212681	3.229169144	1.582841061
2012	0.037775209	0.141561091	-0.038518334	-0.012938591	0.174083455	1.368635716	3.845540758
2013	0.084454506	0.217198723	0.058501291	-0.006796314	0.158639554	0.412440245	0.307170531
2014	0.136509873	0.196333566	0.531699631	0.14412116	0.114454057	0.135281016	-0.37973102
2015	0.137343296	-0.08896177	-0.113463156	-0.202711642	-0.11300859	0.068373461	0.021790443
2016	-0.509190843	-0.292051114	-0.262896209	-0.147333134	0.011973705	0.024988911	-0.32617123
2017	-0.220889148	-0.022156375	-0.130069865	-0.094281938	-0.066114309	0.014682765	-0.423731878
2018	0.60504833	0.384984385	0.218265875	0.352306067	0.159894795	0.277830548	0.035868036
2019	0.764537889	0.50283022	0.451248102	-0.040945204	0.094361916	0.021124772	-0.38187961
2020	-2.050133866	-0.202492865	-0.408305738	-0.155949741	-0.235937678	-0.17805759	-0.546494875
2021	0.656609318	0.614308714	-0.241536056	0.080130583	0.216565319	0.440598679	-0.467755708

Table 14.3.1.3. Plaice in 7.d: Survey residuals.

UK BTS						
age	**1**	**2**	**3**	**4**	**5**	**6**
1989	-1.242695678	-0.642117345	-0.110538568	0.313445879	-0.108227085	0.115885641
1990	-0.370755515	-0.606766831	-0.541083305	-0.217837863	0.167025302	-0.347753469
1991	-0.273977404	-0.083224579	0.086847481	-0.033840818	0.190120382	-0.205407219
1992	-0.23375123	-0.089190312	-0.291894504	0.290318376	0.436817897	0.291182084
1993	-1.024544959	-0.321663123	-0.41227018	-0.357484664	0.121526775	-0.096348691
1994	-0.084164782	-0.426072272	-0.320247491	0.130134623	-0.001574593	-0.726849294
1995	-0.24271424	-0.573448651	-0.540981541	0.026888726	-0.056356148	-0.259912214
1996	-0.091557561	-0.240940236	-1.190010083	-0.796078992	-0.111441562	0.119084304
1997	0.103078573	-0.062196784	-0.148527681	-0.513418403	0.522840016	-0.597878755
1998	0.37135262	-0.38328624	-0.431318274	0.009913906	-0.179879494	0.388637782
1999	-0.256081544	-0.913409488	-0.18457302	-0.497667851	-0.191105733	-0.041733602
2000	0.131234749	0.395940163	0.161762725	0.308268725	0.377566529	0.216626997
2001	0.485359782	0.018461848	0.234817774	0.336441916	0.720696563	0.38772754
2002	0.33274127	0.267612557	0.187805158	0.119578384	-0.26622064	0.263584063
2003	-0.328933713	0.169417793	-0.084183417	-0.012915651	-0.056734373	-0.482935302
2004	1.100513818	0.123040962	0.028209052	-0.008267311	-0.621370945	-1.321438633
2005	0.037538168	0.3836672	-0.014053501	0.049337926	0.26966605	-0.113034627
2006	0.76828976	0.308464411	0.022500189	-0.069099042	-0.140545206	0.001050543
2007	0.939648333	0.420604716	-0.11166338	-0.271055589	-0.054892906	0.02945285
2008	0.637620213	0.396321475	-0.097943462	-0.439738942	-0.142351601	-0.080733266
2009	0.731707011	0.350763176	0.224720968	0.033696402	-0.137731738	-0.169733536
2010	0.08738017	0.214408661	-0.022217961	0.093863874	-0.014996976	-0.280382718
2011	0.504694567	0.2654723	0.058411309	0.083301904	0.386978375	0.339258493
2012	-0.427963152	-0.247232961	-0.164357375	-0.092900782	-0.236006475	0.089884913
2013	-0.289689187	0.064369733	0.06027674	0.175184429	-0.143368669	-0.007470955
2014	0.77187869	0.878867534	0.086765412	0.24321055	0.194953055	0.169297476
2015	-0.38508217	0.579023595	0.186497039	0.098604494	0.169074897	0.127571822
2016	-1.260241594	0.204270978	0.265322653	0.225412411	0.315689051	0.295271115
2017	0.129298029	0.44612447	0.276364731	0.242861874	-0.002572387	-0.081371227
2018	-0.627203165	0.401935956	0.825797335	0.433873193	0.255160088	-0.02097615
2019	0.430886921	0.133289058	0.10717587	0.352824323	0.022991478	-0.122051488
2020	-0.237794218	-0.052160722	0.05463048	-0.079074395	0.093335046	-0.279082296
2021	-1.207185711	0.584086156	-0.025011282	0.789240755	-0.202961019	-0.001545595

Table 14.3.1.3. (cont.) Plaice in 7.d: Survey residuals.

FR GFS						
age	1	2	3	4	5	6
1993	0.471057441	0.129994198	0.163194519	0.386933701	0.023687958	-0.168613788
1994	1.124644979	0.230489852	-0.172541245	0.034984624	0.390160268	1.114679078
1995	-0.46518645	-0.719870976	-0.438401193	-0.388494588	-0.276679663	1.553797387
1996	0.159328173	-0.471253447	-0.523425108	-0.228707909	0.155319992	0.617853063
1997	0.090000003	-0.088429504	0.347862369	0.110533092	0.421386892	1.361666539
1998	0.22838285	-0.114867934	-0.10562821	-0.119025258	-0.742567086	1.14189646
1999	1.146399847	-0.081661699	0.440071204	0.369703294	0.23530745	1.459791434
2000	-0.088359102	0.644088986	0.07944489	-0.22054539	-0.111355441	0.447997772
2001	0.338854944	-0.020954352	0.066459731	0.084912263	-0.580569272	0.025597233
2002	0.074986873	0.258429454	0.568051011	0.555505777	0.301946822	-0.331610085
2003	0.605712684	0.42954856	0.27760945	-0.161059307	-0.063514542	0.40828277
2004	0.783361402	0.562024717	0.157754063	0.625532884	-0.666830234	0.612901464
2005	0.50759648	0.540659914	1.172270831	0.433956397	0.774468405	0.775337387
2006	0.700364143	0.386294468	0.21898038	0.354698599	-0.122856	0.616337491
2007	0.338623742	0.412592638	0.508987602	0.051443733	0.037805302	-0.351615297
2008	0.108196392	0.950794574	0.289717153	0.023905417	-0.3151303	-0.04866419
2009	-0.038897588	0.084331364	0.060184962	-0.007574844	-0.236051183	-0.179285037
2010	0.519748588	0.296189362	-0.119271627	-0.601912057	-0.047802373	-0.240057469
2011	-0.136293245	0.21385748	0.130818669	-0.367024959	-0.779882026	0.059817198
2012	0.177915511	0.021115449	0.439476159	0.332867998	0.486275154	-0.253313669
2013	-0.967349438	-0.484968131	-0.180315126	-0.486960535	-0.527836325	-0.503803064
2014	-0.620383995	-0.833584338	-0.74701679	-0.260304925	-0.716782245	-0.695310994
2015	-1.253448608	-0.81026592	0.13971146	-0.056314808	-0.001960802	-0.393448159
2016	-1.408348997	-1.00848386	-0.16807449	0.125337459	0.369238805	-0.405731553
2017	-0.811313742	-0.911449873	-0.425429282	-0.042253509	-0.292840467	-0.564247988
2018	-1.622406312	-0.798355903	-0.702770448	0.033673495	-0.427757663	-0.53064371
2019	-0.142609096	-0.404959326	-0.136784322	-0.170060726	0.553884731	0.363563247
2020	0.719908436	0.155653449	-0.351563014	-0.379343288	-0.065148246	-0.010763786
2021	0.055050585	0.448415889	-0.073657888	-0.606510491	-0.126762391	-0.330663102

Table 14.3.1.4. Plaice in 7.d: Fishing mortality (F) at age.

	1	2	3	4	5	6	7
1980	0.0115902	0.114875	0.3778	0.316549	0.17966	0.104395	0.104395
1981	0.0184568	0.147577	0.437722	0.378729	0.228792	0.140143	0.140143
1982	0.0261201	0.182036	0.502542	0.440309	0.278334	0.179528	0.179528
1983	0.0291947	0.207008	0.566533	0.483357	0.309007	0.209425	0.209425
1984	0.0238387	0.210638	0.620989	0.490513	0.303414	0.215475	0.215475
1985	0.0169861	0.199417	0.652372	0.472541	0.279953	0.208281	0.208281
1986	0.0139506	0.187665	0.646291	0.452201	0.267384	0.209143	0.209143
1987	0.0169931	0.18693	0.596565	0.447507	0.28761	0.237987	0.237987
1988	0.0298555	0.202448	0.529877	0.451391	0.331898	0.289761	0.289761
1989	0.0621589	0.239634	0.480331	0.442569	0.36133	0.326724	0.326724
1990	0.12614	0.310709	0.47023	0.403515	0.328591	0.297574	0.297574
1991	0.219388	0.419948	0.499435	0.351174	0.257912	0.226715	0.226715
1992	0.305448	0.537267	0.551624	0.319106	0.20759	0.17478	0.17478
1993	0.31935	0.590804	0.606432	0.331328	0.203953	0.165265	0.165265
1994	0.257886	0.544333	0.642712	0.397348	0.254368	0.199833	0.199833
1995	0.18739	0.450851	0.646278	0.499707	0.348886	0.262765	0.262765
1996	0.143945	0.362625	0.607629	0.59394	0.450203	0.3151	0.3151
1997	0.128617	0.303252	0.541107	0.62676	0.494862	0.312823	0.312823
1998	0.128618	0.277239	0.489168	0.600467	0.471189	0.274541	0.274541
1999	0.136247	0.290684	0.484461	0.539657	0.400872	0.232001	0.232001
2000	0.143667	0.350908	0.544632	0.469713	0.317399	0.202481	0.202481
2001	0.138498	0.425649	0.632687	0.407676	0.251263	0.18641	0.18641
2002	0.111598	0.440367	0.67385	0.363092	0.214967	0.183112	0.183112
2003	0.0716493	0.347175	0.603666	0.338986	0.210039	0.192365	0.192365
2004	0.0431293	0.241258	0.493968	0.3265	0.220945	0.206879	0.206879
2005	0.0306031	0.185404	0.422771	0.31558	0.227565	0.214892	0.214892
2006	0.0309568	0.190842	0.424716	0.298745	0.211268	0.204601	0.204601
2007	0.0393137	0.239012	0.476627	0.277809	0.179828	0.177749	0.177749
2008	0.0472767	0.287481	0.524674	0.257947	0.149866	0.143577	0.143577
2009	0.0414541	0.266201	0.501225	0.242751	0.130204	0.110099	0.110099
2010	0.0277147	0.191645	0.411753	0.230405	0.119899	0.0840174	0.0840174
2011	0.0185236	0.128498	0.313414	0.216263	0.114987	0.0681935	0.0681935
2012	0.0161828	0.0961314	0.238512	0.197017	0.112833	0.0628461	0.0628461
2013	0.0193008	0.0861598	0.192905	0.177162	0.113379	0.067016	0.067016
2014	0.0256044	0.0880138	0.173362	0.166336	0.119177	0.0800471	0.0800471
2015	0.0304386	0.0968772	0.180696	0.172717	0.133954	0.103386	0.103386
2016	0.029439	0.108718	0.214697	0.19955	0.159981	0.137834	0.137834
2017	0.0256411	0.117864	0.258665	0.23697	0.192467	0.177757	0.177757
2018	0.0226814	0.116984	0.278484	0.26506	0.220163	0.207459	0.207459
2019	0.0220788	0.103231	0.248159	0.26448	0.231203	0.211125	0.211125
2020	0.0231528	0.0836829	0.192386	0.242425	0.227967	0.194574	0.194574
2021	0.0251996	0.0650185	0.139114	0.212976	0.217803	0.170646	0.170646

Table 14.3.1.5. Plaice in 7.d: Stock numbers from the assessment.

	1	2	3	4	5	6	7+
1980	67465.2	29857	9991.45	2405.59	1992.31	638.153	1854.9
1981	33794.6	46848.6	18698.5	4810.64	1231.39	1169.45	1577.77
1982	65393	23306.8	28395.9	8479.25	2314.05	688.153	1677.57
1983	55990.4	44754.6	13648.2	12068.5	3835.17	1230.68	1388.82
1984	56817.6	38201.9	25561.5	5441.08	5228.61	1978.04	1492.51
1985	76695.6	38974.5	21739.9	9650.39	2340.5	2711.85	1965.48
1986	162331	52971.7	22429.8	7954	4226.43	1242.73	2668.05
1987	97493.7	112459	30845.6	8256.49	3555.07	2272.48	2228.87
1988	60682.5	67336	65533.2	11933.3	3707.63	1873.23	2492.51
1989	37702.9	41375.9	38634.6	27101.3	5337.93	1868.98	2295.44
1990	39243.4	24890.3	22873.2	16788.9	12230.2	2612.76	2110.14
1991	68215.7	24301.6	12815.7	10040.6	7878.21	6185.57	2463.91
1992	91906.1	38481.9	11217.7	5463.73	4964.74	4276.3	4843.72
1993	42871.2	47570.8	15797	4539.29	2789.68	2833.95	5379.48
1994	32364.5	21883.9	18510.1	6051.39	2289.52	1598.19	4891.05
1995	55920.8	17568	8920.2	6838.05	2857.19	1247.17	3733
1996	71171	32571.8	7862.67	3283.6	2914.49	1416.03	2690.15
1997	126137	43295.1	15922.3	3008.37	1273.67	1305.25	2104.95
1998	61350.7	77917.5	22458.9	6511.14	1129.23	545.495	1752.16
1999	48646.8	37897.6	41484.1	9673.79	2509.16	495.221	1226.6
2000	50400.6	29821.8	19907.7	17952.9	3961.66	1180.54	959.141
2001	50251	30668.5	14749.8	8112.23	7884.8	2026.2	1227.62
2002	78014.3	30736	14076.2	5503.83	3790.87	4308.43	1897.09
2003	41722.7	49018.3	13901.1	5040.66	2689.22	2147.98	3629.98
2004	48453.4	27283.9	24335.1	5339.86	2523.01	1531.29	3348.75
2005	41310.2	32602	15058.4	10431.7	2706.35	1421.06	2787.58
2006	38132.5	28146	19027.2	6931.43	5345.05	1514.27	2384.88
2007	56958.9	25971.7	16337.5	8741.24	3611.86	3039.83	2232.36
2008	57758.1	38471.4	14366.5	7125.9	4651.28	2119.74	3100.61
2009	102694	38701.8	20273.9	5972.25	3867.81	2812.79	3176.84
2010	160341	69214	20834	8627.97	3291.27	2385.44	3769.08
2011	187961	109562	40143.4	9696.18	4813.89	2050.89	3975.18
2012	102738	129621	67686.6	20613.5	5486.93	3014.45	3954.29
2013	117014	71015.5	82713.4	37460.1	11891.6	3443.32	4597.39
2014	182490	80631.5	45770.5	47912.5	22043.4	7458.46	5282.51
2015	152566	124960	51871.8	27036.2	28501.1	13745.9	8262.07
2016	121187	103965	79679.7	30416.3	15980.4	17512	13942.2
2017	119821	82664.6	65512.5	45160.3	17502.2	9566.61	19251.7
2018	130540	82043.9	51615.8	35533.5	25031.8	10142.8	16948
2019	207083	89648.7	51273.3	27446.7	19150.2	14110	15465.9
2020	71614.4	142301	56801.8	28104	14800.6	10676.1	16822.8
2021	163630	49158.2	91942.1	32920.1	15493	8277.97	15902.5

Table 14.3.1.6 Plaice in 7.d: Summary table (Outputs from the model).

Year	Recruitment			SSB (tonnes)			Landings	Discards	F		
	Age 1	High	Low		High	Low	Tonnes		Ages 3–6	High	Low
1980	67465	88163	51589	8247	10694	5800	1856	410	0.245	0.336	0.153
1981	33795	45124	25307	11002	13604	8400	3281	758	0.296	0.385	0.208
1982	65393	86913	49185	13330	16292	10368	4703	865	0.350	0.449	0.251
1983	55990	74407	42138	13197	16111	10283	4513	995	0.392	0.501	0.283
1984	56818	75097	43022	12962	15795	10129	4845	1083	0.408	0.509	0.307
1985	76696	99900	58928	12794	15521	10067	4628	1033	0.403	0.494	0.312
1986	162331	206612	127440	12832	15350	10314	4573	1245	0.394	0.484	0.303
1987	97494	124179	76613	15793	18456	13130	5883	2006	0.392	0.478	0.307
1988	60683	78355	46958	20853	24330	17376	8304	2063	0.401	0.482	0.319
1989	37703	49395	28750	21777	25484	18070	7577	1490	0.403	0.489	0.316
1990	39243	53429	28851	18447	21903	14991	5757	1245	0.375	0.457	0.293
1991	68216	97591	47642	14568	17722	11414	4167	1873	0.334	0.403	0.264
1992	91906	141071	59933	12222	15048	9396	3929	3212	0.313	0.380	0.247
1993	42871	65353	28126	11489	14034	8944	4256	2678	0.327	0.394	0.259
1994	32365	47006	22292	10583	12844	8322	3842	1574	0.374	0.441	0.306
1995	55921	78056	40088	8733	10665	6802	3200	1394	0.439	0.516	0.363
1996	71171	95532	53039	7307	8943	5671	3052	1590	0.492	0.579	0.405
1997	126137	164743	96554	7732	9357	6106	3531	2240	0.494	0.582	0.406
1998	61351	81144	46352	10662	12655	8669	4706	2241	0.459	0.551	0.367
1999	48647	66087	35785	14242	16784	11700	5929	1801	0.414	0.506	0.322
2000	50401	69691	36468	14835	17591	12079	5470	1556	0.384	0.468	0.299
2001	50251	70214	35979	12957	15661	10253	4421	1550	0.370	0.457	0.282
2002	78014	104608	58222	11691	14338	9044	3994	1687	0.359	0.453	0.264
2003	41723	53410	32606	11571	14227	8915	3930	1472	0.336	0.427	0.245
2004	48453	60341	38880	12280	15114	9446	3897	940	0.312	0.400	0.224
2005	41310	50755	33632	12731	15810	9652	3395	714	0.295	0.385	0.205
2006	38133	46967	30971	13109	16343	9875	3463	732	0.285	0.372	0.198
2007	56959	70298	46143	13303	16692	9914	3459	825	0.278	0.361	0.195
2008	57758	70542	47289	13327	16779	9875	3507	1282	0.269	0.351	0.187
2009	102694	125676	83997	13958	17499	10417	3697	1400	0.246	0.320	0.172
2010	160341	197996	129832	16048	19990	12106	3768	1473	0.212	0.272	0.151
2011	187961	233482	151318	22000	27057	16943	4666	1775	0.178	0.230	0.126
2012	102738	128068	82428	32719	40072	25366	3003	2915	0.153	0.197	0.109
2013	117014	145199	94291	43469	53554	33384	3650	2446	0.138	0.175	0.100
2014	182490	225258	147709	48380	60097	36663	3302	2484	0.135	0.172	0.097
2015	152566	188633	123308	49684	61790	37578	3514	2578	0.148	0.189	0.106
2016	121187	150091	97831	52165	64749	39581	4539	4068	0.178	0.226	0.130
2017	119821	150260	95595	51636	64411	38861	4585	4485	0.216	0.276	0.157

Year	Recruitment			SSB (tonnes)			Landings	Discards	F		
	Age 1	High	Low		High	Low	Tonnes		Ages 3–6	High	Low
2018	130540	169763	100292	45709	57667	33751	3746	3570	0.243	0.312	0.173
2019	207083	285467	150260	39131	49987	28275	3139	4179	0.239	0.307	0.170
2020	71614	117494	43646	35967	46161	25773	2453	2704	0.214	0.279	0.150
2021	163630	411778	64975	34987	45246	24728	1640	2954	0.185	0.251	0.119
2022	122963			41883							

Table 14.5.3.1.1. Plaice in 7.d: Forecast settings, management options for 2023 and their effects on the resident stock.

Variable	Value	Source	Notes
F ages 3–6 (2022)	0.21	AAP	Fsq = $F_{average\ 2019–2021}$
SSB (2023)	41642	AAP	Short term forecast (STF), tonnes
$R_{age\ 1}$ (2021)	163630	AAP	Geometric mean 2016–2020; in thousands
Rage1 (2022–2023)	122963	GM 2016–2020	Thousands individuals
Catch (2022)	5392	AAP	STF, in tonnes (resident stock)
Landings (2022)	2385	AAP	STF, in tonnes; projection based on the average landing ratio (2019–2021) by age
Discards (2022)	3007	AAP	STF, in tonnes; projection based on the average landing ratio (2019–2021) by age

Table 14.5.3.1.1. (continued) Plaice in 7.d: Management options for 2023 and their effects on the resident stock.

	Total catch (2023)	Projected landings* (2023)	Projected discards** (2023)	F_{total} (ages 3–6 2023)	SSB (2024)	% SSB change	% change in projected catches
MSY approach: F_{MSY}	4738	2204	2534	0.156	44175	6.08	0.44
$F = F_{MSY\ lower}$	3493	1627	1866	0.113	45820	10	-26
$F = F_{MSY\ upper}$	6618	3070	3548	0.224	41706	0.15	40
F = 0	0	0	0	0	50473	23	-100
F_{pa} ($F_{P.05}$ with AR)F_{pa}	6992	3506	3750	0.238	41217	-1.02	48
F_{lim}	10578	4876	5702	0.381	36573	-12	124
SSB (2024) = B_{lim}	18080	8210	9870	0.747	27147	-35	283
SSB (2024) = B_{pa}	9655	4457	5198	0.343	37761	-9.32	105
SSB (2024) = MSY $B_{trigger}$	9655	4457	5198	0.343	37761	-9.32	105
$F = F_{2022}$	5556	2581	2975	0.185	43098	3.50	11

*** Marketable landings**

**** Including BMS landings (EU stocks), assuming recent discard rate**

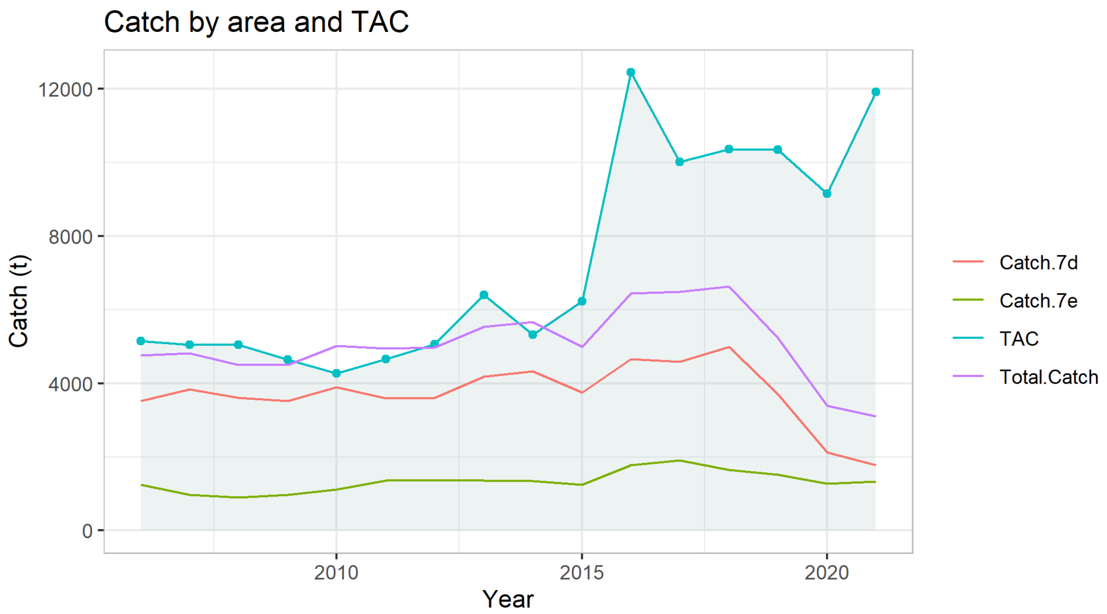


Figure 14.2.1.1. Plaice in 7.d. Official landings in 7.d and 7.e compared to the TAC: since 2019, the advice was given on catch rather than landings.

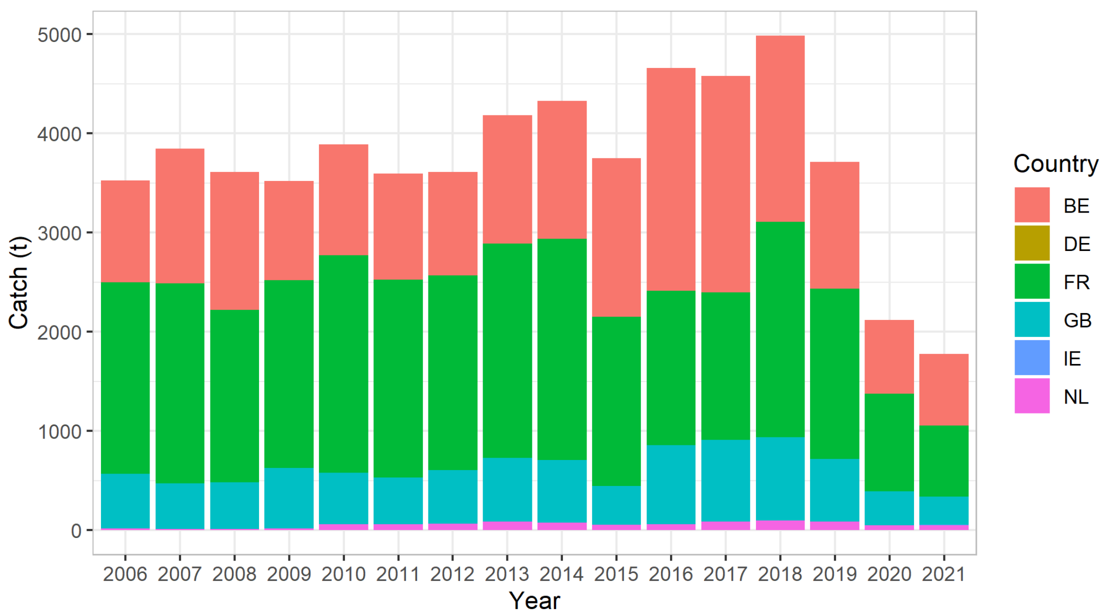


Figure 14.2.1.2. Plaice in 7.d: Official landings.

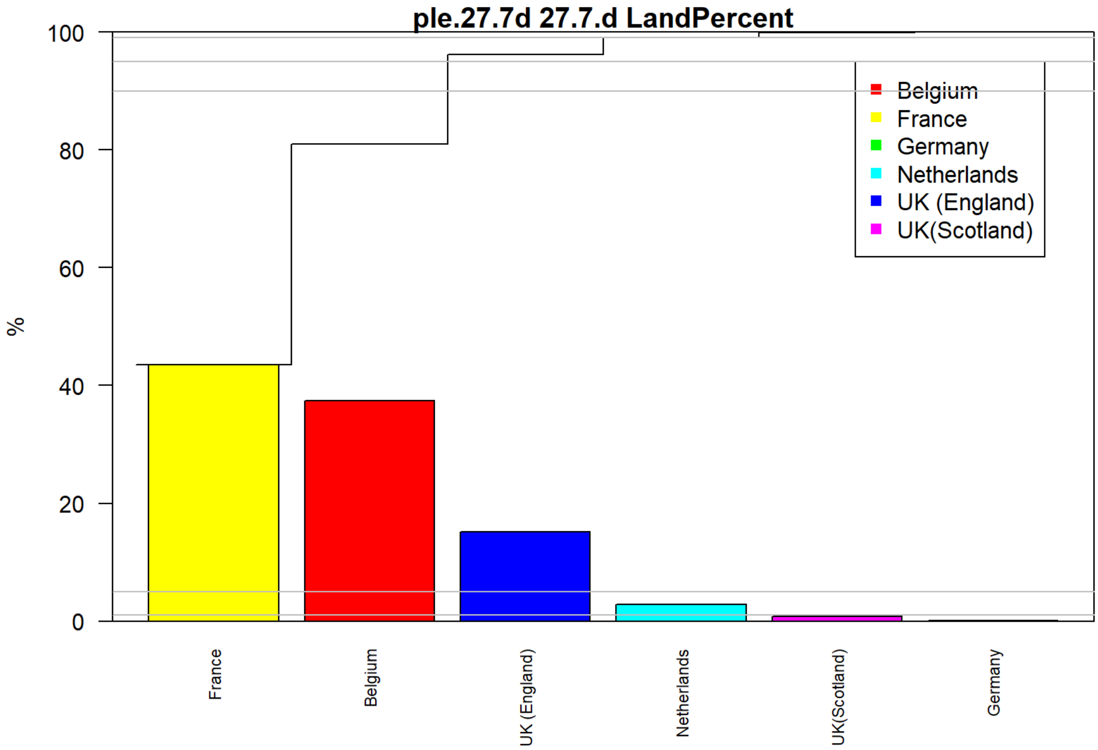


Figure 14.2.2.1. Plaice in 7.d: Proportions of total landings per country with and without age distribution provided.

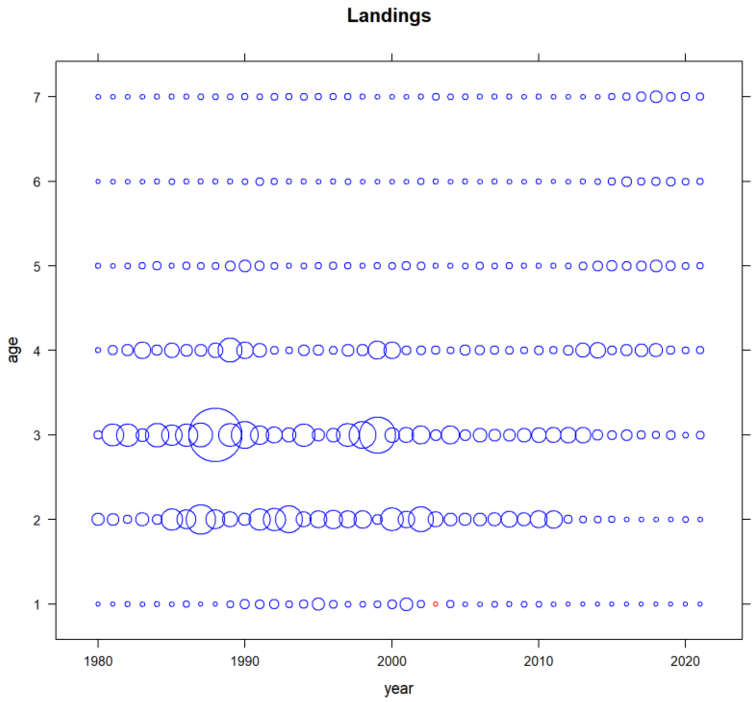


Figure 14.2.3.1. Plaice in 7.d: Age composition of the landings, missing data are presented in red.

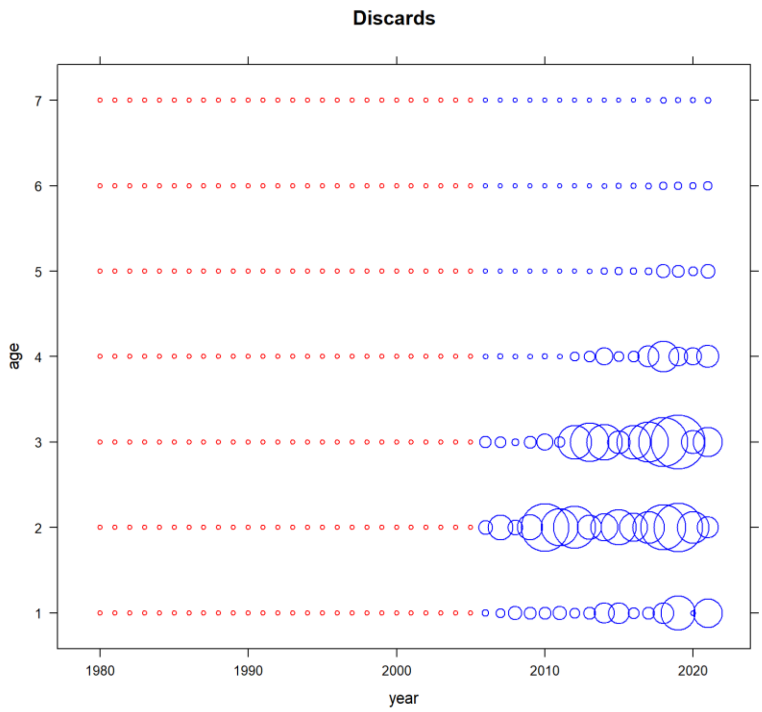


Figure 14.2.3.2. Plaice in 7.d: Age composition of the discards (data available from 2006 onward).

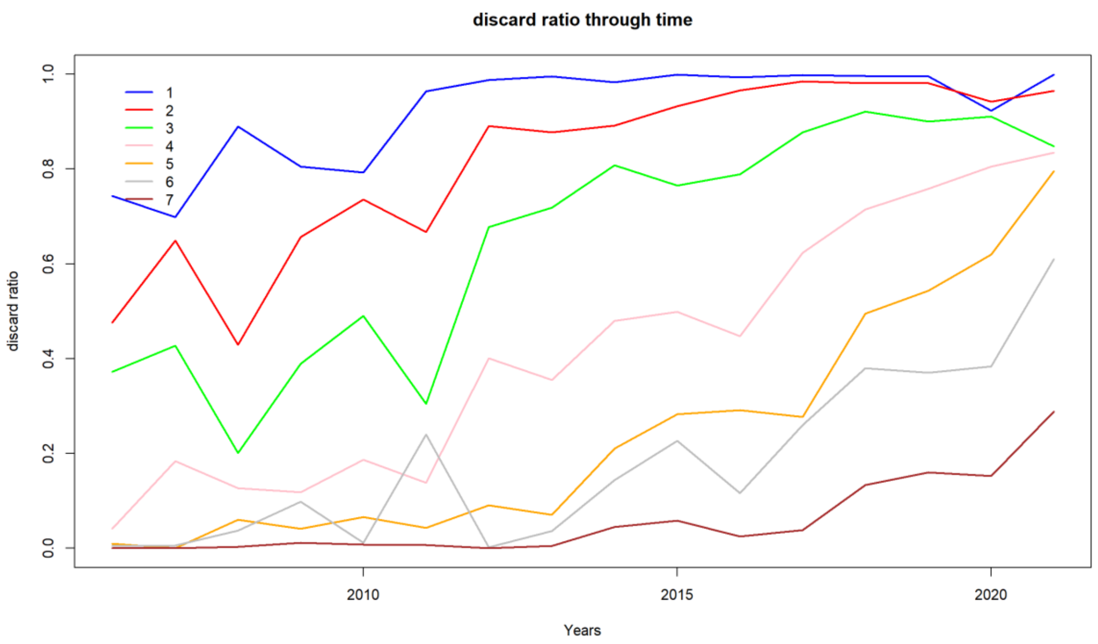


Figure 14.2.3.3: Plaice in 7.d: Discards at age ratio (discards numbers/landings numbers) per age.

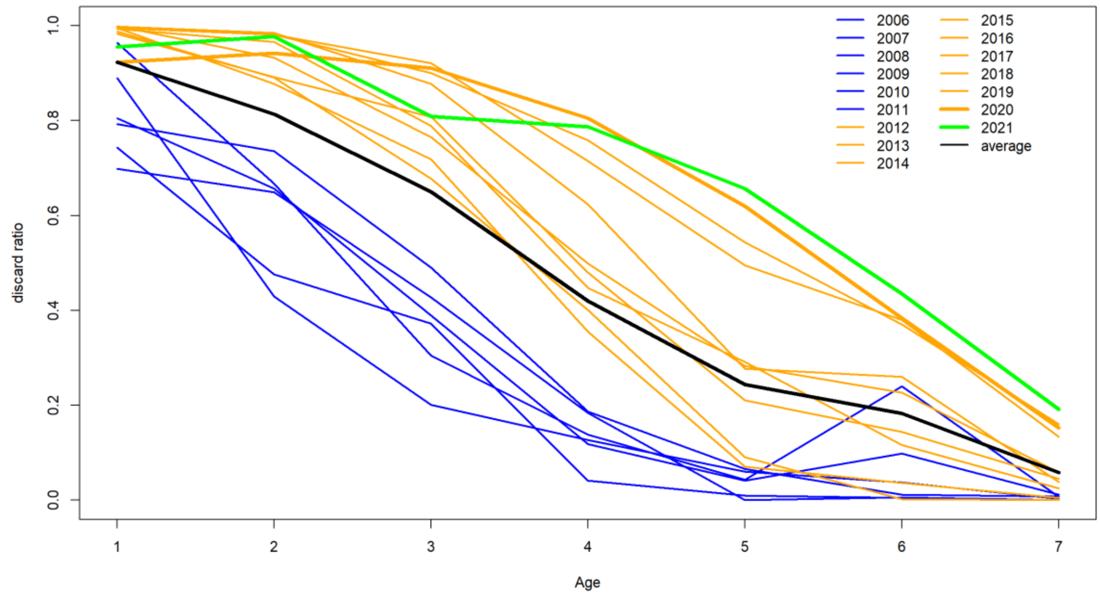


Figure 14.2.3.4. Plaice in 7.d: Discards at age ratio (discards numbers/landings numbers) through time.

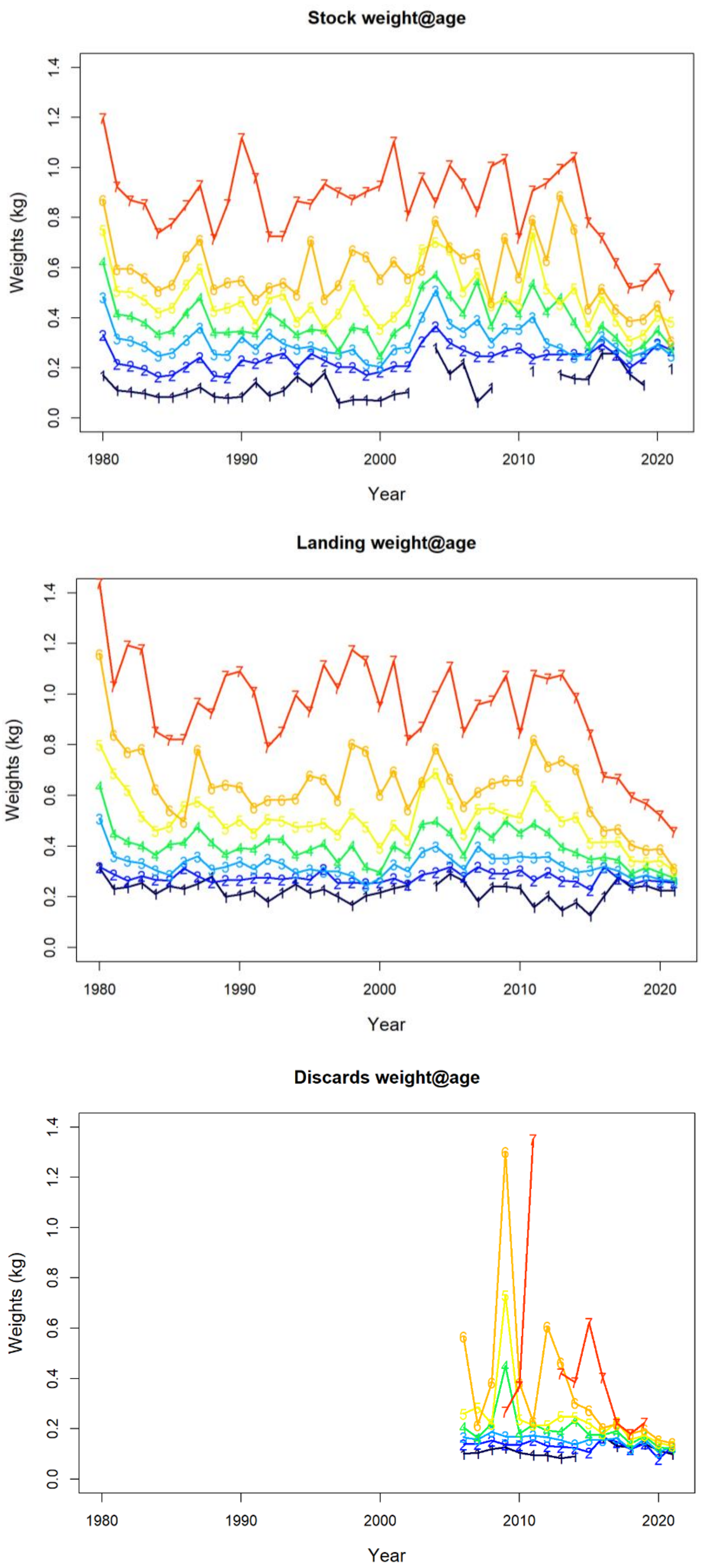


Figure 14.2.4.1. Plaice in 7.d: Stock, Landing and discard weights.

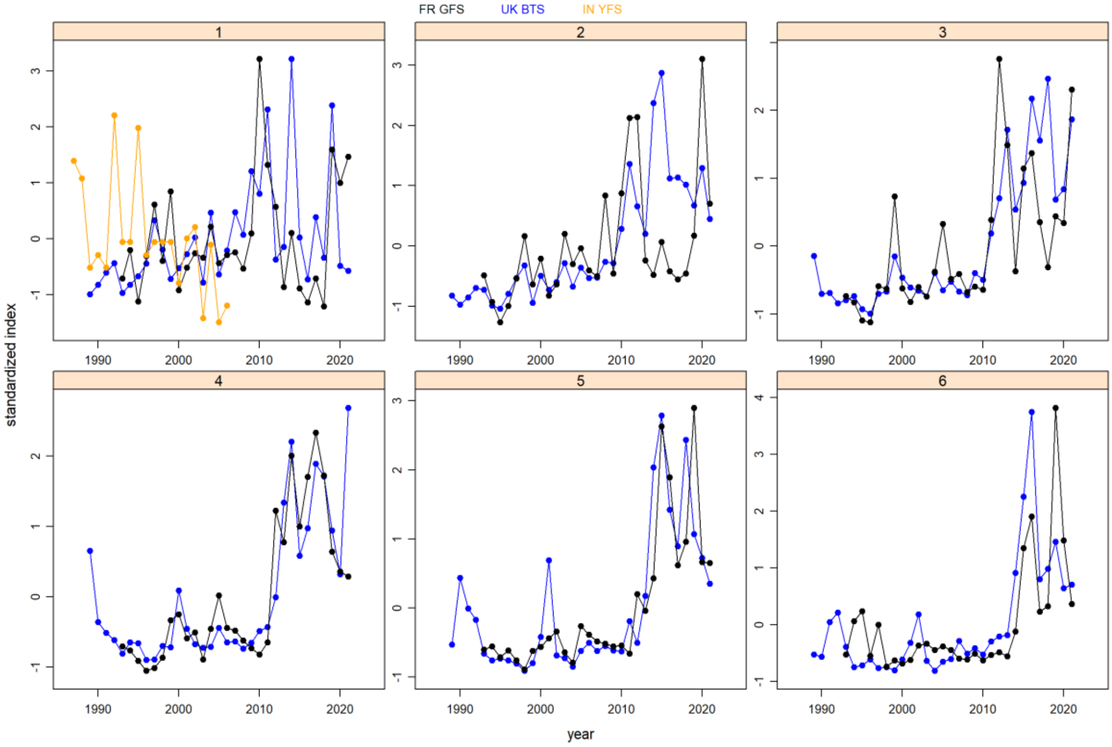


Figure 14.2.6.1. Plaice in 7.d: Survey Consistency: mean standardized indices by surveys for each age.

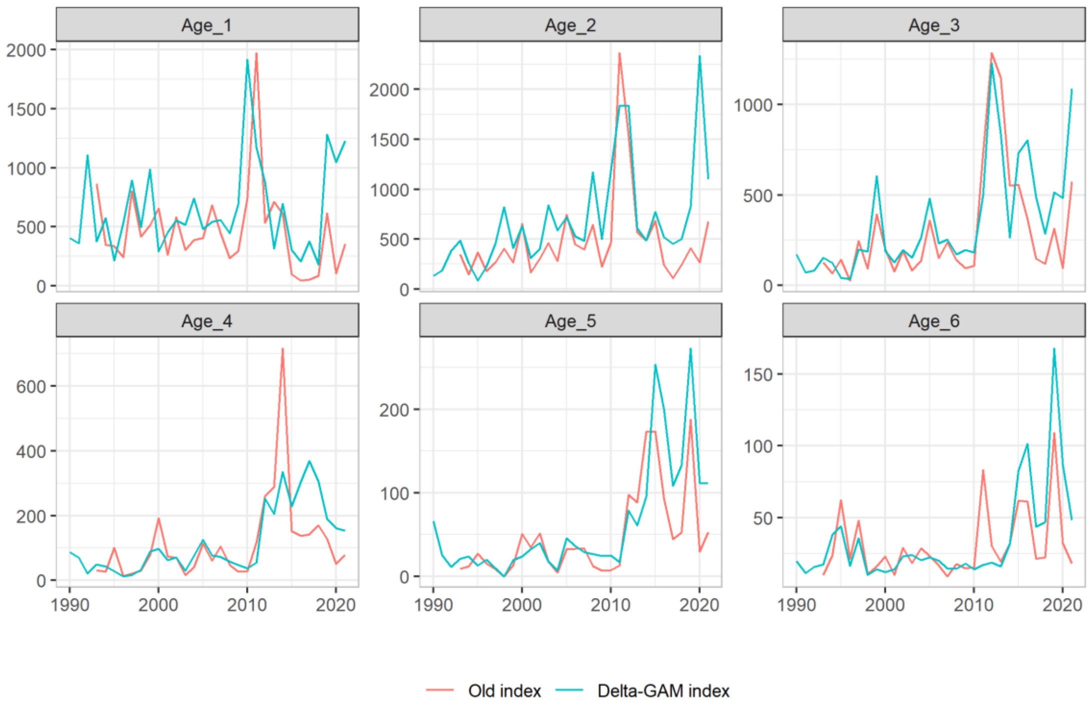
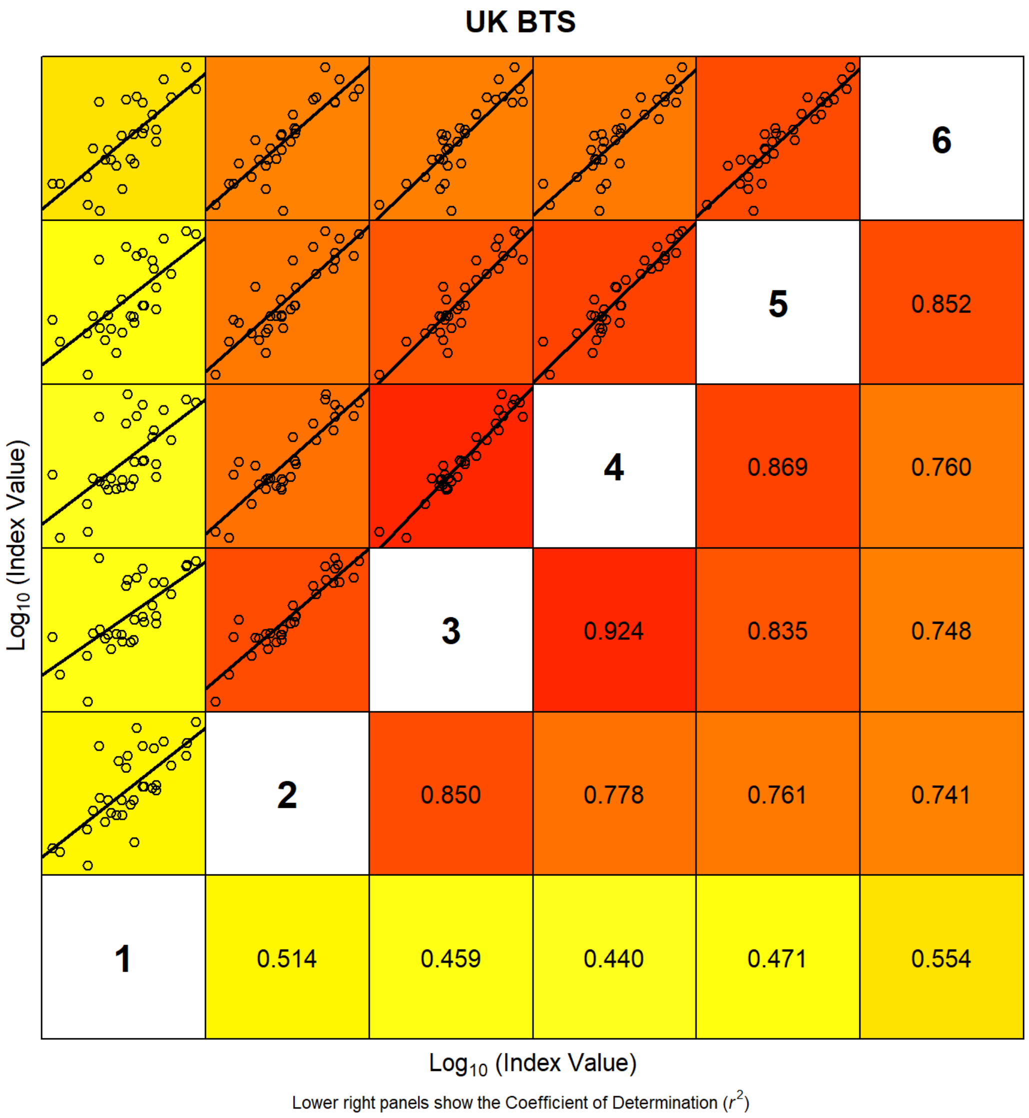


Figure 14.2.6.2. Plaice in 7.d: Raw survey indices (blue: the new Delta-GAM index, red: the former index)


UK BTS
1
2
3
4
5
6
0.514
0.459
0.440
0.471
0.554
0.850
0.778
0.761
0.741
0.924
0.835
0.748
0.869
0.760
0.852
Log10 (Index Value)
Log10 (Index Value)
Lower right panels show the Coefficient of Determination (r2)

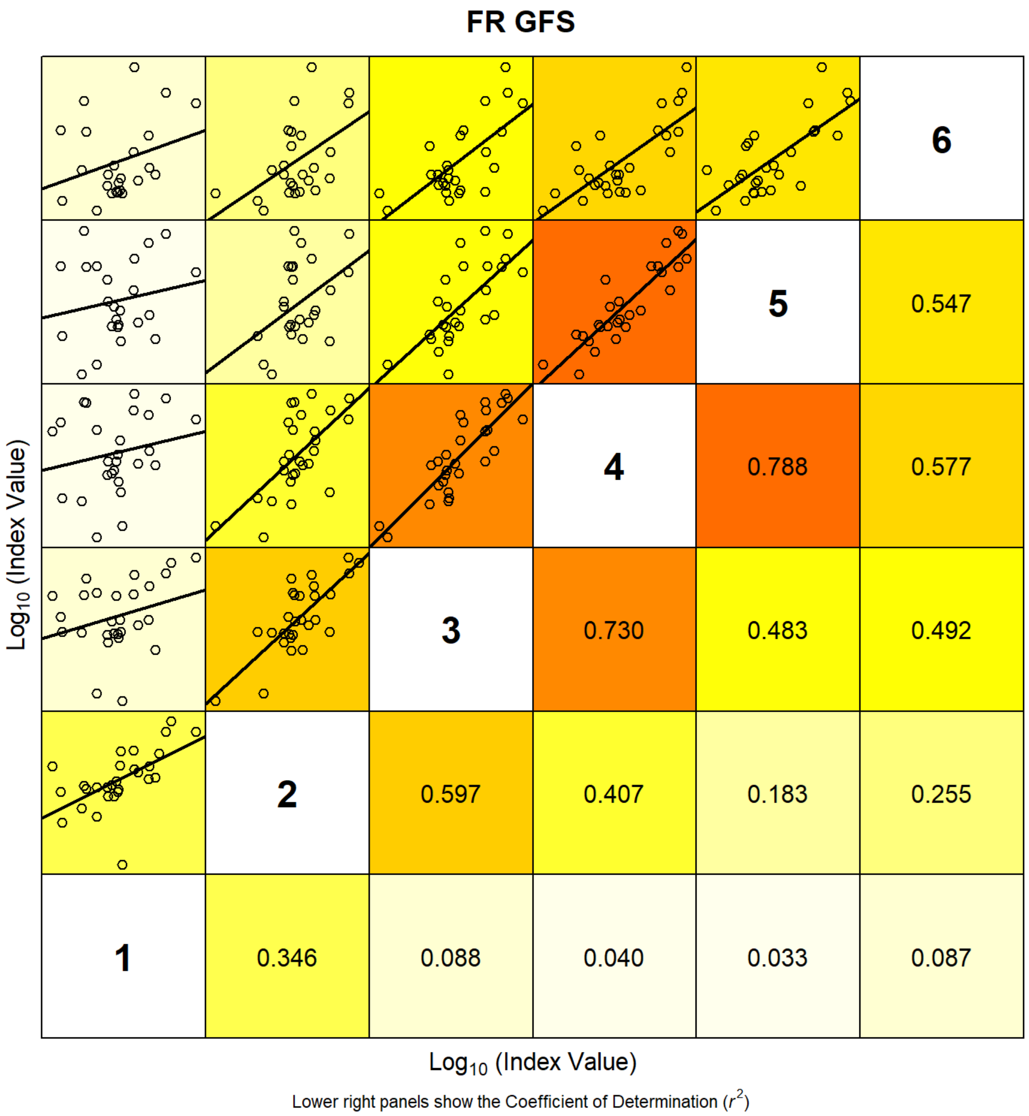


Figure 14.2.6.3. Plaice in 7.d: UK BTS and FR GFS indices consistencies.

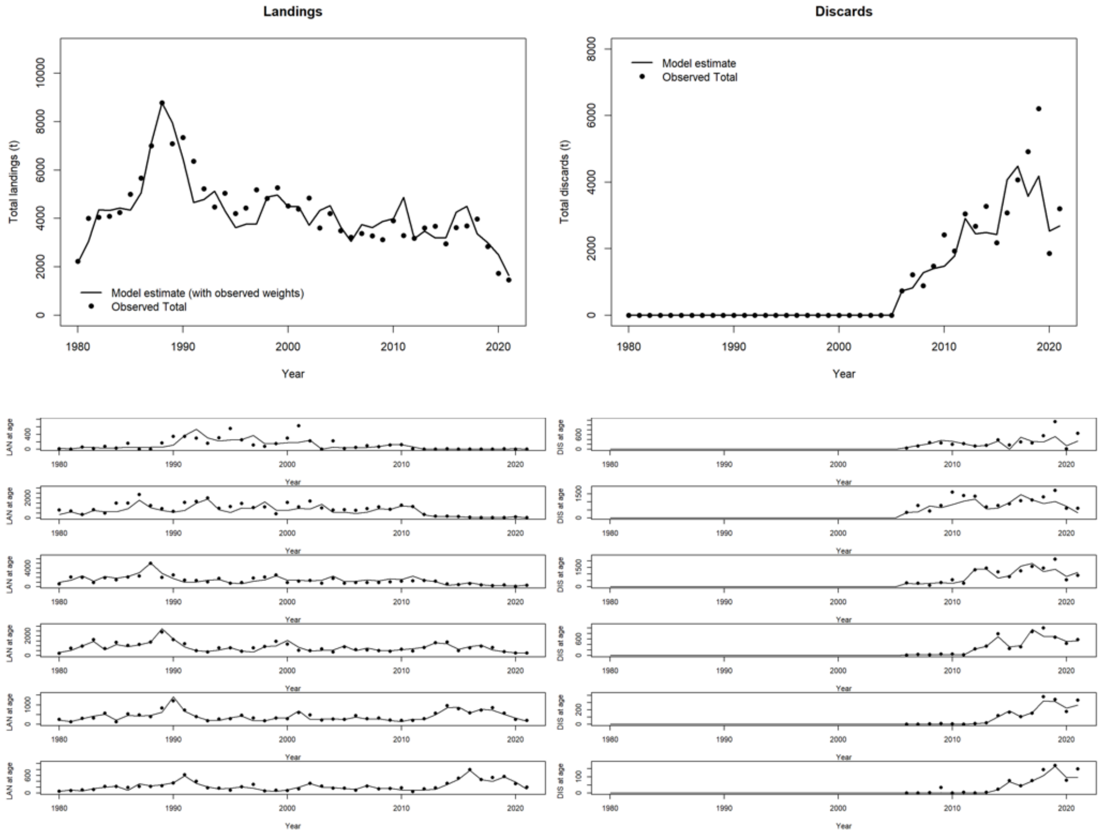


Figure 14.3.1.1. Plaice in 7.d: Landings (left) and discards (right) time series: observed (dots) vs modelled (line), and per age (from 1 to 6: bottom panels).

Figure 14.3.1.2. Plaice in 7.d: Survey residuals from the AAP assessment.

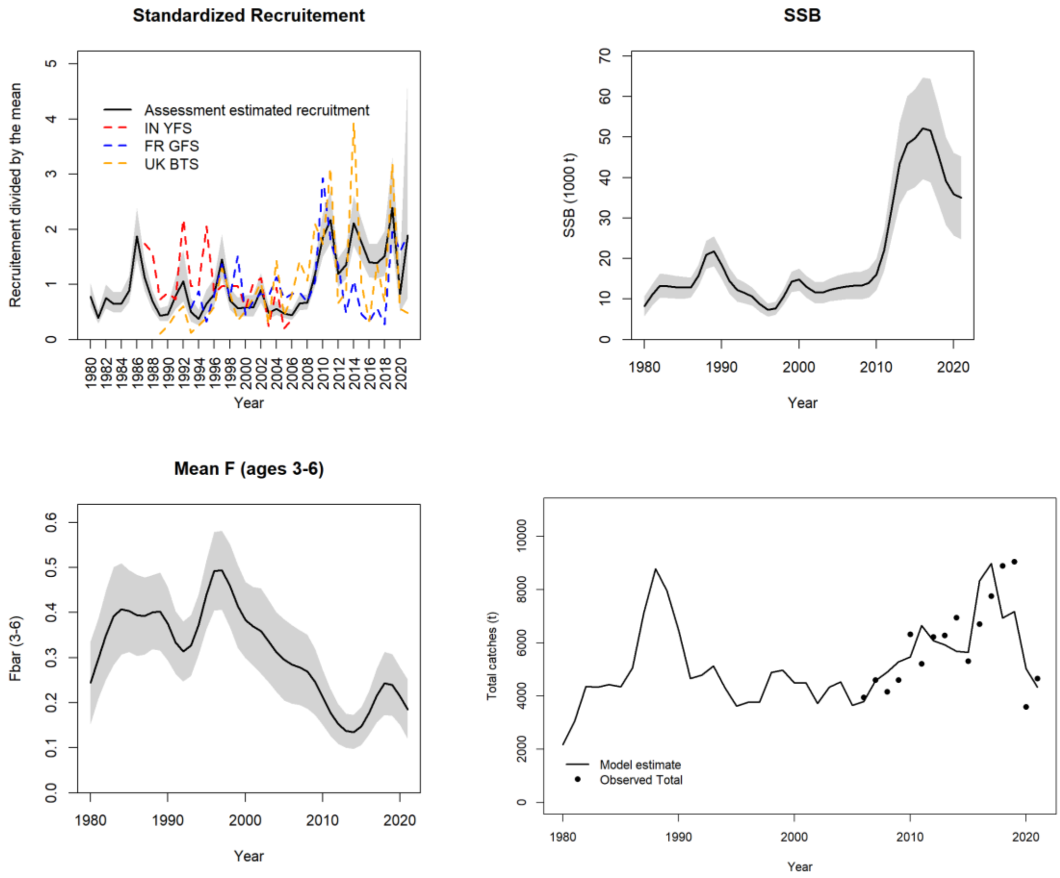


Figure 14.3.1.3. Plaice in 7.d: Summary of assessment results.

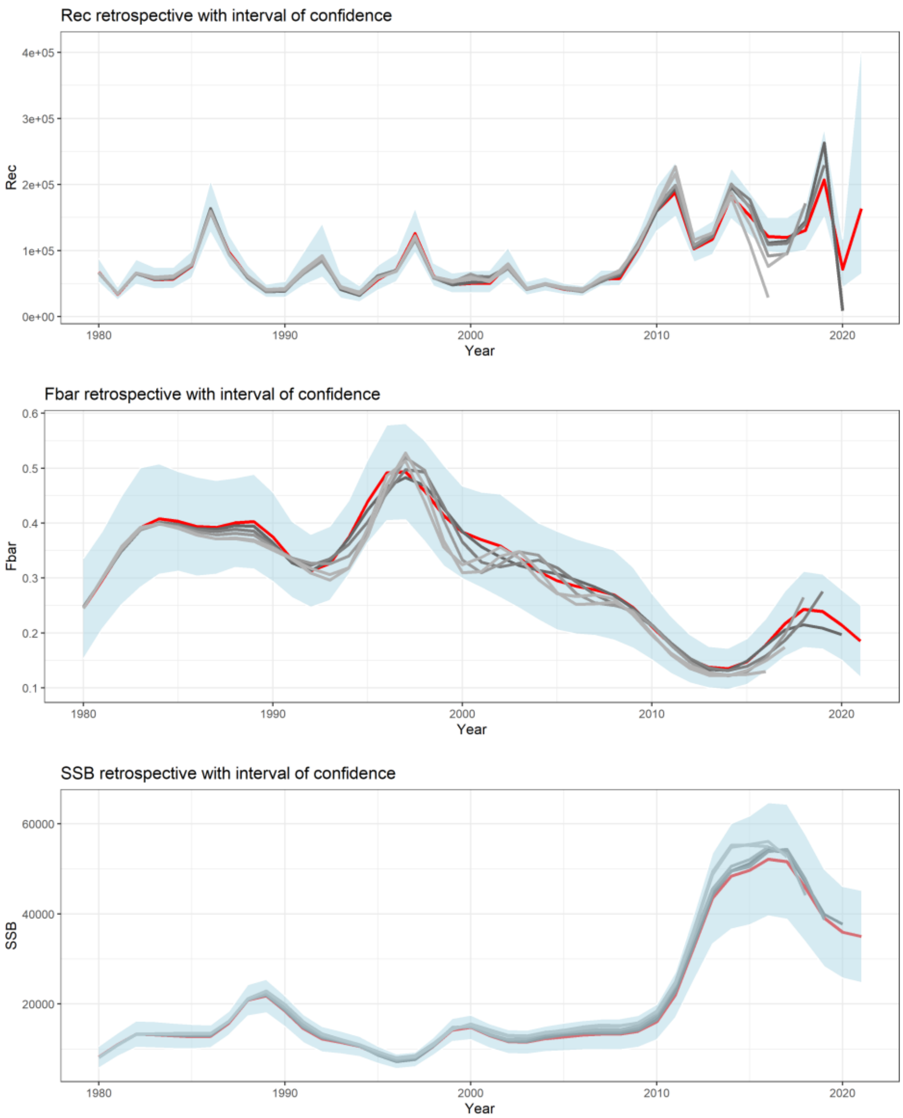


Figure 14.3.1.4: Plaice in 7.d. Retrospective patterns (Mohn's Rho F_{bar} = -0.061, Mohn's Rho SSB = 0.016, Mohn's Rho Rec = -0.282).

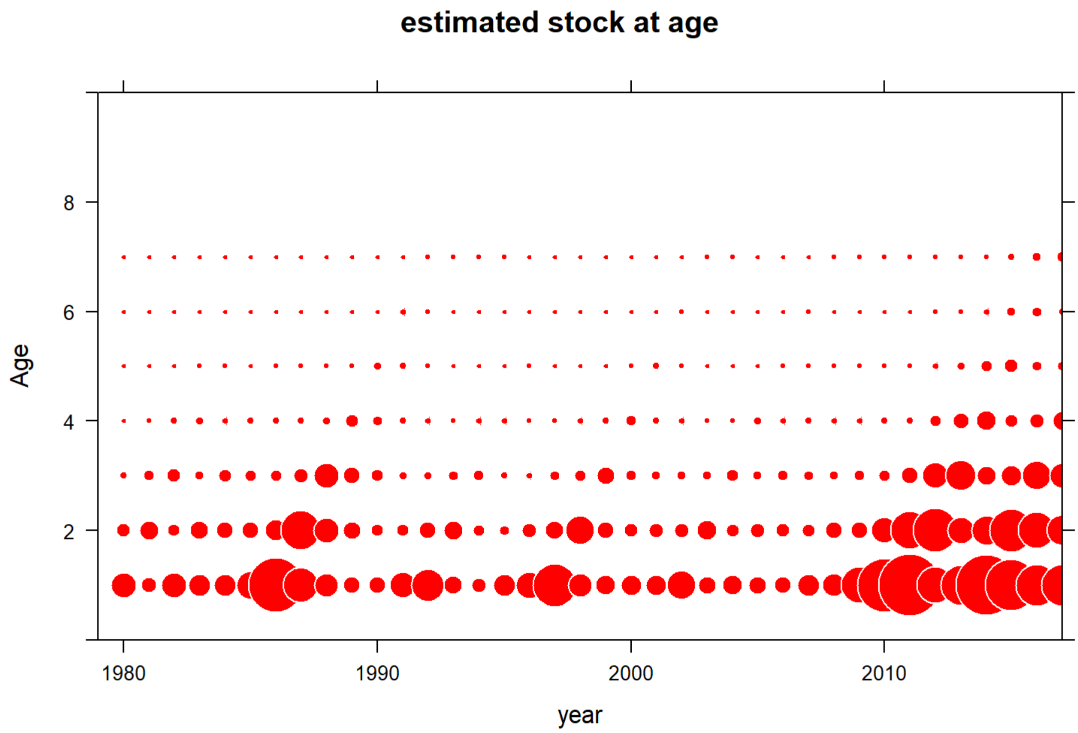


Figure 14.3.1.5: Plaice in 7.d. Estimated stock numbers.

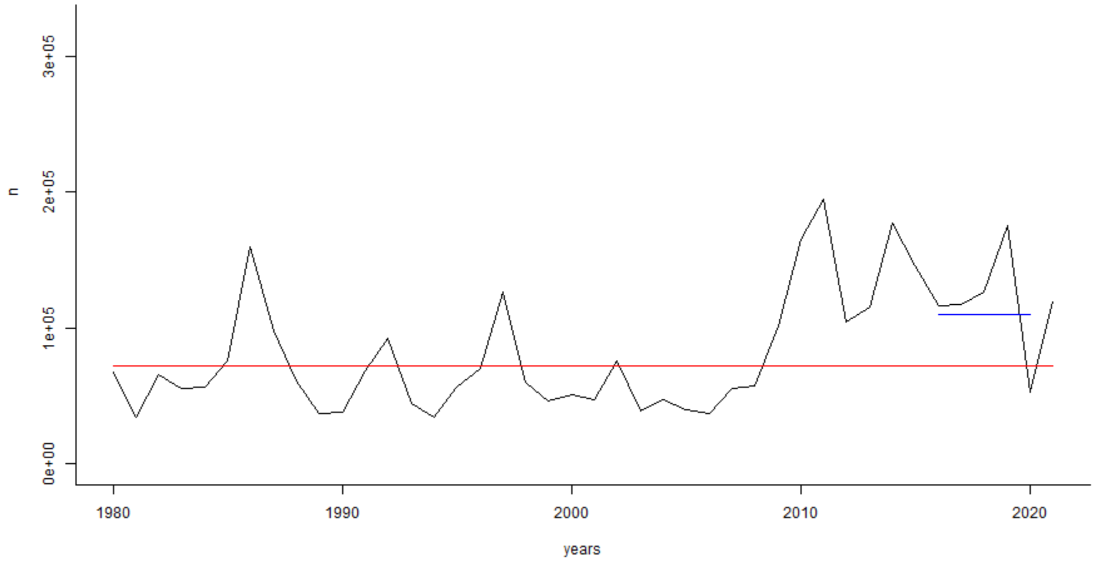


Figure 14.5.1.2. Plaice in 7.d: Number of individuals of age 1 as estimated by the assessment model (black), with the geometric mean over the period 1980–2021 (red), and the geometric mean over 2016–2020 (blue). The black arrow corresponds to the lowest recruitment observed over 1980–2021.

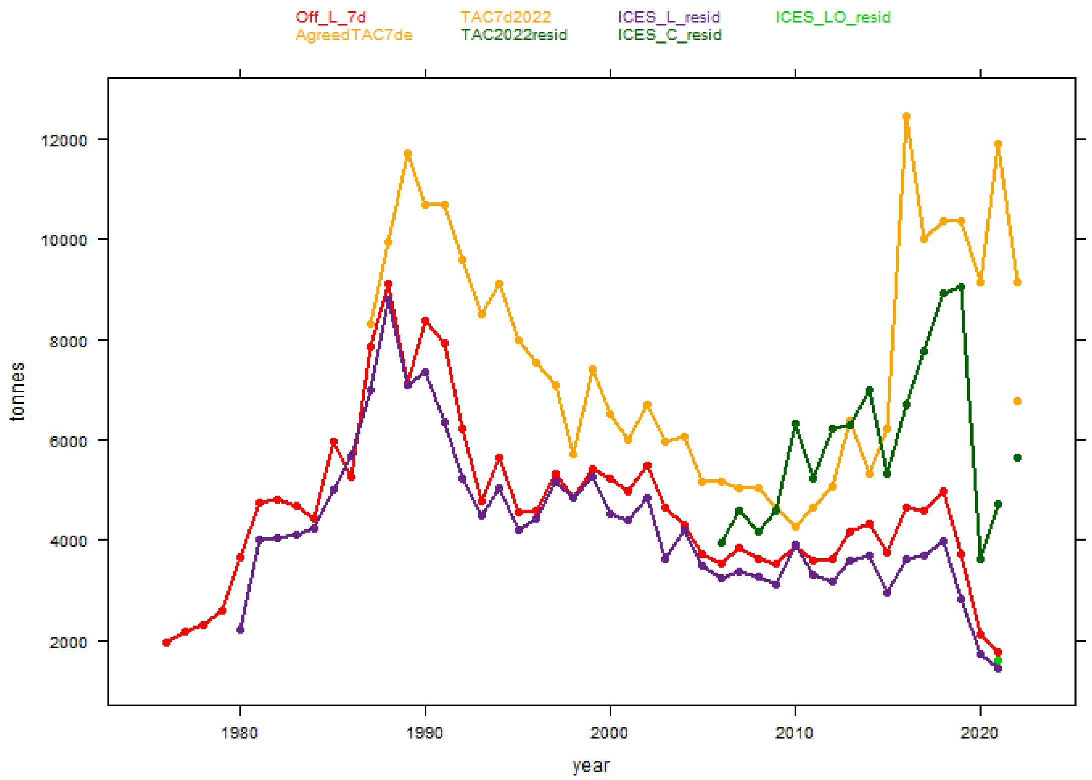


Figure 14.5.2.1. Plaice in 7.d. Official landings in 7.d (red line), ICES landings of resident plaice in 7d (purple line), ICES catches of resident plaice in 7d (dark green line) and agreed TAC for 7d,e plaice (orange line). The orange dot correspond to 7d proportion of 2022 TAC, the dark green dot is the resident plaice in 7d proportion of 2022 TAC, and the green dot is the landings of resident plaice in 7d in 2021 if plaice was under landing obligation in 2021 (ICES catches 2021 minus discards from exempted fleets).

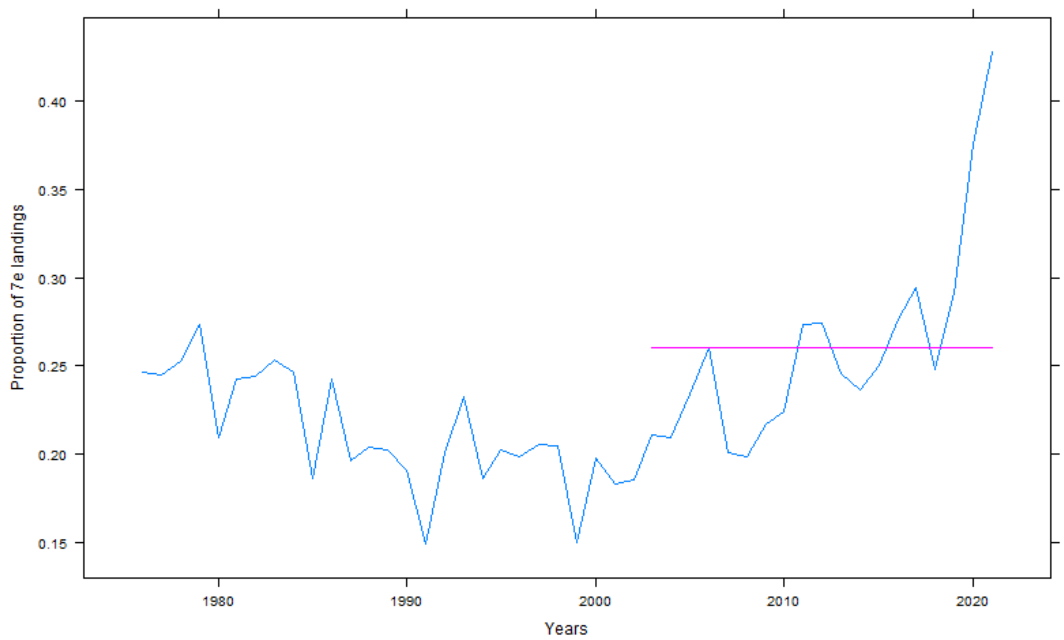


Figure 14.5.2.2. The average official plaice landing proportion between 7.e and 7.d.e over the period 2003–2021.

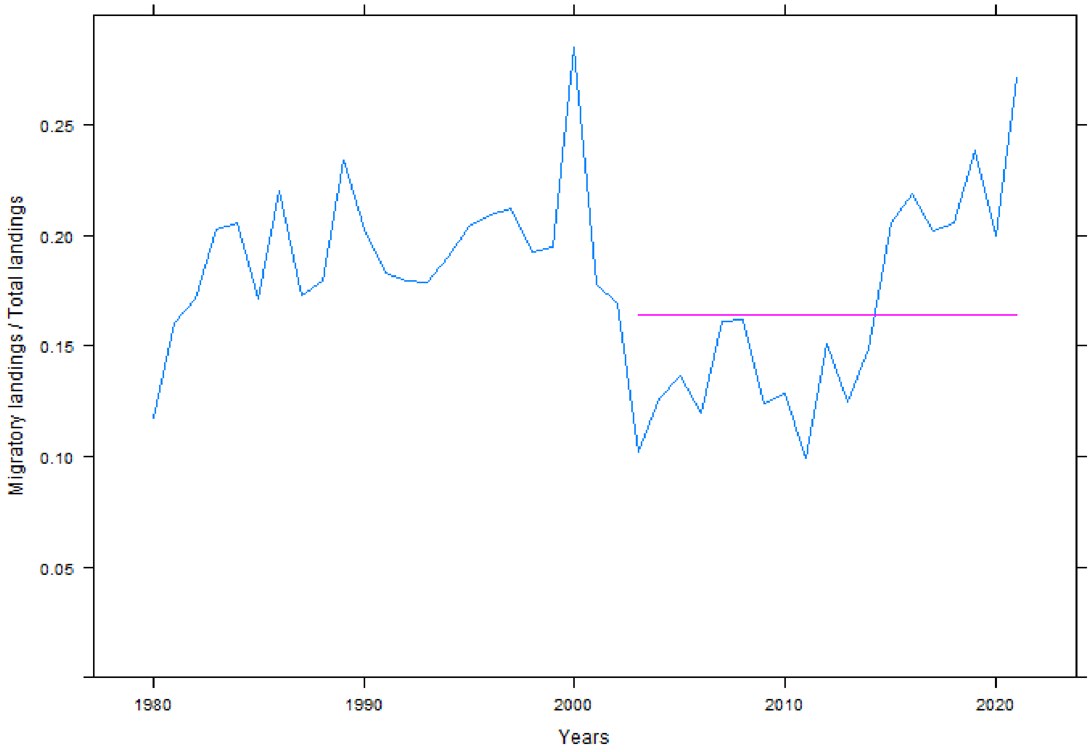


Figure 14.5.2.3. The Q1 removal ratio over the period 2003-2021 to account for migration of mature individuals of plaice from the 7.e and 4.c during Q1

15 Pollack (*Pollachius pollachius*) in Subarea 4 and Division 3.a (North Sea and Skagerrak)

15.1 General Biology

The existing knowledge of pollack biology is summarised in the Stock Annex. According to this information it is benthopelagic, and is found down to 200 m. In Skagerrak, 0-group pollack are regularly found in shallow areas close to the shore. Pollack are therefore protected from the fisheries in the early life stages. Pollack move gradually away from the coast into deeper waters as they grow.

Spawning takes place from January to May, depending on the area, and mostly at 100 m depth. FAO reports maximum length at 130 cm and maximum weight at 18.1 kg. Female length-at-maturity is estimated at >35 cm, at 3–4 years of age and growth after age 3 is about 7 cm per year (Heino *et al.*, 2012). Pollack feeds mainly on fish, and incidentally on crustaceans and cephalopods.

15.2 Stock identity and possible assessment areas

WGNEW (ICES, 2012) proposed, based on a pragmatic approach, to distinguish three different stock units: the southern European Atlantic shelf (Bay of Biscay and Iberian Peninsula), the Celtic Seas, and the North Sea (including 7.d and 3.a). In the ICES advice, it was, however, decided to include 7.d Pollack in the Celtic Seas Ecoregion.

15.3 Management

For 4 and 3.a there are no formal TACs for pollack, but catches of pollack should be counted against the quota for some other species when caught in Norwegian waters south of 62°N. There is a Minimum Landing Size of 30 cm in European Member States (Council Regulation (EU) 850/1998). No explicit objective has been defined, no precautionary reference points have been proposed, and there is no management plan. Analytical assessments leading to fisheries advice have never been carried out for pollack.

15.4 Fisheries data

Landings statistics for pollack are available from ICES, but are clearly incomplete in earlier years. From 1977, the data series appears to be reasonably consistent and adequate for allocating catches at least to ICES subareas. Considering that pollack is not subject to TAC regulations, a major incentive for mis- or underreporting is not present and landings figures are thus probably reflecting main trends in landings in the different areas.

Landings by country for the years 1977–2020 in Division 3.a (Skagerrak/Kattegat) and Subarea 4 (North Sea) are shown in Table 15.1. Figure 15.1 shows total landings in Subarea 4 and Division 3.a from 1977–2020. Two periods with high landings can be seen, and generally the total landings for both areas have declined. In Division 3.a, landings have been low but stable since 2000, although the landings for 2021 were the lowest on record. In Subarea 4 landings fluctuated over the same period, but have now been increasing in the last five years. Swedish fishers targeted pollack from the 1940s until mid-1980s when landings sometimes amounted to over 1000 tonnes. From the 1980s, pollack started to decline severely and is today seldom caught in the Kattegat or along the Swedish Skagerrak coast.

Nowadays, no fishery is targeting pollack, and it is mainly, possibly exclusively, a bycatch in various commercial fisheries. Norwegian catches peak in the months of March and April, and this may be associated with spawning aggregations. In 2021, 45% of the total landings were caught with gillnet and 43% with otter trawls in Division 3.a. In Subarea 4, 20% of the total landings were made with gillnets and 69% with otter trawls. The geographical distribution of Norwegian otter trawl catches resembles those of the saithe fisheries, but the catches of pollack are much lower. Discards are now considered by ICES to be known to take place, although at a seemingly small rate, and discards were estimated at 6.7 tonnes in total between division 3a and subarea 4 in 2021 (see Table 15.2 for total catches and Table 15.3 for estimated discards). Discard numbers were raised for all nations. All discards were reported by bottom trawl fleets from Denmark. In 2021, below minimum size (BMS) landings and logbook reported discards were also reported to ICES for pollack. No BMS landings or logbook reported discards were reported in Intercatch whereas 44 kg of BMS landings were recorded in the preliminary official landings.

Pollack is also frequently caught in recreational fisheries. Regularly collected data about these catches are not available to the working group. Norwegian recreational fishing data collected in 2009 suggests that catches of pollack south of 62° north in the tourist fishery may range between 13–30 tonnes (Vølstad *et al.*, 2011).

15.5 Survey data / recruit series

For the time being, pollack is caught in the IBTS survey only in small numbers; however, in the Skagerrak-Kattegat the CPUE was much higher in the 1970s. They are distributed mainly over the northern North Sea (along the Norwegian Deep) and into the Skagerrak-Kattegat. Time series of abundance (average number per hour) in the IBTS are shown for Subarea 4 and Division 3.a separately, for quarter 1 (from 1983 onwards) and quarter 3 (from 1991 onwards) (Figure 15.2). The catches are small, and rather irregular, and no clear patterns emerge in 3 and 4.

15.5.1 Biological sampling

There has been some collection of length data in Subarea 4 and Division 3.a by Norway. Preliminary analysis of this data indicates that length ranges of pollack caught in gill net fisheries differ with mesh size and location. The majority of fish caught in western Norwegian fjords had a size range of 60–80 cm (Figure 15.3) compared to 50–70 cm in the Skagerrak (Figure 15.4).

15.5.2 Analysis of stock trends

In previous years the study by Cardinale *et al.* (2012), which analysed the spatial distribution and stock trends for the period 1906–2007, based on IBTS Q1 and commercial catches, was used to assess the stock for Division 3.a (Skagerrak and Kattegat) and it was found that there had a been large decline in stock size from approximately 1960 to 2000. However, during routine IBTS surveys in Subarea 4 and Subarea 3, pollack catches seem rather irregular and with no clear pattern. A spatial analysis of Norwegian fisheries data from 2013, showing total Pollack catches by ICES rectangle, indicates that the surveys do not cover the geographic distribution of the species adequately in both Subarea 4 and Division 3.a (Figures 15.5 and 15.6). The surveys may therefore not be very well suited for monitoring this species as trends in standardised CPUE likely are not a reliable indicator for the status of the stock. However, if the stock increases, it is arguably expected that present trawl surveys (e.g. IBTS) would be able to detect such a stock trend in a consistent manner (Cardinale *et al.*, 2012).

15.6 Living Issues List

15.6.1 Data

In order to get a better understanding of growth and maturity, WGNEW recommended that the collection of otoliths and maturity should be continued during the IBTS surveys for a few years. WGNSSK recommends also that the Norwegian biological data, e.g. age readings of pollack otoliths, from commercial catches should be processed. An effort is underway to see if biological information from commercial catches, especially length information, is available from other countries, especially UK – Scotland, Denmark and Germany, and whether such data can be used to establish future reference points for this stock. Other surveys than IBTS should also be explored to evaluate their usefulness as potential indices for pollack stock size and/or recruitment. Potential candidates are, but not limited to, the annual shrimp survey taking place in the Norwegian trench in January, and the beach seine survey in the autumn along the Norwegian Skagerrak coast.

15.6.2 Assessment

No assessment model exists for pollack.

15.6.3 Forecast

There is no forecast for pollack.

15.7 References

Cardinale, M., H. Svedäng, V. Bartolino, L. Maiorano, M. Casini and H. Linderholm, 2012. Spatial and temporal depletion of haddock and pollack during the last century in the Kattegat-Skagerrak. J. Appl. Ichthyol. 28(2): 200-208

Council Regulation (EU) No 850/1998. Conservation of fishery resources through technical measures for the protection of juveniles of marine organisms.

ICES 2012. Report of the Working Group on the assessment of new MoU species (WGNEW). ICES CM 2012/ACOM:20. 258 pp.

Heino, M., Svåsand, T., Nordeide, J. T., Otterå, H., 2012. Seasonal dynamics of growth and mortality suggest contrasting population structure and ecology for cod, pollack, and saithe in a Norwegian fjord. – ICES Journal of Marine Science 69: 537–546

Vølstad, J. H., Korsbrekke, K., Nedreaas, K. H., Nilsen, M., Nilsson, G. N., Pennington, M., Subbey, S.,Wienerroither, R., 2011. Probability-based surveying using self-sampling to estimate catch and effort in Norway's coastal tourist fishery. ICES Journal of Marine Science. 68: 1785–1791

Table 15.1. Pollack in Subarea 4 and Division 3.a. Landings (tonnes) by country as officially reported to ICES 1977–2021.

	ICES Division 3.a							
	Belgium	Denmark	Germany	Netherl.	Norway	Sweden	UK	Official Total
1977	10	1764	4	3	449	706		2936
1978	1	2077	4		556	794		3432
1979	13	1898	<0.5		824	1066		3801
1980	13	1860			987	1584	<0.5	4444
1981	5	1661			839	1187	1	3693
1982	1	1272			575	417	<0.5	2265
1983	2	972			438	288		1700
1984	2	930	<0.5		371	276		1579
1985	-	824	<0.5		350	356		1530
1986	4	759	<0.5		374	271		1408
1987	6	665			342	246		1259
1988	4	494			350	136		984
1989	3	554			313	152		1022
1990	8	1842	<0.5		246	253		2349
1991	2	1824			324	281		2431
1992	8	1228			391	320		1947
1993	6	1130	1		364	442		1943
1994	5	645	<0.5		276	238		1164
1995	10	497			322	271		1100
1996		680			309	273		1262
1997		364	<0.5		302	178		844
1998		299			330	105		734
1999		192			342	88		622
2000		199			268	33		500
2001		201	1		253	46		501
2002		228	3		202	44		477
2003		168	3	1	236	17		425
2004		140	2	4	179	34		359
2005		160	5	7	173	153		498
2006		103	10	3	178	36		330
2007		172	9		245	38		464
2008		166	5		247	33		451
2009		208	7		220	38		473
2010		313	8	1	195	35		552
2011		193	7		168	28		395
2012		200	7		171	37		414
2013		210	3		172	35		420
2014		191	5	1	156	30		383

ICES Division 3.a							
	Belgium	Denmark	Germany	Netherl.	Norway	Sweden	UK	Official Total
2015		190	14	1	138	48		390
2016		151	8	1	134	47		341
2017		185	7	4	117	44		357
2018		226	10	1	105	64		406
2019		196	5	1	81	30		313
2020		163	5	18	47	17		251*
2021		131	2	1	40	17		192*

*** Preliminary**

ICES Subarea 4											
	Belgium	Denmark	Faeroes	France	Germany	Netherl.	Norway	Poland	Sweden	UK	Total
1977	121	275		75	142	38	419	9	0	442	1521
1978	102	249		98	154	21	492	2	0	471	1589
1979	62	333		72	64	8	563	11	31	429	1573
1980	82	407		66	58	2	1095		38	355	2103
1981	59	500		173	21	2	1261		12	362	2390
1982	46	431		59	40	1	1169	33	23	270	2072
1983	58	481		79	44	1	1081		57	300	2101
1984	52	402		108	37	0	880	2	106	315	1902
1985	14	308		69	23	0	686		51	363	1514
1986	44	550		45	21	0	602		67	362	1691
1987	21	427		988	21	0	471		40	290	2258
1988	32	432		367	30	10	560		20	296	1747
1989	31	273		0	21	4	568		37	269	1203
1990	44	924		0	34	3	651		126	366	2148
1991	31	1464		0	48	4	887		153	684	3271
1992	49	794		18	59	7	1051		141	1310	3429
1993	46	1161		8	161	19	1429		217	1561	4602
1994	42	635		12	55	14	845		113	872	2588
1995	56	532	1	7	84	18	1203		175	1525	3601
1996	13	366		4	99	13	909		82	945	2431
1997	20	272	1	1	115	11	733		82	1185	2420
1998	21	265		7	44	5	567		75	780	1764
1999	21	288		0	62	5	768		72	636	1852
2000	45	291		24	38	5	880		91	877	2251
2001	36	156		6	40	1	860		63	809	1971
2002	27	234		6	112	0	879		68	711	2037
2003	13	191		9	82	1	971		36	837	2140
2004	28	162		5	57	0	517		16	612	1397

ICES Subarea 4											
	Belgium	**Denmark**	**Faeroes**	**France**	**Germany**	**Netherl.**	**Norway**	**Poland**	**Sweden**	**UK**	**Total**
2005	26	173		3	128	3	511		46	477	1367
2006	18	152		4	80	1	545		12	587	1399
2007	18	192		130	137	2	754		43	905	2181
2008	15	150		129	114	1	840		46	999	2294
2009	13	121	2	6	50	1	668		32	658	1551
2010	12	163		10	129	0	599		32	540	1485
2011	12	106	0	10	67	0	580	0	35	489	1299
2012	17	123	0	3	102	1	433		42	443	1164
2013	17	128	0	2	66	4	371	0	29	463	1080
2014	24	121		32	145	1	476		40	377	1215
2015	20	183		3	237	3	473		50	627	1594
2016	21	127		2	107	2	447		37	430	1174
2017	18	187		8	269	3	510		44	511	1551
2018	14	139		23	154	2	739		30	486	1588
2019	20	184		23	159	6	893		38	556	1879
2020	22	241		20	262	9	1128		71	619	2373*
2021	15	136		60	178	8	637		75		1492*

*** Preliminary**

Table 15.2. Pollack in Subarea 4 and Division 3.a. Catches (tonnes) by country as estimated by the Working Group 2013–2021.

ICES Division 3.a									
	2013	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
Denmark	214	192	192	152	187	229	196	163	138
Germany	11	6	35	7	11	13	5	5	2
Netherlands	<0.5	0	0	1	5	2	1	18	1
Norway	174	156	138	135	117	108	81	48	40
Sweden	36	30	46	47	43	64	30	17	17
ICES Total	435	384	413	343	363	415	307	251	199
Official Total	420	383	389	338	357	406	314*	251*	192*
Diff ICES-Off	15	1	24	5	6	9	-6	0	7

*** Preliminary**

ICES Subarea 4									
	2013	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
Belgium	17	24	20	21	18	14	20	22	14
Denmark	150	122	183	127	187	139	184	241	136
France	2	32	2	2	8	46	24	20	61
Germany	59	145	216	107	267	151	159	262	179
Netherland.	3	1	2	2	2	2	4	8	7
Norway	379	481	466	440	508	738	901	1129	636
Sweden	29	41	50	36	44	30	38	71	75
UK	456	377	626	423	508	488	569	621	382
Ices Total	1103	1227	1567	1159	1543	1608	1899**	2374	1492
Official Total	1080	1215	1594	1174	1551	1588	1881*	2373*	1492*
Diff ICES-Off	23	12	-27	-15	-8	20	18	1	0

*** Preliminary**

****Swedish catches for Subarea 4 were added manually to the data after exporting the data from Intercatch.**

Table 15.3. Pollack in Subarea 4 and Division 3.a. Discards (tonnes) by country estimated by the Working Group, 2013–2021.

ICES Division 3.a								
	Belgium	**Denmark**	**Germany**	**Netherl.**	**Norway**	**Sweden**	**UK**	**Total**
2013		1.949	0.139		1.795	1.528		5.41
2014		0.62	0.008		0.441	0.473		1.54
2015		2.026	0.385		0.667	0.094		3.17
2016		1.436	0.021	0.002	1.706	1.685		4.85
2017		1.152	0.047	0.001	0.892	0.237		2.32
2018		2.39				0.28		2.67
2019			0.856					0.86
2020		0.72	0.025		0.26	0.122		1.13
2021		6.67						6.67

ICES Subarea 4											
	Belgium	**Denmark**	**Faeroes**	**France**	**Germany**	**Netherl.**	**Norway**	**Poland**	**Sweden**	**UK**	**Total**
2013	0.111	22.785		0.050	0.229	1.320	7.967		0.662	8.923	42.05
2014	0.181	0.973		0.241	0.154	0.009	5.200		0.309	4.461	12.16
2015		0.069		0.005	0.075	0.001	0.691		0.090	1.59	2.52
2016	<0.001	0.109		0.001	0.073	<0.001	0.357		0.021	0.278	0.84
2017											0
2018		0.026		22.49							22.47
2019		0.341		1.65							1.99
2020	0.057	0.022		0.0138	0.023	0.009	0.55		0.048	0.70	1.42
2021											0

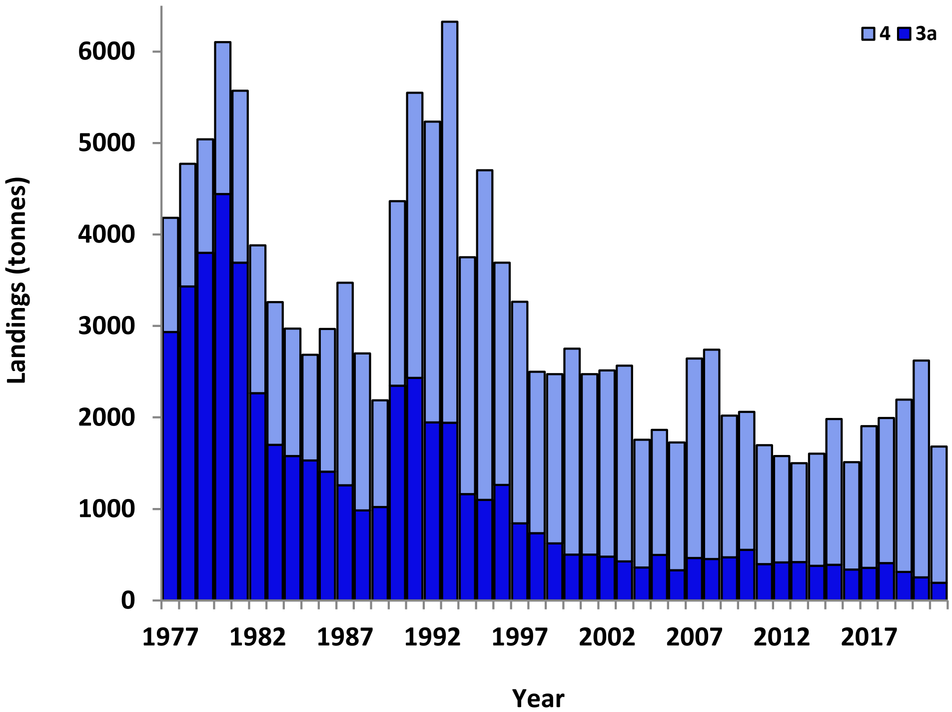


Figure 15.1. Pollack. Total landings of pollack from 1977–2021 in Division 3.a and Subarea 4 as officially reported to ICES.

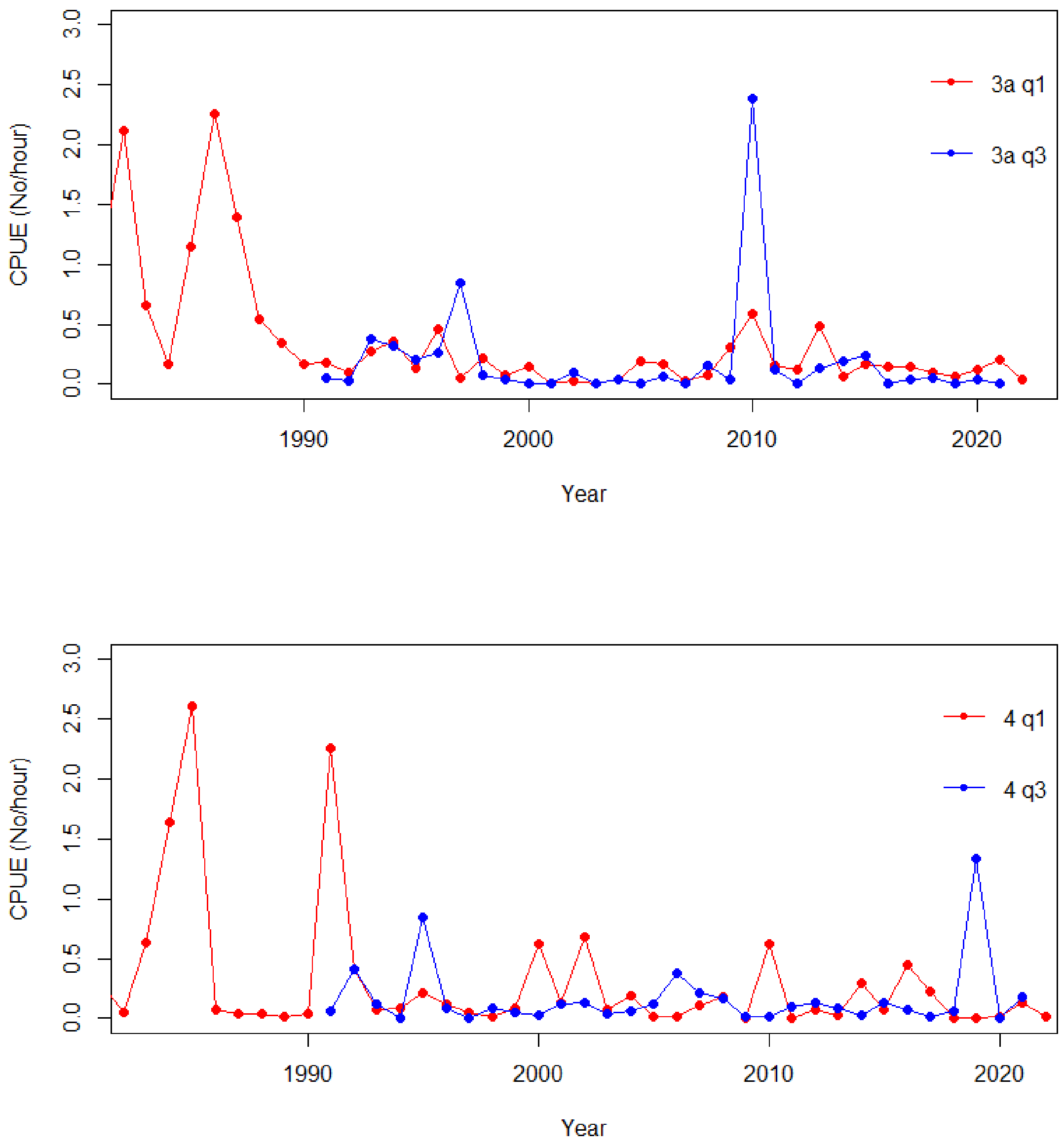


Figure 15.2. Time series of catches of pollack in ICES Division 3.a (top graph) and Subarea 4 (bottom graph) for 1983–2022 in the Q1 (red) and for 1991–2021 in Q3 (blue) IBTS surveys, shown as numbers caught per hour with the GOV-trawl. Data from DATRAS.

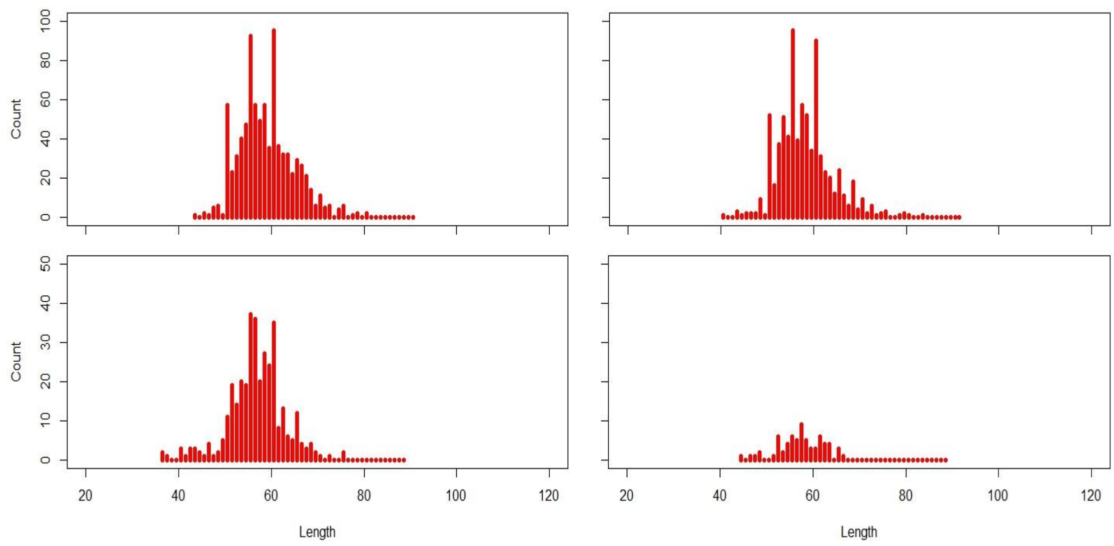


Figure 15.3 Length distributions of pollack sampled by the Norwegian reference fleet in the years 2010 (top left panel), 2011 (top right panel), 2012 (bottom left panel) and 2013 (bottom right panel), Area 3.a. The data is aggregated for gillnets with a 63 mm mesh size.

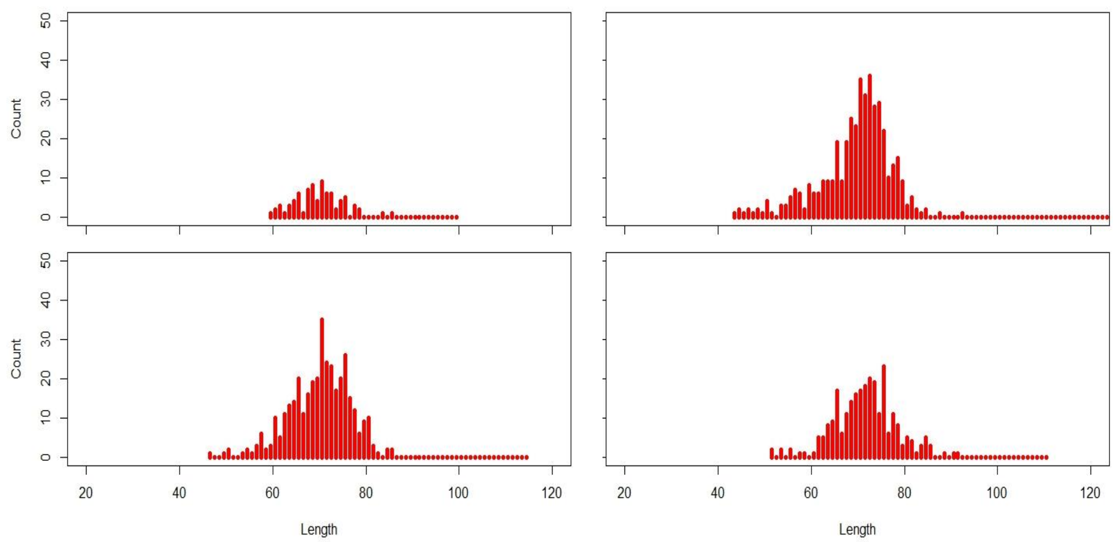


Figure 15.4 Length distributions of pollack sampled by the Norwegian reference fleet in the years 2010 (top left panel), 2011 (top right panel), 2012 (bottom left panel) and 2013 (bottom right panel), Area 4. The data is aggregated for gillnets with a 70 mm mesh size.

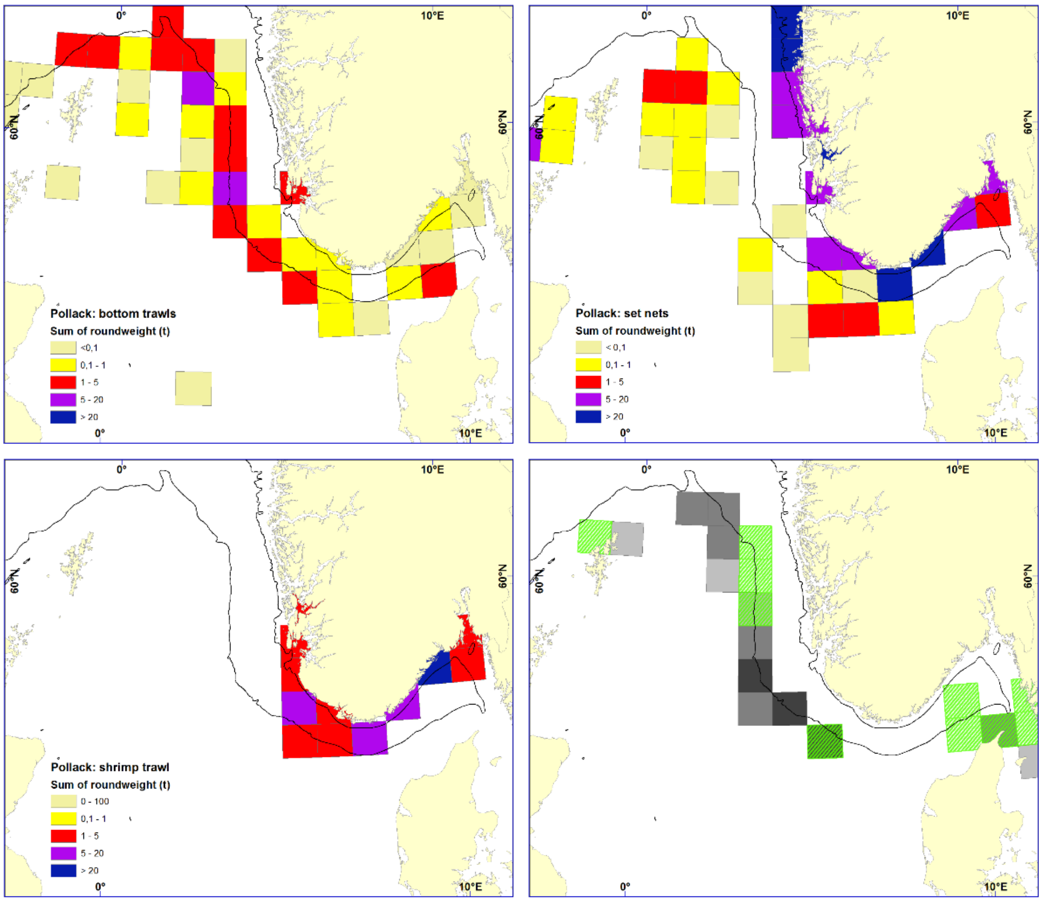


Figure 15.5 Distribution of total pollack catches (Norwegian landings) for 2013 aggregated by fishing gear (bottom trawls, set nets, shrimp trawls), and pollack catches from IBTS surveys in 2012 (grey) and 2013 (green).

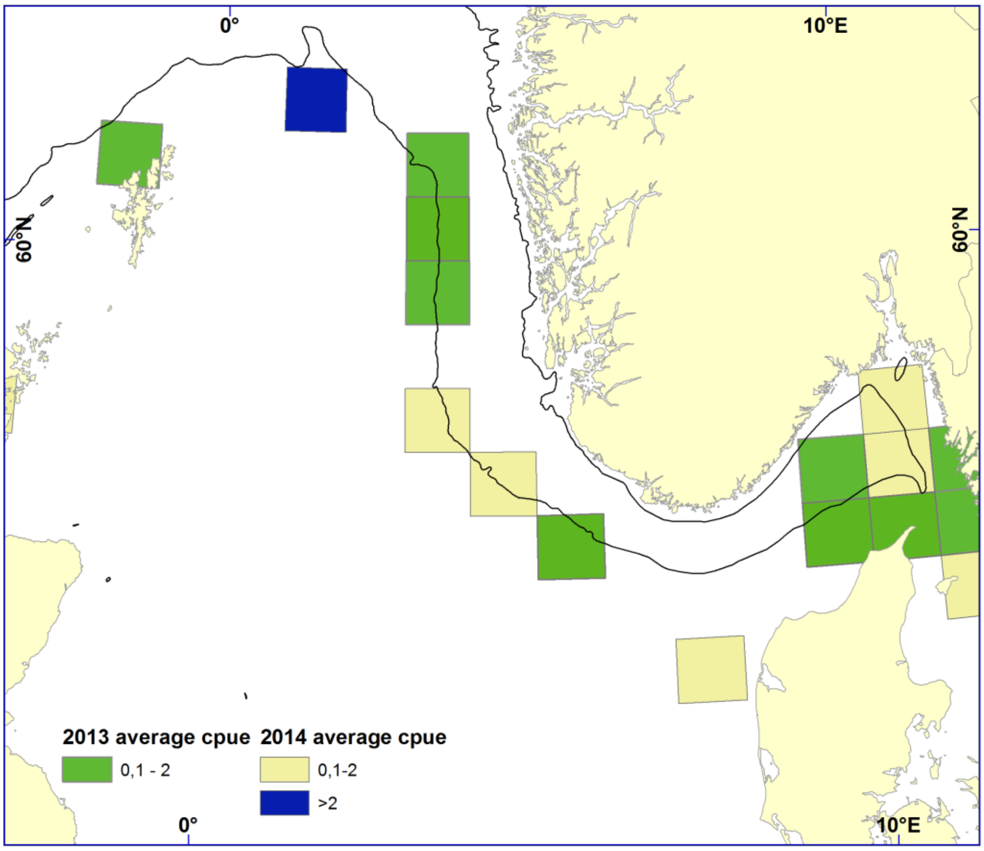


Figure 15.6 Pollack catches from IBTS surveys in 2013 (green) and 2014 (yellow, blue).

16 Saithe (*Pollachius virens*) in Subarea 4, 6 and Division 3.a (North Sea, Rockall, West of Scotland, Skagerrak and Kattegat)

The assessment of saithe in Division 3.a and subareas 4 and 6 follows the protocol defined during the inter-benchmark in January 2019, which revised errors in the assessment code that existed from 2016–2018 and triggered a revised advice for 2018 (published 22 February 2019). With the code error corrected, the model produced lower biomass estimates in recent years, slightly different reference points, and a lower recommended TAC, which explain part of the retrospective pattern observed in the advice prior to 2018. Additional mistakes found by WGNSSK in 2021 triggered a revision of some reference points and further update of the Stock Annex (ICES 2021a).

16.1 General

16.1.1 Stock definition

A summary of available information on stock definition can be found in the Stock Annex.

16.1.2 Ecosystem aspects

No new information on ecosystem aspects was presented at WGNSSK in 2022. A summary of available information, prepared during WKBENCH 2011 (ICES WKBENCH, 2011), can be found in the Stock Annex.

16.1.3 Fisheries

A general description of the fishery (along with its historical development) is presented in the Stock Annex.

Saithe are taken mainly in the trawler fisheries by Norway, Germany, and France. Changes in the fishing pattern of these three fleets began in 2009, but all fleets had largely reverted to their original fishing patterns by 2011 (see Stock Annex for years 2000–2015). For the German and Norwegian fleets, the original fishing pattern is mainly along the shelf edge in Subarea 4 and Division 3.a, while French fleets fish along the northern shelf and west of Scotland (subareas 4 and 6). But in 2017, there appeared to be minimal overlap in the areas fished by the three nations.

The German fleet has been restructured during the last 5 years, and two new vessels entered the fleet while older vessels were taken out. Although the new vessels have very similar characteristics to the old vessels, this change could have an impact on the CPUE index (see Section 16.3.5). However, CPUE index calculations with and without the two new vessels were very similar. The French fishery is currently at capacity for processing the catch at the vessel; this fishery cannot increase their catches.

The Scottish fleets catch a large amount of saithe in subareas 4 and 6, a large part of which is then discarded due to lack of quota. Discarding continued in 2021 in areas 4 and 3.a despite a full landing obligation in place. In area 6, fisheries targeting saithe were under the landing obligation. Discards can also be high in a few Danish and Swedish fisheries in the Skagerrak because these fleets do not have sufficient quota allocations.

In 2021, part of the Norwegian TR1 fleet relocated north of 62°N, because of the low North Sea saithe quota and perceived large bycatch of cod (while quota was very low as well) on usual fishing grounds. Feedback from the industry is that those boats do not intend to fish their North Sea saithe quota in 2022 either.

16.1.4 ICES Advice

The information in this section is taken from the 2021 Advice sheet.

Advice for 2022

"ICES advises that when the MSY approach is applied, catches in 2022 should be no more than 49 614 *tonnes."*

The agreed TAC (trilateral agreement) was in line with the ICES advice.

16.2 Management

Changes to the stock assessment and reference points during the benchmark in 2016 and the interbenchmark in 2019, further corrected during WGNSSK 2021 (ICES, 2021), imply a need to re-evaluate the EU-Norway management strategy to ascertain if it can still be considered precautionary under the new stock perception. Until such an evaluation is conducted, advice will be given according to the ICES MSY approach.

16.3 Data available

16.3.1 Catch

Official landings for each country participating in the fishery, together with the corresponding WG estimates and the agreed international quota ("total allowable catch" or TAC) and ICES estimated discards and BMS landings are presented in Table 16.3.1. No resubmission of earlier data to Intercach occurred, and only 2021 estimates were appended.

In 2021, official landings and ICES estimates were close in both 3.a-4 and 6. ICES estimates correspond to the sum of products (SOP) uploaded to Intercatch and present a reasonable match for overall catch (101.9%).

In 2021, 75% of discards were imported to Intercatch while 25% were raised (Table 16.3.2). Discard observations were not available for some of the fleets landing larger amounts of saithe (Figure 16.3.1). This is mainly the case for the Norwegian fleets. While Norway has a landings obligation policy for all métiers and in all areas, discarding is not monitored and discard information is not collected; therefore, discards for the Norwegian, French, and German trawler fleets (TR1) were raised using provided discard information from the French and German trawler fleets (i.e., targeted saithe fisheries; quarterly stratification). Discards in the trawler fleets (TR1) from other countries were matched for raising by quarter and area (4/6 and 3.a were distinguished). Because of lack of sampling data in 2021, likely linked to the Covid-19 situation, all seasons were raised together for all other métiers (all countries) in areas 4 and 6 together. For other métiers in area 3, discards were still matched per quarter. Information on discarding from Scottish métiers were not included when raising discards for active gears from other countries because rates were typically high.

The complete time series of catch, landings, and discards as used in the assessment is summarized in Table 16.3.3 and illustrated in Figure 16.3.2. Catch has been relatively stable from 1990 through 2008 and then declined slightly. The WG estimates of saithe discards (as a proportion of total catch) has remained relatively constant since 2003. Discard estimates were lowest for the period when the saithe trawler fleet changed its exploitation pattern (2009–2011). Prior to 2002, discards were estimated using a constant age-specific discarding rate (see ICES, 2016b). High discards, particularly in 2016, were due to reported discarding by Scottish fisheries.

Targeted saithe fisheries were covered by the EU Landing Obligation since 2016. Since 2018 saithe is under the landing obligation in all fleets in areas 4 and 3.a. Very few BMS landings and no logbook reported discards were reported into InterCatch in since 2018 (Table 16.3.2). Sampled and estimated discard rates as well, show a steady reduction after 2018.

16.3.2 Age compositions

International catch data were collated and catch-at-age were generated using InterCatch. Age composition in the landings was based on samples, provided by Denmark, France, Scotland, Germany, Ireland, and Norway, which accounted for 62% of the total landings in 2021 (Table 16.3.4; Figure 16.3.3), down from ≥90% in the years before 2020. This was mostly due to the French OTB_DEF_>=120_0_0 stratum (reported without selectivity device suffix) not being sampled in 2020 and 2021, unlike previous years, and is likely due to the Covid-19 situation. Although this may induce some noise, it is not believed to impair substantially the quality of the assessment. Many fleets do not provide samples for the landings, but these do not usually contribute to a large proportion of the catch. However, the number of samples taken, especially in the targeted trawl fisheries, is an issue (see ICES, 2016b). Stratification for age compositions was by quarter and area for the unsampled landings, as described in ICES (2016b). For 2021, however, age composition of landings in area 6 were matched to all seasons due to lack of sufficient seasonal data. The seasonal partition is prioritized because the fleets, particularly the target trawl fishery, are targeting the spawning fish in the first two quarters, while a wider range of age classes are captured in the latter part of the year. Smaller and younger fish are generally found in Division 3.a.

96 percent of the provided discards were sampled for age distributions in 2021 (Table 16.3.4). All age information from discards were from Denmark and Scotland (Figure 16.3.4) which also have by far the largest amounts of discards. While the proportion of discards sampled for age distribution was high (Table 16.3.4), the number of age samples per metier is often low (ICES, 2016b). Due to a very uneven spatial and temporal coverage, especially poor in area 3 and 6, catch-at-age information was estimated for areas 3 and 6 based on all information available (all areas and seasons together), and for area 4 for all seasons together. This is however believed not to be a critical issue for the quality of assessment as discards are typically low. Catch-at-age for the BMS landings was generated from the discards age information.

Total catch-at-age data are given in Table 16.3.5, while catch-at-age data for each catch component are given in Tables 16.3.6 and 16.3.7. Age 3 fish make up a smaller portion of the landings in recent years (Figure 16.3.5). The last strong year class in the catch appears to be the 2009 year-class as seen in the discards in 2012 at age 3 and landings in 2013 at age 4. A slightly stronger year class appears to be entering the discards at age 3 in 2016 and at age 4 in the landings in 2017. Weak cohorts entering the fisheries at age 3 resulted in respective low discards from 2018 onwards.

16.3.3 Weight-at-age

Weight-at-age from the catch, landing and discard components for ages 3–10+ are presented in tables 16.3.8–16.3.10 and Figure 16.3.6. Catch weights are also used as stock weights in the assessment. There was a decreasing trend in mean weight for ages 6 and older, but that has stopped or been reversed after 2008 (Figure 16.3.6). Weights-at-age for ages 3–5 have been relatively stable, with some variation, over the last decade. The noisy weights-at-age for discards of older age classes during the last decade, reflect a lack of data due to minor discard rates, and should therefore trigger no concern.

16.3.4 Maturity and natural mortality

The following maturity ogive, revised during the 2016 benchmark, is used for all years (see Stock Annex for details):

Age	1	2	3	4	5	6	7	8+
Proportion mature	0.0	0.0	0.0	0.2	0.65	0.84	0.97	1.0

A natural mortality rate of 0.2 is used for all ages and years.

16.3.5 Catch per unit effort and research vessel data

Indices used in the final assessment are included in Table 16.3.11. Data for the Norwegian, French, and German commercial trawler fleets were combined into one standardized CPUE index (integrating Year, Quarter, Nation, Power and Area effects, without interactions), which is then tuned to the exploitable biomass (see Stock Annex for details). One fisheries-independent survey index was included for tuning of the assessment; the survey is the IBTS quarter 3, ages 3–8, 1992–2021 ("IBTS-Q3").

The IBTS index (DATRAS product), exhibited in 2021 a substantial drop for age classes 3-7, when compared to 2020 (Table 16.3.11).

The CPUE index, on the other hand, exhibited, in 2021, a stabilisation (very slight decline) after several years of steep decline (Figure 16.3.7). Although the model was still performing decently, it showed once again signs of strains on assumptions, such as the absence of Year:Nation or Year:Area interactions. The inability of the model to account for spatial-temporal interactions, in particular, leads to strong residual patterns in space, fluctuating through time (Figure 16.3.8) which are in breach of the modelling assumptions regarding residuals independence and may lead to biases. A leave-one-nation-out analysis (Figure 16.3.9) shows a good consistency in the trends exhibited by data from different countries across the series, except for a few years. The downwards trends in the last years of the series, in particular, is consistently captured by all three fleets until 2020, although with different magnitudes. Between 2020 and 2021 an increase of CPUEs from low levels were detected in the French fleet while they decreased for the German vessels and were nearly stable for the Norwegian ones. The observed variations among countries is likely linked to differences in spatial coverage among fleets. In 2021, for instance, France was the only of the three countries fishing west of Scotland.

Inspection of the commercial CPUE model assumptions and consideration of alternative modelling approaches have consequently been kept on the list of issues for the next benchmark, with explicit mention to spatial-temporal modelling.

16.4 Data analyses

16.4.1 Exploratory survey-based analyses

Numbers-at-age for saithe ages 3 to 8 (IBTS–Q3) on the log–scale, linked by cohort, showed year effects (for example, low values around 2010) (Figure 16.4.1, top-left panel). The ability to track cohorts has been diminished in later years of the survey (post-2000) (Figure 16.4.1, top right panel). The survey catch-numbers correlate poorly between cohorts for ages 3 and 4, but are stronger for subsequent ages (Figures 16.4.1, top-right panel, and 16.4.2). This is likely because age 3 fish are not consistently fully represented in the survey ("hook" patterns at age 3 in the abundances of some cohort: Figure 16.4.1, bottom-left); fish begin migrating out of the inshore nursery areas at age 3, but do not fully recruit to the more oceanic population (and fishery) until after age 5.

A high degree of uncertainty in the IBTS–Q3 index has been commented on previously (ICES 2016b), especially in terms of the influence of single samples that may influence the overall index, or lack of sampling of un-trawlable areas on the northern part of the shelf where dense aggregations are common. Despite this, the index is still currently used in the assessment, although the assessment places more weight on the CPUE index (estimated observation variance 0.1 vs. 0.7 for the IBTS index; also highlighted by the leave-one-out analyses in former years; see Section 16.4.4). IBTS–Q3 indices used in the final assessment are in Table 16.3.11.

16.4.2 Exploratory catch-at-age-based analyses

The outcome of WKNSEA 2016 was to remove the 3 CPUE series for the targeted trawl fisheries, partially due to concerns over using information in the catch-at-age matrix in both the CPUE and in the catch-at-age and because more weight was given to 3 indices within the former assessment model (artificially giving higher weighting to the CPUE indices). A standardized combined CPUE index was created for the French, German, and Norwegian trawl fleet targeting saithe, which was then tuned to the exploitable biomass, removing the need to use the information in the catch-at-age matrix twice (see ICES (2016b) for details).

The fit of the CPUE to the exploitable biomass shows limited ability to render annual variations between 2010–2016, but then reflects well the index increase again in 2017 as well as the substantial decline in the following years (Figure 16.4.3). In addition to changes in resource abundance, the CPUE index may also reflect changes in the spatial distribution of the effort and/or resource, as well as a possible drift in fishing strategy and experience, which are not accounted for in the model and may in turn contribute to the weaker fit over some periods.

16.4.3 Assessments

The assessment of North Sea saithe was carried out using a state-space stock assessment model (SAM; Nielsen and Berg 2014; Berg and Nielsen 2016). The assessment was an update assessment. Settings used in the final assessment are given in Table 16.4.1.

16.4.4 Final assessment

Estimated fishing mortality-at-age are given in Table 16.4.2 and Figure 16.4.4. F for age 3 has declined drastically from 1990 and is now close to 0.1, while F for the older age classes has also decreased slightly until 2016. The change in F at age 3 occurred when the catches in the purse seine fishery declined. Age 4 moreover shows a declining trend in relative catchability in recent years (Figure 16.4.4, right panel). For ages 5+, catchability shows a dome shaped pattern, with highest catchability for age 6 in recent years. With the lower fishing mortalities up to 2016, fish have been allowed to increase in size (and age) and are likely targeted more than the younger age classes up to age 4 (as observed in Figure 16.4.4). Fishing mortality, after 2016, has however increased again for age classes 4+, followed by a decrease in 2020–2021 (more pronounced for older ages). Recruitment was also very low from 2018 to 2021. Estimated population numbers-at-age are in Table 16.4.3.

The survey index at age fits are shown in Figure 16.4.5. While accounting for the correlation between ages within years, the IBTS–Q3 residuals show little patterns (one-step ahead residuals, Figure 16.4.6). A slight trend however appears: the DATRAS series reveals rather positive residuals for ages 4–7 in the last years, while the CPUE residuals are dominated by overestimations over the same period. This is likely due to conflicting signals borne by both sources of information. The strength of the correlation between survey residuals is strong between subsequent ages for all ages (Figure 16.4.7). Process residuals (Figure 16.4.8) do not exhibit obvious trends, except maybe for F at age 9-10 in the last ten years.

The retrospective analysis shows a retrospective pattern for SSB and F while recruitment is well estimated for the last 5 years (Figure 16.4.9). Although SSB tends to be overestimated and F to be underestimated, the peels for SSB all fall within the confidence intervals of the most recent assessment. For F, however, the last two out of five peels fall out of the confidence interval of the whole series, which may be due to the persistent mismatch of signals carried by the CPUE and survey indices in previous years. Overall, the retro becomes better over the three most recent years. Mohn's rho, estimated using the last 5 years, is 0.083 for SSB, -0.110 for F, and -0.057 for recruitment, all within acceptable limits.

The leave-one out and final assessment results are in Figures 16.4.10 and 16.5.1 respectively. Unlike previous assessment years, the two series yield very similar final year's trends in the present assessment for SSB and F. The runs without the CPUE series even depict a slightly more pessimistic scenario than without the IBTS index, which contrasts with former years. This is likely du to the severe drop of the IBTS-Q3 index in 2021 for most age-classes. Recruitment estimates, as usual, are little affected by the choice of data series and mostly exhibit slightly less optimistic estimates in "good recruitment years" when leaving the IBTS series out.

16.5 Historic stock trends

The historic stock and fishery trends from the final assessment are presented in Figure 16.5.1 and Table 16.5.1. Because of the inter-benchmark in January 2019, the historic perception of the stock has changed. Recruitment has been low and highly variable since 1990. Both 2015 and 2016 show slightly higher recruitment than the average of the last ten years, while 2018-2021 were the lowest estimates for the whole time series. SSB, has fluctuated around 195 000 tonnes in the 2010s, which is below the average of the 2000s (around 235 000 tonnes). Short term variations show a decline since 2017. The final year estimate of SSB is just below B_{pa} and MSY $B_{trigger}$, while survivors from 2021 amount for an SSB in 2022 even slightly lower (not dependent on recruitment forecast assumption as the proportion mature at age 3 is null) but still above B_{lim}. Fishing mortality has generally declined since the mid–1980s but has exhibited a distinct raise from 2016 to 2019. It has since decreased again and is now estimated to be just above F_{MSY} but well below F_{pa}.

16.6 Recruitment estimates

Currently, no independent survey provides an estimate of incoming recruitment. The resampling among 2012–2021 values (with a geometric mean about 66 million individuals) used in the short-term forecast is a conservative assumption taking into account recent low recruitment, although still optimistic while considering the recruitments estimated over the previous four years only (between 31 and 53 million individuals for 2018–2021).

16.7 Short-term forecasts

16.7.1 Short-term forecast

A short-term forecast was carried out based on the final assessment.

Weight-at-age in the stock and catch were the mean values for the last 3 years. The exploitation pattern (selectivity pattern) was chosen as the mean exploitation pattern over the last three years scaled to $F_{4\text{–}7}$ in 2021. The fishing mortality in the intermediate year was based on a TAC 2022 constraint (49 614 t; https://ec.europa.eu/oceans-and-fisheries/system/files/2021-12/2022-EU-NO-UK-Agreed-Records.pdf). A F *status quo* assumption, as used in the former years, would have led to an unrealistic (see Figure 16.3.2 and feedback from the industry, section 16.1.3) 7 000 tonnes TAC overshoot. Population numbers-at-age for ages 4 and older in 2022 were survivor estimates, while numbers at age 3 were resampled from the past 10 years (2012–2021). The short-term projection was run in SAM.

The intermediate year assumptions for the short-term forecast are given in Table 16.7.1. Given the options above results in an F_{2022} of 0.34 and an SSB in 2023 of 141 805 tonnes, below MSY $B_{trigger}$ (149 098 tonnes), but in the rise compared to 2022 (127 092 tonnes forecasted in 2021; 137 451 tonnes estimated in the current assessment). Reference points and their technical basis are in Table 16.7.2.

The management options are given in Table 16.7.3. Because reference points were re-estimated during the last inter-benchmark and Brexit, the management plan for this shared stock (EU, Norway and the UK – as of early 2021) is no longer in use (a new EU-Norway-UK management plan is under discussion); therefore, the MSY approach is used as the basis for advice. The total catch in 2023 is advised to be no more than 58 912 tonnes, where landings are 56 645 tonnes; this is a 18.7% increase when compared to the advised total catch in 2022. This is due to the expected moderate increase of SSB in 2023 which entails (i) larger catch at a given F and (ii) a less penalised F target than for 2022 following the standard advice rule (SSB < $B_{trigger}$). More catch options can be found in Table 16.7.3.

The contribution of the 2014–2020 year-classes to landings in 2023 are shown in Table 16.7.4. The 2018-2020 year-classes are expected to contribute the most to the landings in numbers, while landings weights should be dominated by the year-classes 2017-2019. The weaker 2015 year-class is expected to contribute substantially less. Recruitment at age 3 in 2023 is not expected to contribute greatly to the catches in 2023; rather, ages 4–6 are the main contributors (over 60% of projected landings for 2023). This is clearly seen in the catch-at-age (Figure 16.3.5) and F at age (Figure 16.4.4).

16.8 Medium-term and long-term forecasts

No medium-term or long-term forecasts were carried out.

16.9 Quality and benchmark planning

16.9.1 Quality of the assessment and forecast

Many of the issues noted after the benchmark and last years' assessment still hold.

The commercial CPUE indices may introduce biases into the assessment if changes in fishing patterns occur. Factors, such as vessel experience and fishing behaviour, likely contribute to the variability in CPUE for all fleets, but these factors are not captured in the CPUE model.

The scientific survey used in the assessment does not cover the whole stock distribution; however, it is considered generally representative. The number of observations (trawl stations) where saithe is caught is low, and can be influenced by occasional large catches. The resulting survey index is uncertain.

Conflicting signals between the survey and fishable biomass index contributes to the assessment uncertainty and a retrospective pattern observed.

The fraction of fish at age 3 migrating into the survey area (and the fishery) is low and varying between years with no obvious trend. Observations of saithe at age 3 are not suitable for predicting year class strength. This means that estimated recruitment values in the final assessment year are highly uncertain. Estimates of recruitment for a given year class tend to be revised considerably with successive assessments.

16.9.2 Issues for future benchmark

16.9.2.1 Data

Stock definition

The North Sea saithe stock is influenced by migrations to and from the North Sea. This can potentially lead to the observed year effects in survey indices. It needs to be analyzed if the inclusion of spawning grounds north of 62°N could improve the assessment. An intended tagging study (IMR) may help inform on this issue, although results would most probably not be available by the next benchmark.

New survey indices

IMR-Norway has set-up a new hydro-acoustic survey targeting spawning aggregations in Quarter 1. Germany has also participated in this survey in recent years. The inclusion of this survey in the assessment should be evaluated once a sufficiently long time series has been developed.

The inclusion of the summer acoustic series (Noracu – IMR), dropped from the assessment in 2016 on account of now addressed inconsistencies, should also be re-evaluated.

Obsolescence of DATRAS products

The phasing out of IBTS DATRAS indices (Q3 used in the current assessment), together with future phasing in of a new IBTS trawl (ICES 2022), entails consideration of alternative index modelling approaches, such as the popular delta-GAM approach, in case IBTS series were to be kept in the assessment (to be evaluated too).

Catch-per-effort index

The current commercial CPUE index is standardized for fleet, area, quarter and engine power effects. The explanatory variables included should be reviewed (e.g. examine need for a vessel random effect) and alternative modelling approaches evaluated. The model in its current formulation cannot account for different dynamics in space (Figure 16.3.8). The prospect to include spatial-temporal interactions in the model should therefore also be evaluated. Furthermore, different countries seem to report data with different levels of aggregation (although this is difficult to formally investigate, given the sensitive nature of the commercial data). Weighting of observations (*e.g.*, based on effort) could therefore be additionally considered, and the associated risks of bias (or absence thereof) evaluated.

Maturity ogive

A constant over time maturity ogive is currently used in the assessment and exploration of recent data indicates possible deviations from this ogive. The assumption should be re-evaluated, especially in the light of improved sampling during the spawning season (Q1 acoustic survey).

Recreational catches

Although not expected to be important within the North Sea, the magnitude of recreational saithe catches should be formally investigated to inform the assessment quality. In the context of uncertain geographical stock limits, the NS saithe dynamics might, for instance, be influenced by comparatively more important recreational fisheries in the Norwegian Sea.

16.9.2.2 Assessment

Variance by age

The last inter-benchmark for saithe in 2019 revealed that uncoupling of the variance parameters for the observations by age (i.e. age 3 receiving a separate parameter) could improve the model fit statistics (e.g. log-likelihood, AIC). This should be investigated further.

16.9.2.3 Forecast and reference points

Forecast

The SAM forecast assumption for recruitment is based on resampling from historical recruitment values from a defined number of historical years. Depending on the time-series, this may result in a bimodal distribution for the assumed recruitment in forecasted years. Forecasted numbers (and SSB) are likely to be smoother in their distribution due to forecast stochasticity, but the effect of this behaviour on advice should be investigated further. Use of a geometric mean of historical recruitment is not currently possible in SAM, but could be suggested in order to reduce this effect. Adequacy and implementability of recruitment forecasted as a random effect with autocorrelation (RW, AR1,…), should also be evaluated.

The setting of a random seed value is important for comparing between forecast scenarios. Forecast scenarios involving a prescribed F had consistent median recruitment; however, scenarios that solve for an F that results in a given stock size (e.g. $SSB_{(2022)} = B_{pa}$ or B_{lim} scenarios), which involve a further iteration process with additional random number generation, resulted in different median recruitment values. This is a reporting issue that arise from instability of the median value resampled from an even number of values (while a reported geometric mean would be more stable, and often more informative). It does not affect the quality of the assessment, only the consistency of reported figures. We have therefore made the choice, since the 2020 assessment, to report the geometric mean of resampled recruitments values in the forecast assumption (not to be mistaken for the use of a geometric mean in the forecast).

Reference points

The effect of the current low productivity regime of the stock (i.e. lower recruitment) on reference points should be investigated.

16.10 Status of the stock

Fishing pressure on the stock is above F_{MSY} but below F_{pa} and F_{lim}; spawning-stock size is below MSY $B_{trigger}$ and between B_{pa} and B_{lim}.

16.11 Management considerations

The assessment is sensitive to relatively small changes in the input data. Because this stock suffers from 'poor data', the assessment is relatively uncertain. Recruitment is currently at a low level and it appears that strong recruitment pulses are more sporadic than in the past.

The reported landings have been relatively stable since the early 1990s – with the exception of the last two years, when a drastic reduction occurred. Landings have been lower than the TAC in most years since 2002, despite consecutive reductions in the TAC.

Information from fishers' survey (Napier, 2014) has been moved to the Stock Annex.

Bycatch of other demersal fish species does occur in the target trawl fishery for saithe. Saithe is also taken as unintentional bycatch in other fisheries, and discards do occur.

16.11.1 Evaluation of the management plan

Because reference points were re-estimated after the inter-benchmark, the management plan is no longer valid. New EU/Norway management strategies have been proposed and evaluated (ICES, 2019b).

16.12 References

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ICES. 2022. IBTS working group report (draft)

Table 16.3.1. Saithe in subareas 4 and 6 and Division 3.a. Official nominal landings (tonnes) of saithe by nation, 2005–2021. ICES estimates are landings reported to ICES and the Working Group.

	Subarea 4 and Division 3.a															
Country	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020***	**2021***
Belgium	15	18	7	27	15	2	2	3	5	6	16	15	14	6	5	11
Denmark	7471	5443	8068	8802	8018	6331	5171	5695	4913	4512	4084	5690	7017	5275	3777	2947
Faroe Isl.	60	15	108	841	146	2	8	3	1	0	18	16	4	14	28	0
France	16953	15083	15881	7203	4582*	13856*	14093*	8475	7910	11574	10794	10334	12598	11361	9487	9146
Germany	14397	12791	14140	13410	11193	10234	8052	9690	8602	7954	6279	7943	7952	7055	6853	4444
Greenland	924	564	888	927	0	0	0	0	0	0	0	0	0	0	0	0
Ireland	0	0	0	1	0	0	0	0	0	0	0	0	0	<1	4	0
Lithuania	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0
Netherlands	28	5	3	16	3	24	34	168	43	75	112	191	267	178	181	140
Norway	61318	45396	61464	57708	52712	46809	33288	35701	37519	35631	31596	49580	38787	50306	39630	20442
Poland	1084	1384	1407	988	654	584	0	0	0	0	0	0	0	0	0	0
Portugal	228	68											0	0	0	0
Russia	2	5	5	13	0	0	0	0	0	0	0	0	0	0	0	0
Sweden	1746	1381	1639	1363	1545	1335	1306	1402	1329	1156	1198	1186	1316	1413	1181	1001
UK (E/W/NI)	9128**	9625**	11804**	12584**	11887**	10250**	7287**	10379**	687	8888**	8561**	8640**	12575**	11868**	8557**	8037**
UK (Scotland)									7686							
Total reported	113354	91778	115414	103883	90755	89427	69241	71516	68695	69796	62658	83594	80531	87476	69705	46168
Unallocated	−1509	824	57	2090	6012	2101	1623	−110	677	−393	-154	−2024	1335	173	153	779
BMS landings												< 1	11	20	10	4
ICES estimate	111845	92602	115471	105973	96767	91528	70864	71406	69372	69403	62504#	81570#	81866#	87649#	69858#	46947#
TAC	123250	135900	135900	125934	107000	93600	79320	91220	77536	66006	65696	100287ǂ	105793ǂ	93614	79813	59512

*** Official values are preliminary.**
**** Scotland+E/W/NI combined.**
ǂ Includes top-up (4.1% in 2017, 12.57% in 2018)
 # Since 2016, landings includes the Norwegian component of BMS landings.

	Subarea 6															
Country	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020***	**2021***
Denmark	0	0	0	0	0	0	0	0	20	0	0	5	1	7	0	0
Faroe Islands	76	32	23	60	24	5	6	25	29	3	7	13	21	7	3	2
France	6092	4327	4170	2102	2008	2357	2612	3814	2904	3484	2299	3968	3626	1336	1263	1314
Germany	532	580	148	298	257	0	9	0	0	0	9	< 1	<1	0	0	1
Ireland	267	322	288	407	520	359	364	313	128	105	185	171	231	109*	125	72
Netherlands	3	36	1	0	0	0	0	0	0	6	12	3	100	4	< 1	3
Norway	28	377	78	68	121	240	5	715	442	677	555	633	955	478	1	0
Poland																1
Russia	7	2	50	4	2	0	0	0	9	1	0	2	0	2	0	0
Spain	6	3	4	8	18	31	13	21	9	15	15	4	7	24	15	38
Sweden	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
UK (E/W/NI)	2748**	1424**	2955**	3491**	3168**	4500**	4549**	3646**	97	3286**	2770**	2652**	2764**	2824**	2666**	2001**
UK (Scotland)									3191							
Total reported	9759	7103	7717	6438	6118	7492	7558	8534	6829	7577	5852	7453	7706	4791	4074	3432
Unallocated	−1191	−501	−1005	−144	145	−575	−9	119	191	−43	−279	−337	-1065	84	7	102
BMS landings												0	31	< 1	< 1	<1
ICES estimate	8568	6602	6712	6294	6263	6917	7549	8653	7020	7534	5573 ǂ	7116 ǂ	6641 ǂ	4875#	4081#	3534#
TAC	12787	14100	14100	13066	11000	9570	8230	9464	8045	6848	6816	10404 ǂǂ	10215ǂǂ	9713	8280	6175

*** Official values are preliminary.**

**** Scotland+E/W/NI combined.**

ǂ Does not include BMS landings.

ǂǂ Includes top-up (4.1% in 2017, 4.76% in 2018).

	Subareas 4 and 6 and Division 3.a															
	2006	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
ICES estimate	121320	99204	122184	112267	103030	98446	78414	80059	76392	76936	68709 #	88686 #	88507 #	92524 #	73938 #	50482#
TAC	136037	150000	150000	139000	118000	103170	87550	100684	85581	72854	72512	110691 ǂǂ	116008 ǂǂ	103327	88093 ǂǂ	65687

ǂǂ Agreed upon TAC including landings top-up.

 # Since 2016, landings includes Norwegian component of BMS landings.

Table 16.3.2. Saithe in subareas 4 and 6 and Division 3.a. Catch data (2021; all ages, not the sum over products for ages 3–10+ used in the assessment) imported into InterCatch and proportion of sampling strata for discards raised within InterCatch.

		2021	
Catch Category	Raised or Imported	Weight (tonnes)	Proportion
BMS landing	Imported data	0.37	100
Discards	Imported data	699	75
Discards	Raised discards	235	25
Landings	Imported data	49550	100
Logbook registered discard	Imported data	0	0

Table 16.3.3. Saithe in subareas 4 and 6 and Division 3.a. Working Group estimates of catch components by weight (t) for ages 3–10+, as used in the assessment. Norway was under landings obligations since 1988, but records are unclear whether saithe was fully in the landings obligation from that time.

Year	Catches	Landings	BMS Landings	Discards	Proportion discards
1967	101331	88339		12992	13
1968	134559	113741		20818	15
1969	150293	130580		19713	13
1970	270829	235012		35817	13
1971	309177	265356		43821	14
1972	296481	261914		34567	12
1973	275164	242513		32651	12
1974	337021	298347		38674	11
1975	304645	271610		33035	11
1976	423347	343898		79449	19
1977	239913	216393		23520	10
1978	176851	155124		21727	12
1979	142647	128352		14295	10
1980	145289	131897		13392	9
1981	148244	132273		15971	11
1982	202111	174336		27775	14
1983	203018	180040		22978	11
1984	240566	200843		39723	17
1985	273672	220870		52802	19
1986	232795	198605		34190	15
1987	192380	167503		24877	13
1988	154252	135176		19076	12
1989	124599	108892		15707	13
1990	124450	103831		20619	17
1991	130973	108071		22902	17
1992	115537	99745		15792	14
1993	132618	111499		21119	16

Year	Catches	Landings	BMS Landings	Discards	Proportion discards
1994	126759	109621		17138	14
1995	141190	121795		19395	14
1996	128896	114968		13928	11
1997	120103	107348		12755	11
1998	117222	106126		11096	9
1999	119467	110531		8936	7
2000	93795	85781		8014	9
2001	102859	91741		11118	11
2002	129847	110911		18936	15
2003	121656	110282		11374	9
2004	113792	107356		6436	6
2005	121217	118625		2592	2
2006	128711	120414		8297	6
2007	106333	94958		11375	11
2008	129887	121618		8269	6
2009	114520	110972		3548	3
2010	104723	102128		2595	2
2011	102006	98034		3972	4
2012	87049	78144		8905	10
2013	87271	79859		7412	8
2014	82172	76057		6115	7
2015	81445	76748		4697	6
2016	77672	67620#	0	10052##	13
2017	94581.5	88010#	0.5	6571##	7
2018	95447	88328#	42	7076##	7
2019^	96634	92390#	19.85	4224##	4
2020	76820	73791	10	3019##	4
2021	50951	50124	0.4	827##	1.9

 # Since 2016, landings include the Norwegian component of BMS landings.

Since 2016, discards minus BMS landings from EU fleets officially reported in logbooks.

^ Includes 937 tonnes of missing Swedish landings and corresponding 109 tonnes of discards (based on discard rate estimated in division 4.a).

Table 16.3.4. Saithe in subareas 4 and 6 and Division 3.a. Amount (weight and proportion) of sampled or estimated age distributions of catch data (2021) imported or raised in InterCatch. Weight in tonnes corresponds to the catch in tonnes imported for all ages, and not to the SOP used in the assessment for ages 3–10+).

Catch Category	Raised or Imported	Sampled or Estimated	2021	
			Weight	Proportion
Logbook Registered Discard	Imported_Data	Estimated_Distribution	0	0
Landings	Imported_Data	Sampled_Distribution	30936	62
Landings	Imported_Data	Estimated_Distribution	18613	38
Discards	Imported_Data	Sampled_Distribution	669	72
Discards	Raised_Discards	Estimated_Distribution	235	25
Discards	Imported_Data	Estimated_Distribution	30	3
BMS landing	Imported_Data	Sampled_Distribution	0	0
BMS landing	Imported_Data	Estimated_Distribution	0.37	100

Table 16.3.5. Saithe in subareas 4 and 6 and Division 3.a. Catch numbers (thousands) at age for the age range used in the assessment.

Year/Age	3	4	5	6	7	8	9	10+
1967	26948	19395	16672	2358	1610	299	203	185
1968	36111	25387	14153	6166	433	247	127	147
1969	47014	21142	11869	7790	5795	810	642	151
1970	57920	91668	16102	12416	3932	1834	326	270
1971	108549	69105	35143	4848	4290	2910	1922	782
1972	74755	79033	27178	21711	3709	3014	1682	1625
1973	84484	45078	28822	16443	8511	2047	1391	2407
1974	104086	40345	15160	21179	14810	5321	1514	1977
1975	88613	30927	11077	7746	13792	9577	3591	2717
1976	323156	63447	12556	6401	4016	5488	3678	3528
1977	42701	65727	15839	5620	3814	3528	3909	4753
1978	54515	32608	19389	3390	1149	1057	788	3522
1979	25395	16999	12004	8906	2833	750	554	2112
1980	27203	14757	9677	6878	5714	1177	522	2327
1981	40705	9971	7235	3763	3368	3475	674	2564
1982	49595	48533	9848	6120	2166	1489	1007	1268
1983	43916	24637	27924	5813	4942	1529	1062	1342
1984	125848	38470	13910	13320	1673	1281	344	653
1985	208401	66489	14257	4878	3034	698	409	750
1986	86198	109080	16302	5509	2629	1490	457	910
1987	48545	116551	15019	3233	1829	1269	933	707
1988	50657	31577	37919	3918	1927	1130	796	687
1989	34408	36772	14156	11211	1572	757	430	493
1990	63454	23416	12154	4826	2803	762	288	368
1991	71710	35719	8016	3669	1733	976	376	463

Year/Age	3	4	5	6	7	8	9	10+
1992	28617	40193	13691	3269	1539	712	531	426
1993	58813	24905	12715	3199	1583	1547	835	1037
1994	31034	48062	13992	4399	957	354	438	803
1995	41461	31130	15884	3864	3529	690	566	809
1996	17208	46468	12653	7915	3194	827	215	496
1997	23380	23077	32395	3763	2666	1036	299	292
1998	16113	37088	17570	16459	2253	1234	581	280
1999	14661	16588	28645	8588	10169	2401	914	665
2000	10985	20680	9597	12632	3190	3302	657	446
2001	24961	21100	24068	3429	3621	1814	1655	248
2002	17570	37489	14736	13731	2309	2544	1321	1575
2003	28296	31752	20631	6836	6855	1535	2000	2042
2004	13642	24479	15649	15220	2037	2164	1300	1066
2005	12690	15473	19060	20042	7956	1628	1188	1151
2006	17313	31972	10381	11286	8395	3824	1008	1281
2007	24614	13314	20919	7175	5564	3610	1218	930
2008	7620	30911	12540	14941	5088	3285	3551	3118
2009	7438	15507	14222	5847	8512	2994	1519	2945
2010	8766	9249	9440	6511	2671	4773	1679	2707
2011	12786	24269	8980	3674	2867	1208	1564	3877
2012	14334	13053	16948	4075	1977	1268	541	2611
2013	7267	30318	5312	7869	1890	1241	616	1658
2014	4055	14322	15195	3957	4124	1040	429	1389
2015	8369	8323	14259	8254	1862	1623	715	977
2016	7382	14241	9661	5729	2758	1430	853	1317
2017	4977	18989	9773	6247	5364	1876	820	1113
2018	2603	16250	18858	7376	2142	2027	978	1178
2019	6240	8570	14841	10394	2881	1127	1027	1236
2020	2511	11823	7627	7436	4246	967	381	627
2021	6129	6236	4910	2899	2924	1061	347	695

Table 16.3.6. Saithe in subareas 4 and 6 and Division 3.a. Landings numbers (thousands) at age for the age range used in the assessment.

Year/Age	3	4	5	6	7	8	9	10+
1967	17330	16220	15531	2303	1594	292	198	183
1968	23223	21231	13184	6023	429	242	123	145
1969	30235	17681	11057	7609	5738	791	626	150
1970	37249	76661	15000	12128	3894	1792	318	267
1971	69808	57792	32737	4736	4248	2843	1874	774
1972	48075	66095	25317	21207	3672	2944	1641	1607
1973	54332	37698	26849	16061	8428	2000	1357	2381
1974	66938	33740	14123	20688	14666	5199	1477	1955
1975	56987	25864	10319	7566	13657	9357	3501	2687
1976	207823	53060	11696	6253	3976	5362	3586	3490
1977	27461	54967	14755	5490	3777	3447	3812	4701
1978	35059	27269	18062	3312	1138	1033	768	3484
1979	16332	14216	11182	8699	2805	733	540	2089
1980	17494	12341	9015	6718	5658	1150	509	2302
1981	26178	8339	6739	3675	3335	3396	657	2536
1982	31895	40587	9174	5978	2145	1454	982	1254
1983	28242	20604	26013	5678	4893	1494	1036	1327
1984	80933	32172	12957	13011	1657	1252	335	646
1985	134024	55605	13281	4765	3005	682	399	742
1986	55435	91223	15186	5381	2603	1456	445	900
1987	31220	97470	13990	3158	1811	1240	910	700
1988	32578	26408	35323	3828	1908	1104	776	680
1989	22128	30752	13187	10951	1557	739	419	488
1990	40808	19583	11322	4714	2776	745	281	364
1991	46117	29871	7467	3583	1716	953	367	458
1992	18404	33614	12753	3193	1524	696	518	422
1993	37823	20828	11845	3125	1568	1511	814	1026
1994	19958	40193	13034	4297	947	346	427	794
1995	26664	26034	14797	3774	3494	674	552	800
1996	11066	38861	11786	7731	3163	808	210	491
1997	15036	19299	30177	3676	2640	1012	291	288
1998	10363	31017	16367	16077	2231	1206	567	277
1999	9429	13872	26684	8389	10070	2346	891	657
2000	7064	17295	8940	12339	3159	3226	641	441
2001	16052	17646	22421	3349	3586	1772	1614	245
2002	9131	31779	12286	13307	2245	2220	1199	1479
2003	13009	24646	20397	6836	6855	1535	2000	2042
2004	8037	20071	15649	15220	2037	2164	1300	1066
2005	9191	15473	19060	20042	7956	1628	1188	1151

Year/Age	3	4	5	6	7	8	9	10+
2006	12200	26690	9986	11286	8395	3824	1008	1281
2007	15181	10163	19157	7078	5564	3610	1218	930
2008	6924	23230	10930	14196	4977	3276	3551	3118
2009	6607	14349	13827	5817	8419	2978	1505	2934
2010	7880	8859	9174	6394	2670	4762	1679	2669
2011	10150	22799	8852	3630	2860	1183	1563	3869
2012	7029	11712	15572	4016	1971	1267	537	2610
2013	4999	25516	4974	7645	1886	1241	616	1658
2014	3099	12117	13380	3737	4047	1036	429	1388
2015	6206	7392	13555	8021	1844	1621	715	975
2016	3508	10374	8756	5156	2732	1423	852	1317
2017	3033	15139	8795	6179	5362	1876	820	1111
2018	2017	12994	16936	7043	2125	2016	976	1177
2019	5456	8125	13826	9797	2842	1116	1025	1235
2020	1997	10870	7243	7326	4113	959	377	619
2021	5693	6073	4859	2863	2924	1061	347	695

Table 16.3.7. Saithe in subareas 4 and 6 and Division 3.a. Discards numbers (thousands) at age for the age range used in the assessment.

Year/Age	3	4	5	6	7	8	9	10+
1967	9617	3175	1141	55	16	7	5	2
1968	12888	4156	969	143	4	6	3	2
1969	16779	3461	813	181	57	19	16	2
1970	20671	15007	1102	288	38	42	8	3
1971	38741	11313	2406	112	42	67	48	9
1972	26680	12938	1861	504	36	69	42	18
1973	30152	7380	1973	381	83	47	35	26
1974	37148	6605	1038	491	144	122	38	22
1975	31626	5063	758	180	135	220	89	30
1976	115333	10387	860	148	39	126	92	38
1977	15240	10760	1084	130	37	81	97	52
1978	19456	5338	1327	79	11	24	20	38
1979	9063	2783	822	207	28	17	14	23
1980	9709	2416	662	160	56	27	13	25
1981	14527	1632	495	87	33	80	17	28
1982	17700	7945	674	142	21	34	25	14
1983	15673	4033	1912	135	48	35	26	15
1984	44915	6298	952	309	16	29	9	7
1985	74378	10885	976	113	30	16	10	8
1986	30764	17857	1116	128	26	34	11	10

Year/Age	3	4	5	6	7	8	9	10+
1987	17326	19080	1028	75	18	29	23	8
1988	18079	5169	2596	91	19	26	20	7
1989	12280	6020	969	260	15	17	11	5
1990	22647	3833	832	112	27	18	7	4
1991	25593	5847	549	85	17	22	9	5
1992	10213	6580	937	76	15	16	13	5
1993	20990	4077	871	74	15	36	21	11
1994	11076	7868	958	102	9	8	11	9
1995	14797	5096	1087	90	34	16	14	9
1996	6141	7607	866	184	31	19	5	5
1997	8344	3778	2218	87	26	24	7	3
1998	5751	6072	1203	382	22	28	14	3
1999	5233	2716	1961	199	99	55	23	7
2000	3920	3386	657	293	31	76	16	5
2001	8908	3454	1648	80	35	42	41	3
2002	8439	5710	2451	425	64	324	121	96
2003	15288	7106	234	0	0	0	0	0
2004	5605	4407	0	0	0	0	0	0
2005	3498	0	0	0	0	0	0	0
2006	5114	5282	394	0	0	0	0	0
2007	9433	3152	1762	97	0	0	0	0
2008	696	7682	1610	745	111	9	0	0
2009	831	1158	395	30	93	16	14	11
2010	886	390	266	117	1	11	0	38
2011	2636	1470	129	44	7	25	1	8
2012	7305	1341	1377	58	7	1	4	1
2013	2268	4801	339	224	4	0	0	1
2014	955	2205	1816	220	77	4	0	1
2015	2163	931	704	232	17	3	0	2
2016	3874	3867	905	573	26	7	1	0
2017	1943	3850	978	69	2	0	0	2
2018	586	3256	1922	333	17	11	2	1
2019	785	445	1016	597	39	11	1	1
2020	514	953	383	110	133	8	4	8
2021	436	163	51	36	0	0	0	0

Table 16.3.8. Saithe in subareas 4 and 6 and Division 3.a. Catch weight-at-age (kg).

Year/Age	3	4	5	6	7	8	9	10+
1967	0.898	1.339	2.094	3.183	3.753	5.316	5.891	7.719
1968	1.234	1.624	1.979	3.007	4.039	4.428	6.136	7.406
1969	0.933	1.530	2.251	2.711	3.558	4.406	5.220	6.767
1970	0.908	1.416	2.049	2.716	3.599	4.463	5.687	6.845
1971	0.811	1.325	2.167	2.934	3.765	4.634	5.172	6.163
1972	0.780	1.175	1.952	2.367	3.793	4.228	4.630	6.326
1973	0.792	1.382	1.633	2.569	3.356	4.684	4.814	6.445
1974	0.831	1.534	2.372	2.751	3.428	4.498	5.713	7.857
1975	0.862	1.472	2.479	3.298	3.764	4.296	5.540	7.562
1976	0.678	1.287	2.250	3.068	4.034	4.383	5.112	7.147
1977	0.733	1.234	1.926	3.108	4.161	4.605	4.859	6.542
1978	0.793	1.304	2.145	3.338	4.521	4.900	5.449	7.400
1979	1.069	1.595	2.228	3.093	4.049	5.274	6.308	7.955
1980	0.921	1.790	2.380	3.028	4.089	5.126	5.939	8.148
1981	0.927	1.790	2.705	3.584	4.535	5.478	6.980	8.724
1982	1.048	1.548	2.518	3.218	4.206	5.125	5.905	8.823
1983	0.992	1.688	2.139	3.135	3.690	4.632	5.505	8.453
1984	0.767	1.586	2.286	2.688	3.895	4.665	6.183	8.474
1985	0.640	1.244	1.941	2.769	3.406	4.950	5.865	8.854
1986	0.670	1.018	1.786	2.430	3.571	4.209	5.651	8.218
1987	0.650	0.861	1.815	3.072	4.209	5.330	6.128	8.603
1988	0.752	0.964	1.379	2.789	4.023	5.254	6.322	8.649
1989	0.864	1.018	1.413	1.997	3.913	5.017	6.430	8.431
1990	0.815	1.175	1.575	2.245	3.241	4.858	6.315	8.416
1991	0.764	1.138	1.744	2.363	3.165	4.222	6.066	8.191
1992	0.930	1.169	1.599	2.240	3.667	4.330	5.412	7.045
1993	0.868	1.239	1.746	2.634	3.184	3.980	5.080	6.891
1994	0.911	1.100	1.594	2.432	3.617	4.787	6.548	8.326
1995	0.967	1.272	1.807	2.560	3.554	4.767	5.267	7.891
1996	0.933	1.167	1.798	2.366	2.951	4.705	6.092	8.382
1997	0.873	1.125	1.445	2.585	3.555	4.525	6.158	8.866
1998	0.861	0.949	1.386	1.743	2.948	3.883	4.996	7.227
1999	0.850	1.042	1.206	1.752	2.337	3.493	4.844	6.745
2000	0.992	1.107	1.532	1.683	2.593	3.084	4.773	7.461
2001	0.774	1.053	1.307	2.093	2.546	3.485	4.141	6.141
2002	0.776	1.014	1.495	1.791	2.961	3.761	4.638	5.750
2003	0.636	0.889	1.167	1.810	2.368	3.176	3.768	5.065
2004	0.794	1.010	1.392	1.896	2.860	3.687	4.814	7.059
2005	0.715	1.155	1.325	1.710	2.132	3.026	3.622	5.713

Year/Age	3	4	5	6	7	8	9	10+
2006	0.904	1.012	1.489	1.906	2.424	3.058	4.318	5.734
2007	0.769	1.124	1.286	1.834	2.328	2.887	3.600	4.975
2008	0.916	1.065	1.488	1.692	2.210	2.792	3.206	4.565
2009	1.033	1.333	1.672	1.994	2.566	3.086	3.651	4.790
2010	1.037	1.474	2.033	2.597	3.163	3.488	3.968	5.223
2011	0.955	1.192	1.787	2.571	3.068	3.418	3.718	4.289
2012	0.910	1.287	1.383	2.196	3.221	3.536	4.181	4.482
2013	0.878	1.132	1.586	1.957	3.076	3.841	4.541	5.648
2014	1.091	1.265	1.568	2.334	2.607	4.010	5.530	6.679
2015	0.951	1.253	1.621	2.180	3.037	3.793	4.228	7.285
2016	0.937	1.239	1.611	2.231	2.888	3.450	4.331	6.208
2017	0.956	1.228	1.755	2.356	2.987	4.232	4.473	6.287
2018	1.095	1.239	1.549	2.234	3.112	3.867	4.465	6.708
2019	1.133	1.442	1.809	2.320	3.081	3.897	4.677	6.613
2020	1.061	1.529	1.914	2.439	3.106	4.038	4.918	6.985
2021	1.043	1.413	1.899	2.365	2.984	4.038	5.179	6.852

Table 16.3.9. Saithe in subareas 4 and 6 and Division 3.a. Landings weight-at-age (kg).

Year/Age	3	4	5	6	7	8	9	10+
1967	0.931	1.362	2.104	3.186	3.754	5.316	5.891	7.719
1968	1.278	1.652	1.989	3.009	4.040	4.428	6.136	7.406
1969	0.966	1.557	2.261	2.713	3.559	4.406	5.220	6.768
1970	0.941	1.441	2.059	2.718	3.600	4.463	5.687	6.845
1971	0.840	1.348	2.178	2.936	3.766	4.634	5.173	6.163
1972	0.808	1.196	1.961	2.369	3.794	4.228	4.630	6.326
1973	0.821	1.406	1.641	2.571	3.357	4.684	4.814	6.445
1974	0.861	1.561	2.383	2.753	3.429	4.498	5.713	7.857
1975	0.893	1.498	2.490	3.300	3.765	4.296	5.540	7.562
1976	0.702	1.309	2.260	3.071	4.035	4.383	5.112	7.147
1977	0.760	1.256	1.935	3.111	4.162	4.605	4.859	6.542
1978	0.822	1.327	2.155	3.340	4.522	4.901	5.449	7.400
1979	1.107	1.623	2.238	3.095	4.050	5.274	6.308	7.955
1980	0.955	1.821	2.391	3.030	4.090	5.126	5.939	8.148
1981	0.961	1.821	2.718	3.587	4.536	5.478	6.980	8.724
1982	1.086	1.575	2.529	3.220	4.207	5.125	5.905	8.823
1983	1.028	1.718	2.149	3.138	3.691	4.632	5.505	8.453
1984	0.795	1.614	2.297	2.690	3.896	4.665	6.183	8.474
1985	0.663	1.265	1.951	2.772	3.407	4.950	5.865	8.854
1986	0.694	1.035	1.794	2.432	3.572	4.209	5.651	8.218
1987	0.674	0.876	1.824	3.075	4.210	5.330	6.128	8.603

Year/Age	3	4	5	6	7	8	9	10+
1988	0.779	0.981	1.386	2.791	4.024	5.254	6.322	8.649
1989	0.895	1.036	1.420	1.998	3.914	5.018	6.430	8.431
1990	0.844	1.196	1.583	2.247	3.242	4.858	6.315	8.416
1991	0.791	1.158	1.752	2.365	3.165	4.222	6.066	8.191
1992	0.964	1.189	1.607	2.242	3.668	4.330	5.413	7.046
1993	0.899	1.260	1.754	2.636	3.185	3.980	5.080	6.891
1994	0.944	1.119	1.601	2.434	3.618	4.787	6.548	8.326
1995	1.002	1.294	1.816	2.562	3.555	4.767	5.267	7.891
1996	0.967	1.187	1.807	2.368	2.952	4.705	6.092	8.382
1997	0.905	1.145	1.452	2.587	3.556	4.525	6.158	8.866
1998	0.892	0.966	1.393	1.744	2.949	3.883	4.996	7.227
1999	0.881	1.061	1.211	1.754	2.337	3.493	4.844	6.745
2000	1.027	1.127	1.539	1.684	2.594	3.084	4.773	7.462
2001	0.802	1.072	1.313	2.095	2.546	3.485	4.141	6.141
2002	0.923	1.035	1.478	1.769	2.947	3.426	4.407	5.674
2003	0.833	0.980	1.173	1.810	2.368	3.176	3.768	5.065
2004	0.918	1.084	1.392	1.896	2.860	3.687	4.814	7.059
2005	0.921	1.155	1.325	1.710	2.132	3.026	3.622	5.713
2006	0.945	1.069	1.514	1.906	2.424	3.058	4.318	5.734
2007	0.837	1.143	1.317	1.840	2.328	2.887	3.600	4.975
2008	0.944	1.193	1.565	1.720	2.226	2.795	3.206	4.565
2009	1.036	1.340	1.664	1.992	2.563	3.085	3.648	4.793
2010	1.036	1.479	2.034	2.597	3.164	3.488	3.968	5.199
2011	1.007	1.207	1.783	2.573	3.068	3.404	3.717	4.284
2012	1.015	1.321	1.408	2.201	3.223	3.536	4.177	4.482
2013	0.898	1.156	1.614	1.976	3.078	3.841	4.541	5.648
2014	1.126	1.300	1.607	2.384	2.617	4.013	5.530	6.679
2015	0.977	1.244	1.625	2.190	3.043	3.796	4.228	7.287
2016	0.998	1.292	1.628	2.283	2.892	3.453	4.333	6.208
2017	1.047	1.302	1.809	2.361	2.988	4.232	4.473	6.292
2018	1.153	1.287	1.575	2.266	3.107	3.868	4.463	6.707
2019	1.147	1.448	1.829	2.343	3.094	3.905	4.680	6.616
2020	1.066	1.542	1.938	2.447	3.132	4.043	4.912	6.984
2021	1.044	1.416	1.903	2.362	2.984	4.038	5.179	6.852

Table 16.3.10. Saithe in subareas 4 and 6 and Division 3.a. Discards weight-at-age (kg).

Year/Age	3	4	5	6	7	8	9	10+
1967	0.748	1.076	1.818	2.972	3.590	5.316	5.891	7.719
1968	1.028	1.306	1.719	2.808	3.864	4.428	6.136	7.406
1969	0.777	1.230	1.955	2.531	3.403	4.406	5.220	6.767
1970	0.757	1.139	1.780	2.536	3.442	4.463	5.687	6.845
1971	0.676	1.065	1.882	2.739	3.601	4.634	5.172	6.163
1972	0.650	0.945	1.695	2.210	3.628	4.228	4.630	6.326
1973	0.660	1.111	1.419	2.399	3.210	4.684	4.814	6.445
1974	0.692	1.233	2.060	2.568	3.279	4.498	5.713	7.857
1975	0.718	1.184	2.153	3.079	3.600	4.296	5.540	7.562
1976	0.565	1.035	1.954	2.865	3.858	4.383	5.112	7.147
1977	0.611	0.993	1.673	2.902	3.980	4.605	4.859	6.542
1978	0.661	1.049	1.862	3.116	4.325	4.900	5.449	7.400
1979	0.890	1.283	1.935	2.888	3.873	5.274	6.308	7.955
1980	0.768	1.439	2.067	2.827	3.911	5.126	5.939	8.148
1981	0.773	1.439	2.349	3.346	4.338	5.478	6.980	8.724
1982	0.873	1.245	2.186	3.004	4.023	5.125	5.905	8.823
1983	0.826	1.358	1.858	2.927	3.529	4.632	5.505	8.453
1984	0.639	1.276	1.985	2.510	3.726	4.665	6.183	8.474
1985	0.533	1.000	1.686	2.586	3.258	4.950	5.865	8.854
1986	0.558	0.818	1.551	2.269	3.416	4.209	5.651	8.218
1987	0.542	0.693	1.576	2.869	4.026	5.330	6.128	8.603
1988	0.626	0.775	1.198	2.604	3.848	5.254	6.322	8.649
1989	0.720	0.819	1.227	1.865	3.743	5.017	6.430	8.431
1990	0.679	0.945	1.368	2.097	3.100	4.858	6.315	8.416
1991	0.636	0.915	1.515	2.206	3.027	4.222	6.066	8.191
1992	0.775	0.940	1.389	2.092	3.508	4.330	5.412	7.045
1993	0.723	0.996	1.517	2.460	3.046	3.980	5.080	6.891
1994	0.759	0.884	1.384	2.271	3.459	4.787	6.548	8.326
1995	0.806	1.023	1.570	2.390	3.400	4.767	5.267	7.891
1996	0.778	0.938	1.562	2.209	2.823	4.705	6.092	8.382
1997	0.728	0.905	1.255	2.413	3.400	4.525	6.158	8.866
1998	0.717	0.764	1.204	1.627	2.820	3.883	4.996	7.227
1999	0.708	0.838	1.047	1.636	2.235	3.493	4.844	6.745
2000	0.826	0.890	1.330	1.571	2.480	3.084	4.773	7.461
2001	0.645	0.847	1.135	1.955	2.435	3.485	4.141	6.141
2002	0.616	0.896	1.580	2.483	3.469	6.058	6.935	6.927
2003	0.469	0.571	0.641	1.689	2.265	3.176	3.768	5.065
2004	0.617	0.676	1.203	1.769	2.735	3.687	4.814	7.059
2005	0.741	0.913	1.146	1.595	2.038	3.026	3.622	5.713

Year/Age	3	4	5	6	7	8	9	10+
2006	0.808	0.724	0.859	1.778	2.318	3.058	4.318	5.734
2007	0.660	1.062	0.949	1.365	2.227	2.887	3.600	4.975
2008	0.633	0.680	0.967	1.161	1.495	1.820	3.206	2.797
2009	1.010	1.253	1.946	2.403	2.838	3.388	3.934	3.911
2010	1.046	1.374	1.987	2.561	3.025	3.351	3.968	6.895
2011	0.756	0.971	2.054	2.445	3.170	4.072	4.369	6.618
2012	0.808	0.997	1.101	1.831	2.675	3.411	4.804	5.313
2013	0.835	1.003	1.180	1.300	2.298	3.841	4.541	5.861
2014	0.977	1.072	1.274	1.487	2.077	3.223	5.530	7.568
2015	0.877	1.326	1.531	1.848	2.410	2.184	4.228	5.911
2016	0.882	1.096	1.440	1.764	2.384	2.864	2.634	4.282
2017	0.815	0.937	1.269	1.907	2.484	4.232	4.473	2.817
2018	0.894	1.049	1.318	1.554	3.770	3.715	5.371	7.697
2019	1.033	1.336	1.537	1.932	2.162	2.991	2.816	2.969
2020	1.042	1.379	1.456	1.937	2.306	3.448	5.480	7.101
2021	1.025	1.305	1.466	2.583	2.984	4.038	5.179	6.852

Table 16.3.11. Saithe in subareas 4 and 6 and Division 3.a. Data available for calibration of the final assessment. Indices include one commercial standardized CPUE index (year effects), tuned to the exploitable biomass within SAM, and indices for age 3–8 from one research survey, the third quarter NS-IBTS.

Year	IBTS–Q3 (DATRAS standard index)						CPUE
	3	4	5	6	7	8	
1992	1.077	2.760	0.516	0.098	0.057	0.050	
1993	7.965	2.781	1.129	0.197	0.011	0.040	
1994	1.117	1.615	0.893	0.609	0.091	0.040	
1995	13.959	2.501	1.559	0.533	0.172	0.049	
1996	3.825	6.533	1.112	0.971	0.212	0.069	
1997	3.756	3.351	7.461	0.698	0.534	0.181	
1998	1.181	4.134	1.351	1.580	0.149	0.179	
1999	2.086	1.907	3.155	0.619	0.632	0.074	
2000	3.479	8.836	1.081	0.868	0.114	0.152	2.133
2001	21.475	6.169	3.936	0.356	0.444	0.113	2.156
2002	10.748	18.974	1.327	1.090	0.162	0.264	1.777
2003	19.272	23.802	13.402	0.393	0.439	0.168	1.647
2004	4.930	6.727	3.237	0.921	0.064	0.085	2.020
2005	8.916	7.512	4.428	1.914	1.082	0.104	2.140
2006	10.553	29.579	2.835	1.177	0.445	0.242	2.180
2007	34.006	5.578	11.700	1.016	0.743	0.358	1.882
2008	3.312	5.584	0.907	1.997	0.254	0.254	2.078
2009	1.346	1.703	0.568	0.101	0.229	0.200	1.720
2010	1.361	0.964	0.471	0.205	0.045	0.166	1.584
2011	4.520	8.451	1.059	1.114	0.426	0.080	1.658
2012	11.134	2.497	2.968	0.503	0.483	0.344	1.541
2013	14.701	16.279	1.830	1.858	0.308	0.146	1.646
2014	1.649	3.923	2.822	0.481	0.520	0.114	1.489
2015	11.001	5.613	4.611	1.581	0.289	0.285	1.774
2016	37.901	17.439	3.255	2.681	0.945	0.195	1.547
2017	11.447	13.102	3.068	1.267	0.942	0.473	1.786
2018	1.877	6.885	6.027	1.450	0.322	0.183	1.655
2019	2.143	3.189	3.071	0.999	0.194	0.077	1.309
2020	1.445	2.8	1.618	1.115	0.644	0.188	1.237
2021	0.599	0.609	0.73	0.555	0.389	0.17	1.197

Table 16.4.1. Saithe in subareas 4 and 6 and Division 3.a. Model configuration for the SAM assessment.

Min Age:

3

Max Age:

10

Max Age considered a plus group:

Yes

The following matrix describes the coupling of fishing mortality STATES, where rows represent fleets (catch, IBTSQ3 index, commercial CPUE index) and columns represent ages (-1 = not estimated):

```
 0  1  2  3  4  5  6  6
-1 -1 -1 -1 -1 -1 -1 -1
-1 -1 -1 -1 -1 -1 -1 -1
```

Use correlated random walks for the fishing mortalities: (2=AR1)

2

Coupling of catchability PARAMETERS

```
-1 -1 -1 -1 -1 -1 -1 -1
 0  1  2  3  4  5 -1 -1
 6 -1 -1 -1 -1 -1 -1 -1
```

Coupling of power law model EXPONENTS (if used)

```
-1 -1 -1 -1 -1 -1 -1 -1
-1 -1 -1 -1 -1 -1 -1 -1
-1 -1 -1 -1 -1 -1 -1 -1
```

Coupling of fishing mortality RW VARIANCES

```
 0  1  1  1  1  1  1  1
-1 -1 -1 -1 -1 -1 -1 -1
-1 -1 -1 -1 -1 -1 -1 -1
```

Coupling of log N RW VARIANCES

0 1 1 1 1 1 1 1

Coupling of OBSERVATION VARIANCES

```
 0  0  0  0  0  0  0  0
 1  1  1  1  1  1 -1 -1
 2 -1 -1 -1 -1 -1 -1 -1
```

Stock recruitment code (0 for plain random walk, 1 for Ricker, and 2 for Beverton-Holt)

0

Years in which catch data are to be scaled by an estimated parameter

0

Fbar range:

4 to 7

Observation correlation coupling (0 = uncorrelated). Rows represent fleets, columns represent adjacent age groups, i.e. the first column is the correlation between the first and 2nd age group. An NA in all non-empty age groups for a fleet specifies unstructured correlation. NA's and positive numbers cannot be mixed within fleets.

```
NA NA NA NA NA NA NA
NA NA NA NA NA -1 -1
NA -1 -1 -1 -1 -1 -1
```

Table 16.4.2. Saithe in subareas 4 and 6 and Division 3.a. Fishing mortalities at age for the final assessment model. F at age 9 and 10+ are coupled in the model (9+).

Year/Age	3	4	5	6	7	8	9+
1967	0.260	0.379	0.358	0.360	0.316	0.284	0.324
1968	0.236	0.341	0.302	0.285	0.242	0.217	0.252
1969	0.249	0.365	0.323	0.314	0.277	0.252	0.280
1970	0.301	0.417	0.352	0.329	0.281	0.250	0.267
1971	0.369	0.465	0.373	0.343	0.305	0.281	0.298
1972	0.450	0.520	0.397	0.363	0.327	0.304	0.310
1973	0.534	0.574	0.419	0.372	0.339	0.314	0.314
1974	0.654	0.668	0.488	0.429	0.393	0.360	0.345
1975	0.666	0.697	0.528	0.469	0.439	0.408	0.382
1976	0.768	0.785	0.608	0.529	0.483	0.442	0.402
1977	0.633	0.713	0.599	0.545	0.516	0.480	0.429
1978	0.509	0.584	0.489	0.437	0.415	0.388	0.349
1979	0.421	0.516	0.455	0.422	0.412	0.383	0.343
1980	0.404	0.511	0.475	0.455	0.455	0.432	0.389
1981	0.355	0.481	0.462	0.459	0.474	0.467	0.426
1982	0.427	0.573	0.547	0.523	0.516	0.491	0.440
1983	0.506	0.693	0.671	0.634	0.611	0.569	0.498
1984	0.592	0.798	0.727	0.630	0.561	0.503	0.437
1985	0.639	0.891	0.778	0.620	0.532	0.475	0.428
1986	0.586	0.920	0.833	0.651	0.558	0.507	0.478
1987	0.529	0.856	0.801	0.625	0.545	0.507	0.495
1988	0.517	0.836	0.809	0.642	0.562	0.521	0.510
1989	0.513	0.820	0.788	0.626	0.532	0.477	0.464
1990	0.506	0.798	0.757	0.588	0.492	0.428	0.415
1991	0.471	0.761	0.729	0.561	0.471	0.405	0.402
1992	0.413	0.707	0.709	0.561	0.478	0.407	0.408
1993	0.388	0.688	0.718	0.606	0.567	0.500	0.510
1994	0.317	0.603	0.636	0.538	0.518	0.464	0.485
1995	0.269	0.556	0.625	0.563	0.582	0.545	0.570
1996	0.212	0.466	0.554	0.515	0.527	0.500	0.518
1997	0.178	0.401	0.479	0.448	0.447	0.432	0.450
1998	0.178	0.397	0.485	0.460	0.446	0.436	0.451
1999	0.170	0.395	0.503	0.502	0.487	0.490	0.507
2000	0.147	0.345	0.437	0.434	0.399	0.393	0.408
2001	0.146	0.339	0.417	0.409	0.361	0.348	0.359
2002	0.154	0.352	0.448	0.470	0.422	0.409	0.433
2003	0.162	0.357	0.443	0.498	0.461	0.449	0.483
2004	0.137	0.310	0.376	0.427	0.400	0.395	0.422
2005	0.136	0.315	0.381	0.431	0.401	0.389	0.400

Year/Age	3	4	5	6	7	8	9+
2006	0.158	0.347	0.405	0.440	0.406	0.388	0.389
2007	0.152	0.347	0.399	0.414	0.374	0.350	0.341
2008	0.159	0.391	0.469	0.478	0.432	0.406	0.392
2009	0.156	0.397	0.490	0.500	0.450	0.417	0.389
2010	0.140	0.375	0.472	0.483	0.445	0.419	0.384
2011	0.147	0.391	0.482	0.474	0.430	0.409	0.373
2012	0.128	0.365	0.453	0.448	0.402	0.380	0.346
2013	0.106	0.327	0.415	0.421	0.380	0.361	0.325
2014	0.093	0.299	0.397	0.412	0.372	0.350	0.313
2015	0.090	0.296	0.401	0.416	0.371	0.346	0.309
2016	0.083	0.289	0.401	0.423	0.384	0.358	0.319
2017	0.086	0.303	0.432	0.476	0.437	0.393	0.341
2018	0.095	0.328	0.466	0.516	0.472	0.415	0.352
2019	0.117	0.372	0.510	0.557	0.509	0.433	0.359
2020	0.113	0.356	0.466	0.491	0.440	0.359	0.290
2021	0.112	0.338	0.419	0.428	0.377	0.305	0.248

Table 16.4.3. Saithe in subareas 4 and 6 and Division 3.a: Estimated population numbers-at-age for the final assessment model.

Year/Age	3	4	5	6	7	8	9	10+
1967	142300	82031	57180	7140	4895	1144	737	674
1968	160741	92766	50569	31776	3736	2542	656	769
1969	288405	90976	54754	31085	20455	2835	1953	817
1970	295841	217512	49425	35378	18694	11751	1803	1627
1971	357119	192798	119689	24860	19475	11956	7845	2495
1972	223262	210510	103851	67737	14638	11431	7332	6492
1973	200110	111051	106002	63889	36103	8770	6397	8622
1974	198212	89987	48415	63151	42234	20752	5456	8616
1975	234233	75820	35343	24362	36336	25205	12093	8571
1976	407671	101872	29459	17413	12944	19178	13329	11695
1977	149479	147766	35339	12377	8663	7192	10756	14085
1978	120095	72166	57966	14186	5109	4003	3395	13214
1979	87537	53755	34701	29212	7754	2806	2211	9605
1980	85500	47190	25738	18663	15977	3999	1655	7686
1981	164775	42129	25089	12320	9572	8173	2106	5840
1982	141145	109202	23193	15128	6276	4771	3711	4027
1983	148680	70010	55251	11406	8248	3117	2487	3787
1984	255285	76536	30260	23910	4736	3459	1325	2784
1985	355869	108225	29495	12834	9489	2227	1596	2309
1986	292033	141376	32029	11749	6382	4501	1197	2269

Year/Age	3	4	5	6	7	8	9	10+
1987	149344	164247	36076	10148	5143	3292	2291	1799
1988	138595	72006	61139	11402	4556	2599	1737	1926
1989	101911	69874	27765	21685	4730	2103	1246	1647
1990	150317	47885	25727	11128	8405	2329	1038	1414
1991	175572	70876	17184	10244	5285	3839	1254	1403
1992	103646	89417	25538	6667	5189	2883	2087	1495
1993	178040	58230	33982	9085	2863	3131	1807	2253
1994	119769	97576	28055	13291	3402	1406	1461	2117
1995	216503	66481	42216	12793	6239	1608	902	1871
1996	119415	149018	29522	19481	6807	2434	691	1277
1997	155443	78538	89390	13029	9094	3309	1075	916
1998	91899	122839	44655	48384	7142	4516	1787	980
1999	121062	57635	74760	22513	26324	4174	2292	1500
2000	101516	101895	30140	37597	11150	12622	1947	1619
2001	202624	68601	67098	14353	17701	6380	6774	1520
2002	153036	141530	34619	34769	8177	9481	3815	4767
2003	159472	114671	82054	16014	17012	5030	5057	4691
2004	112684	104510	70833	46129	7570	7946	3031	4317
2005	141072	73635	64119	46780	26028	4657	4236	3914
2006	96133	122091	41163	35499	25737	13173	2833	4429
2007	148095	52904	78359	23930	18992	14479	6773	4023
2008	72017	93445	29749	47660	14937	10807	9637	7610
2009	56618	51084	42319	14068	24671	9462	5738	9948
2010	88646	37306	27350	19501	6864	13123	5514	9434
2011	79044	78005	21916	13879	9794	3576	6598	10005
2012	131860	45765	46780	11607	7217	4948	1975	9545
2013	90536	96603	22242	25254	6575	3892	2658	6652
2014	55300	66590	50512	12298	13444	3897	2044	5463
2015	91980	41062	43991	26221	7134	6901	2503	4507
2016	113926	61884	26274	23522	12590	4468	3742	4450
2017	80142	87267	34177	14987	13458	6836	2724	4651
2018	40065	64059	53702	18127	7078	6502	3652	4226
2019	48437	31646	38927	25510	7975	3425	3400	4216
2020	31416	35946	19480	19747	11671	3643	1770	3753
2021	49833	23502	19471	10254	10517	5464	1973	3458

Table 16.5.1. Saithe in subareas 4 and 6 and Division 3.a. Estimated recruitment, total stock biomass (TSB), spawning stock biomass (SSB), and average fishing mortality for ages 4 to 7 ($F_{4–7}$), 1967–2020. Low and High refer to the lower and upper 95% confidence interval estimates.

Year	$R_{(age\ 3)}$	Low	High	SSB	Low	High	$F_{bar(4-7)}$	Low	High	TSB	Low	High
1967	142300	102234	198068	152326	121387	191151	0.353	0.276	0.452	414046	341522	501970
1968	160741	117160	220533	211063	170619	261094	0.293	0.23	0.372	580658	481964	699562
1969	288405	210221	395667	277547	227153	339122	0.320	0.258	0.397	716652	598262	858469
1970	295841	216820	403661	347234	288618	417755	0.345	0.281	0.424	915238	771251	1086105
1971	357119	264255	482618	463449	386260	556064	0.371	0.305	0.452	1061936	904193	1247198
1972	223262	166316	299706	493122	413522	588044	0.402	0.332	0.486	963452	828179	1120821
1973	200110	149228	268342	526082	441237	627242	0.426	0.354	0.513	897933	777538	1036971
1974	198212	147622	266140	580796	489308	689389	0.494	0.415	0.589	928216	808281	1065947
1975	234233	175210	313138	519493	436633	618078	0.533	0.449	0.633	858206	747494	985316
1976	407671	300151	553706	400607	334668	479538	0.601	0.506	0.715	815117	701772	946769
1977	149479	111036	201231	325517	271618	390113	0.593	0.493	0.713	612112	528644	708759
1978	120095	89480	161185	297697	247482	358100	0.481	0.402	0.577	519959	448662	602586
1979	87537	64995	117896	278895	234509	331683	0.451	0.376	0.541	483472	419233	557553
1980	85500	63484	115152	260493	220762	307374	0.474	0.398	0.565	439270	382747	504140
1981	164775	121516	223432	248809	211891	292160	0.469	0.393	0.560	494029	428089	570127
1982	141145	105198	189375	220138	189893	255201	0.540	0.458	0.636	532248	459969	615885
1983	148680	110723	199648	220172	189376	255975	0.652	0.555	0.767	510185	442917	587670
1984	255285	189723	343502	189034	163236	218911	0.679	0.581	0.794	517022	445428	600124
1985	355869	261921	483515	166175	144180	191526	0.705	0.604	0.823	528308	448050	622943
1986	292033	217104	392822	156393	135952	179908	0.741	0.629	0.872	492437	420855	576195
1987	149344	111112	200731	165104	143499	189963	0.707	0.604	0.827	403956	349743	466572
1988	138595	103492	185604	154493	132913	179576	0.712	0.609	0.833	349343	303959	401504
1989	101911	76019	136623	126511	109183	146590	0.692	0.590	0.81	292722	254694	336427
1990	150317	111960	201816	114785	98838	133304	0.659	0.562	0.773	301255	259279	350026

Year	$R_{(age\ 3)}$	Low	High	SSB	Low	High	$F_{bar(4-7)}$	Low	High	TSB	Low	High
1991	175572	131192	234965	107476	93028	124168	0.630	0.537	0.740	320947	274397	375393
1992	103646	77768	138134	112762	98162	129534	0.614	0.521	0.723	310066	266939	360162
1993	178040	133531	237385	119117	103102	137620	0.645	0.546	0.761	356221	304533	416683
1994	119769	89880	159598	123531	107107	142475	0.574	0.486	0.677	339654	291827	395319
1995	216503	160822	291463	142702	123076	165458	0.581	0.490	0.690	452336	382485	534943
1996	119415	88871	160457	153856	132945	178055	0.515	0.433	0.614	430954	366959	506110
1997	155443	114956	210191	191026	162499	224560	0.444	0.371	0.531	449018	384296	524641
1998	91899	67668	124807	188351	160887	220502	0.447	0.375	0.533	396523	342103	459600
1999	121062	89232	164245	199207	169605	233976	0.472	0.394	0.564	389877	338323	449287
2000	101516	75005	137399	194074	166875	225706	0.404	0.336	0.485	412139	357740	474810
2001	202624	150395	272991	200010	172537	231858	0.381	0.316	0.459	451557	391139	521309
2002	153036	113334	206646	218903	189976	252234	0.423	0.353	0.506	481212	417625	554479
2003	159472	118571	214481	204854	177218	236799	0.440	0.367	0.528	427160	371470	491199
2004	112684	83886	151367	254008	219012	294598	0.378	0.313	0.457	477148	416889	546118
2005	141072	104390	190644	245029	212072	283108	0.382	0.318	0.458	458178	401435	522942
2006	96133	70100	131833	259805	224564	300577	0.399	0.333	0.479	479701	421567	545853
2007	148095	106764	205427	243334	209523	282602	0.384	0.320	0.460	448398	391759	513226
2008	72017	53604	96754	244265	210520	283420	0.443	0.372	0.526	419241	367816	477857
2009	56618	42176	76005	242360	207697	282807	0.459	0.385	0.548	386461	339238	440259
2010	88646	65986	119087	227659	193591	267723	0.444	0.372	0.529	391790	342134	448652
2011	79044	57898	107913	182842	155532	214948	0.444	0.373	0.530	353083	307419	405529
2012	131860	98159	177132	166341	141391	195694	0.417	0.348	0.499	360843	311959	417387
2013	90536	67359	121687	170520	145222	200226	0.386	0.321	0.464	358366	311216	412659
2014	55300	40890	74787	189849	162263	222125	0.370	0.307	0.445	350958	306142	402335
2015	91980	67795	124793	195259	166992	228311	0.371	0.308	0.447	358674	312384	411823
2016	113926	84055	154414	181437	155044	212322	0.374	0.310	0.451	373862	324227	431095

Year	$R_{(age\ 3)}$	Low	High	SSB	Low	High	$F_{bar(4-7)}$	Low	High	TSB	Low	High
2017	80142	58968	108921	199442	170738	232972	0.412	0.342	0.496	389679	340385	446113
2018	40065	29414	54573	195111	167087	227834	0.446	0.369	0.538	338724	297301	385918
2019	48437	35257	66543	185595	157964	218060	0.487	0.400	0.592	311839	272782	356488
2020	31416	21220	46511	160486	134172	191960	0.438	0.354	0.542	259642	224377	300449
2021	49833	28557	86961	137451	111291	169761	0.390	0.301	0.507	233747	190182	287291

Table 16.7.1. Saithe in subareas 4 and 6 and Division 3.a. The basis for the catch options.

Variable	Value	Notes
$F_{ages\ 4–7}$ (2022)	0.34	Based on the assumed Total catch (2022); three-years average selectivity pattern (2019-2021) scaled to F_{2022}
SSB (2023)	141 805	Short-term forecast (STF); tonnes
$R_{age\ 3}$ (2022)	66 260 (66 473)	Geometric mean of recruitment resampled from the years 2012–2021 (geometric mean of unique recruitment estimates, or geometric mean expectation, reported in the advice); thousands
$R_{age\ 3}$ (2023)	65 866 (66 473)	Geometric mean of recruitment resampled from the years 2012–2021 (geometric mean of unique recruitment estimates, or geometric mean expectation, reported in the advice); thousands
Total catch (2022)	49 614	TAC 2022 constraint; tonnes
Landings (2022)	47 738	Assuming 2019-2021 average landings fraction by age; tonnes
Discards (2022)	1 876	Assuming 2019-2021 average discards fraction by age; tonnes

Table 16.7.2. Saithe in subareas 4 and 6 and Division 3.a. Reference points and their technical basis.

Framework	Reference point	Value	Technical basis	Source
MSY approach	MSY $B_{trigger}$	149 098 t	B_{pa}	ICES (2019a)
	F_{MSY}	0.363	Eqsim analysis based on the recruitment period 1998–2017.	ICES (2019a)
Precautionary approach	B_{lim}	107 297 t	B_{loss}	ICES (2019a)
	B_{pa}	149 098 t	$B_{lim} \times \exp(1.645 \times 0.2) \approx 1.4 \times B_{lim}$	ICES (2019a)
	F_{lim}	0.668	Eqsim analysis based on the recruitment period 1998–2017.	ICES (2019a, 2021a)
	F_{pa}	0.576	$F_{p.05}$ with AR; the F that leads to SSB ≥ B_{lim} with 95% probability. Eqsim analysis based on the recruitment period 1998–2017.	ICES (2021a, 2021b)
Management plan*	MAP MSY $B_{trigger}$	149 098 t	MSY $B_{trigger}$	ICES (2019a)
	MAP B_{lim}	107 297 t	B_{lim}	ICES (2019a)
	MAP F_{MSY}	0.363	F_{MSY}	ICES (2019a)
	MAP range F_{lower}	0.210	Consistent with ranges provided by ICES, resulting in no more than 5% reduction in long-term yield compared with MSY	ICES (2019a)
	MAP range F_{upper}	0.564	Consistent with ranges provided by ICES, resulting in no more than 5% reduction in long-term yield compared with MSY.	ICES (2019a, 2021a)

Table 16.7.3. Saithe in subareas 4 and 6, and in Division 3.a. Annual catch scenarios. All weights are in tonnes.

Basis	Total catch (2023)	Projected landings (2023)	projected discards (2023)	Projected landings# 3a4	Projected landings# 6	F_{total} (ages 4-7) (2023)	$F_{projected\ landings}$ (ages 4-7) (2023)	$F_{projected\ discards}$ (ages 4-7) (2023)	SSB (2024)	% SSB change *	% TAC change **	% advice change ^
ICES advice basis												
MSY approach: F_{MSY} × SSB (2023) /MSY $B_{trigger}$	58912	56645	2267	51320	5325	0.345	0.334	0.0110	159133	12.2	18.7	18.7
F = $F_{MSY\ lower}$ × SSB (2023) /MSY $B_{trigger}$	36076	34673	1403	31414	3259	0.200	0.193	0.007	179382	26	-27	-27
F_{MSY}	61507	59152	2355	53592	5560	0.363	0.35	0.0120	156893	10.6	24	24
F = $F_{MSY\ lower}$	37777	36309	1468	32896	3413	0.210	0.20	0.0070	177899	25	-24	-24
F = $F_{MSY\ upper}$	88644	85178	3466	77171	8007	0.564	0.55	0.0190	133398	-5.9	79	79
F = 0	0	0	0	0	0	0	0	0	211886	49	-100	-100
F_{pa}	90144	86596	3548	78456	8140	0.576	0.56	0.0190	132129	-6.8	82	82
-13.4F_{lim}	101104	97133	3971	88002	9131	0.668	0.64	0.023	122762	-13.4	104	104
SSB_{2024} = B_{lim}	121742	116900	4842	105911	10989	0.85	0.82	0.029	107297	-24	145	145
SSB_{2024} = B_{pa}	72399	69563	2836	63024	6539	0.44	0.42	0.0140	149098	5.1	46	46
SSB_{2024} = MSY $B_{trigger}$	72399	69563	2836	63024	6539	0.44	0.42	0.0140	149098	5.1	46	46
F = F_{2022}	57384	55183	2201	49996	5187	0.34	0.32	0.0110	160486	13.2	15.7	15.7
TAC_{2022}	49614	47713	1901	43228	4485	0.28	0.27	0.0100	167290	18	0.00	0.00
TAC_{2022} −15%	42172	40544	1628	36733	3811	0.24	0.23	0.0080	173992	23	-15.0	-15.0
TAC_{2022} +15%	57056	54868	2188	49710	5158	0.33	0.32	0.0110	160787	13.4	15.0	15.0
TAC_{2022} −20%	39691	38147	1544	34561	3586	0.22	0.21	0.0080	176170	24	-20	-20
TAC_{2022} +25%	62016	59642	2374	54036	5606	0.37	0.35	0.0120	156417	10.3	25	25

*** SSB_{2024} relative to SSB_{2023}. ** Total catch in 2023 relative to the TAC in 2022 (49 614 t). # Landings split according to the average in 1993–1998, i.e. 90.6% in Subarea 4 and Subdivision 3.a.20 and 9.4% in Subarea 6. ^ Total catch 2023 relative to the advice value 2022 (49 614 t).**

Table 16.7.4. Saithe in subareas 4 and 6 and Division 3.a. Contribution of the year classes to the landings in 2023.

Year class	Contribution to landings (%)	
	Numbers	Weight
2020	16.8	9.2
2019	39.4	29.3
2018	22.2	21.3
2017	8.2	9.9
2016	5.5	8.6
2015	2.6	5.2
2014	2.4	6.1

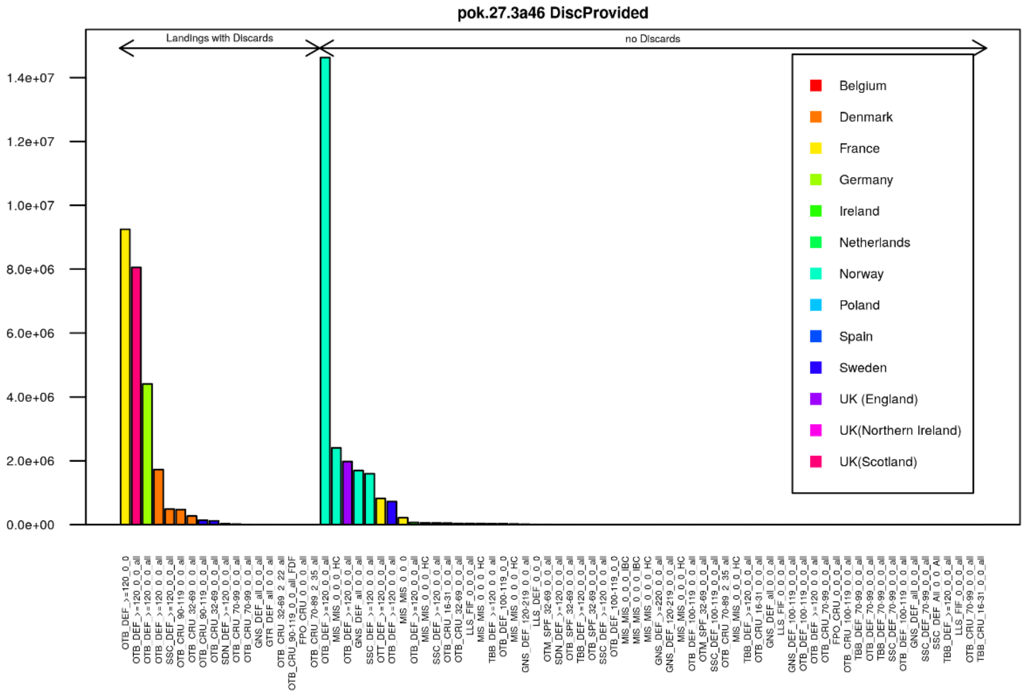

Figure 16.3.1. Saithe in subareas 4 and 6 and Division 3.a: Landings with associated discards for areas and quarters combined by métier for 2021.

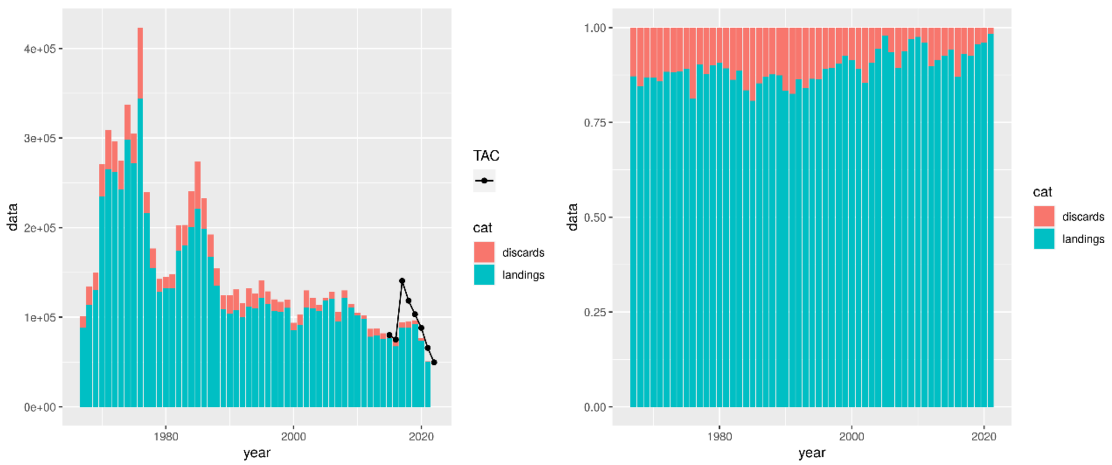

Figure 16.3.2. Saithe in subareas 4 and 6 and Division 3.a: Yield as stacked plot for landings and discards in tonnes (left panel) and as percent (right panel). Landings include BMS landings from Norway since 2016. Discards correspond to unwanted catch (discards + EU/UK BMS) since 2016.

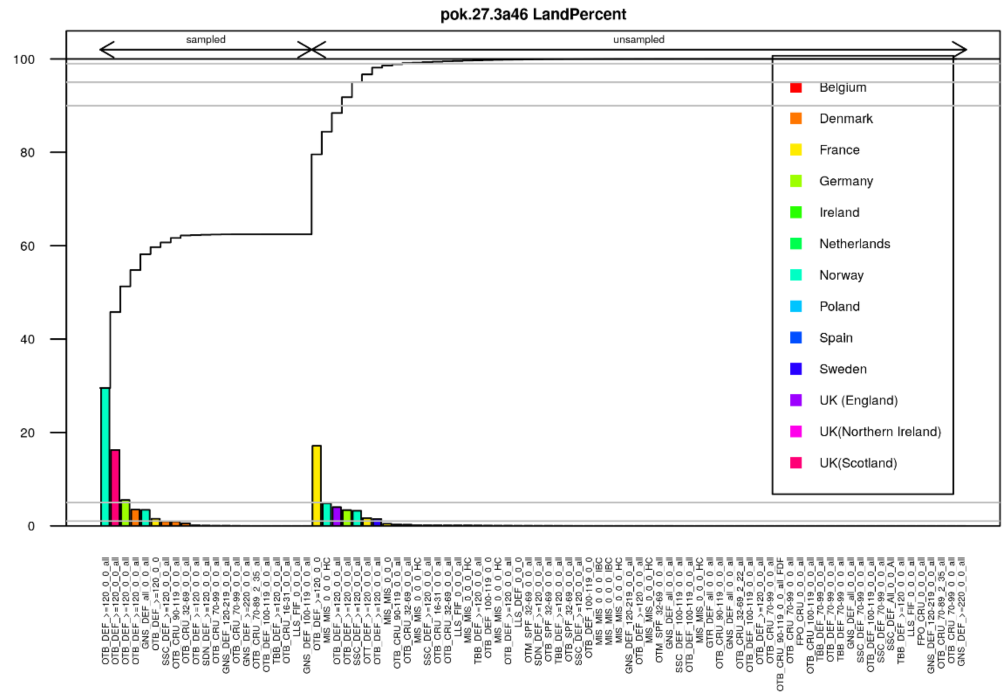

Figure 16.3.3. Saithe in subareas 4 and 6 and Division 3.a: Overview of percent of sampled and unsampled landings by country and métier for 2021.

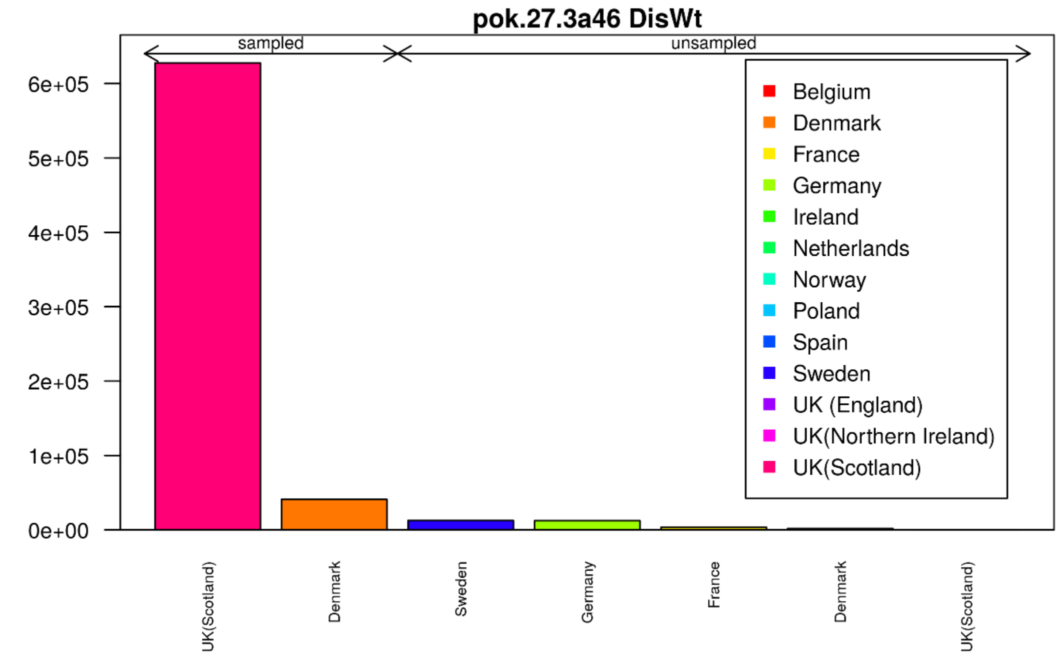

Figure 16.3.4. Saithe in subareas 4 and 6 and Division 3.a: Overview of age sampled and unsampled imported discards by country and métier for 2021.

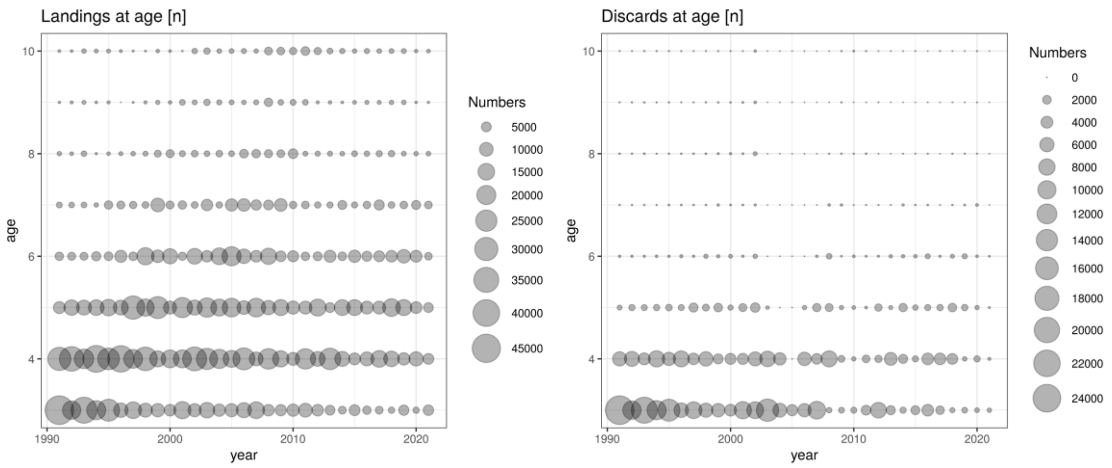

Figure 16.3.5. Saithe in subareas 4 and 6 and Division 3.a. (left) Landings-at-age (x10³) for saithe ages 3–10+, 1990–2021. (Right) Discard numbers (x10³) at age for saithe ages 3–10+, 1990–2021.

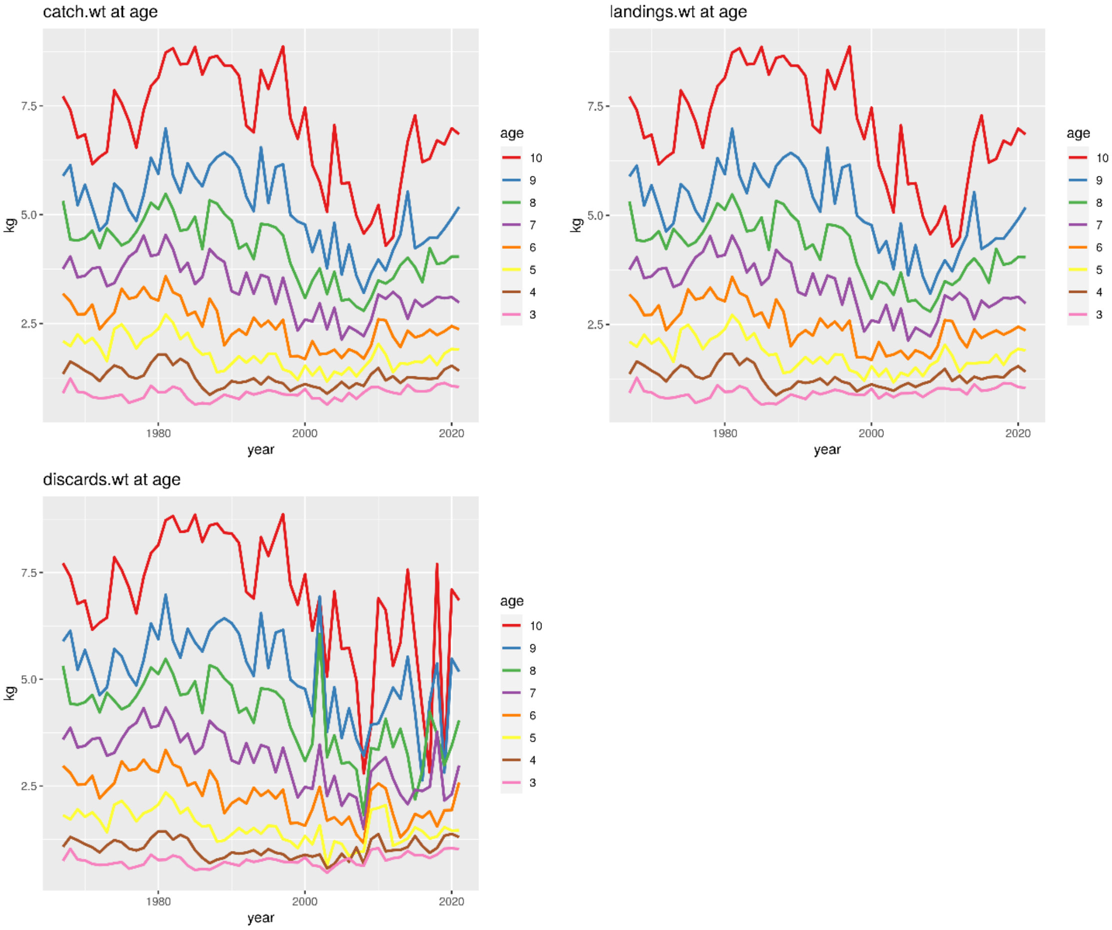

Figure 16.3.6. Saithe in subareas 4 and 6 and Division 3.a. Catch weight-at-age (top left pane), landing weight-at-age (bottom left panel) and discard weights-at-age (bottom right panel), in kilograms, for saithe ages 3–10+, 1967–2021.

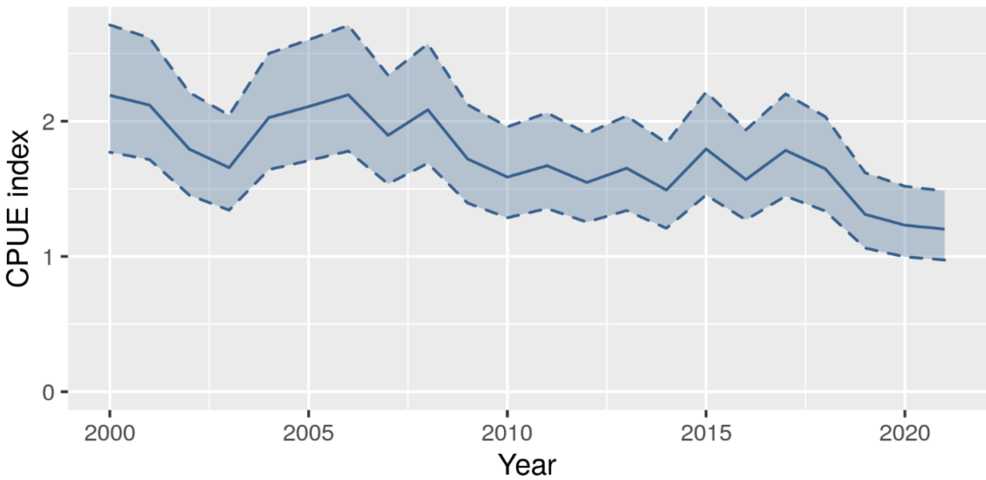

Figure 16.3.7. Saithe in subareas 4 and 6 and Division 3.a: Standardised commercial CPUE index time series and 95% confidence interval. Based on logbook data from France, Germany and Norway.

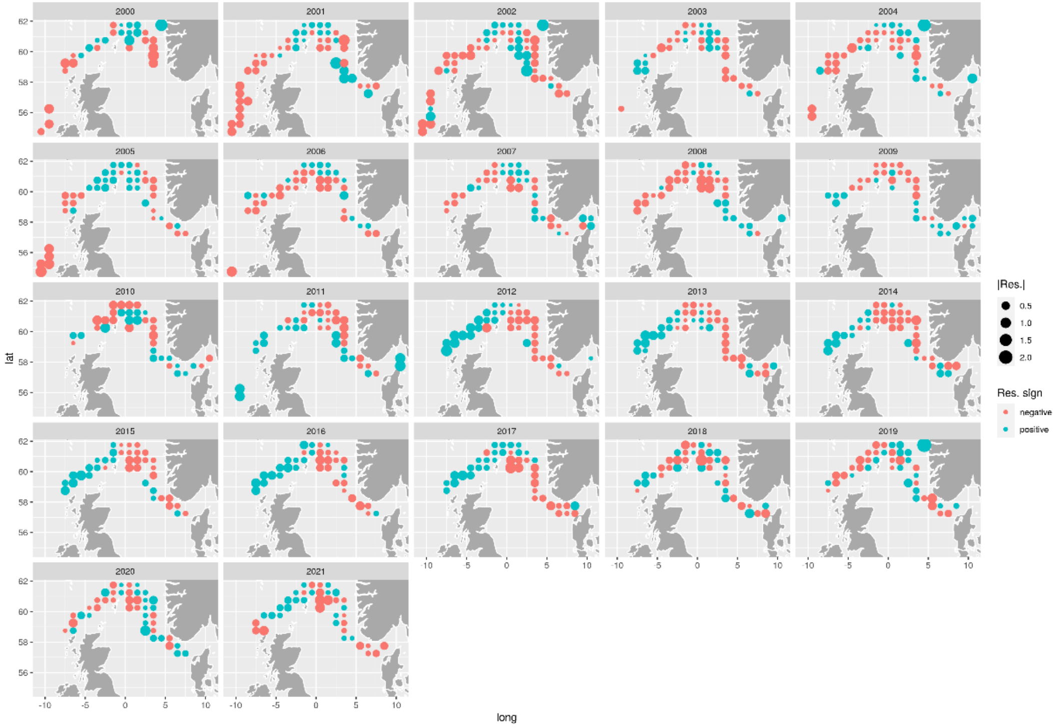

Figure 16.3.8. Saithe in subareas 4 and 6 and Division 3.a. Maps of mean residuals from the CPUE index model per 0.5°x0.5° grid cell, per year (2000–2021).

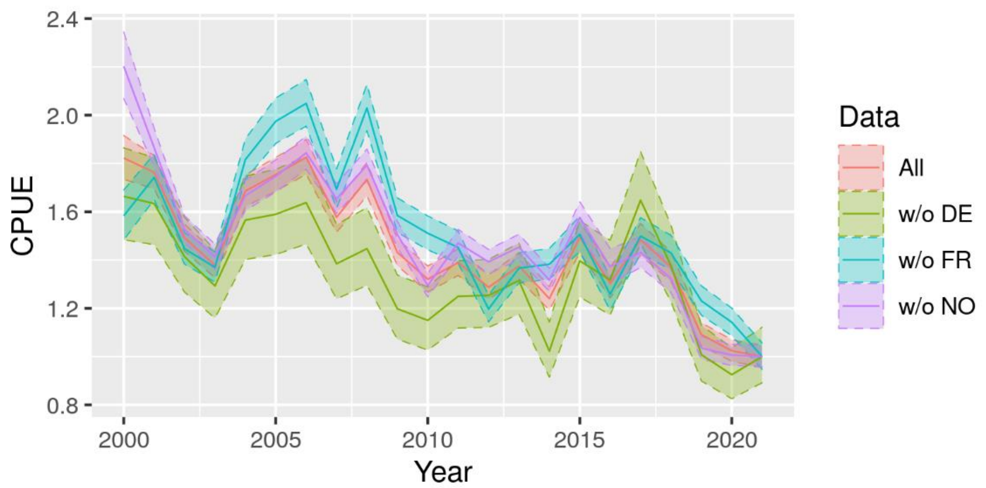

Figure 16.3.9. Saithe in subareas 4 and 6 and Division 3.a: Commercial CPUE index (standardized to one in 2021) fitted with data from one nation sequentially taken out, compared to all data (leave-one-nation-out analysis).

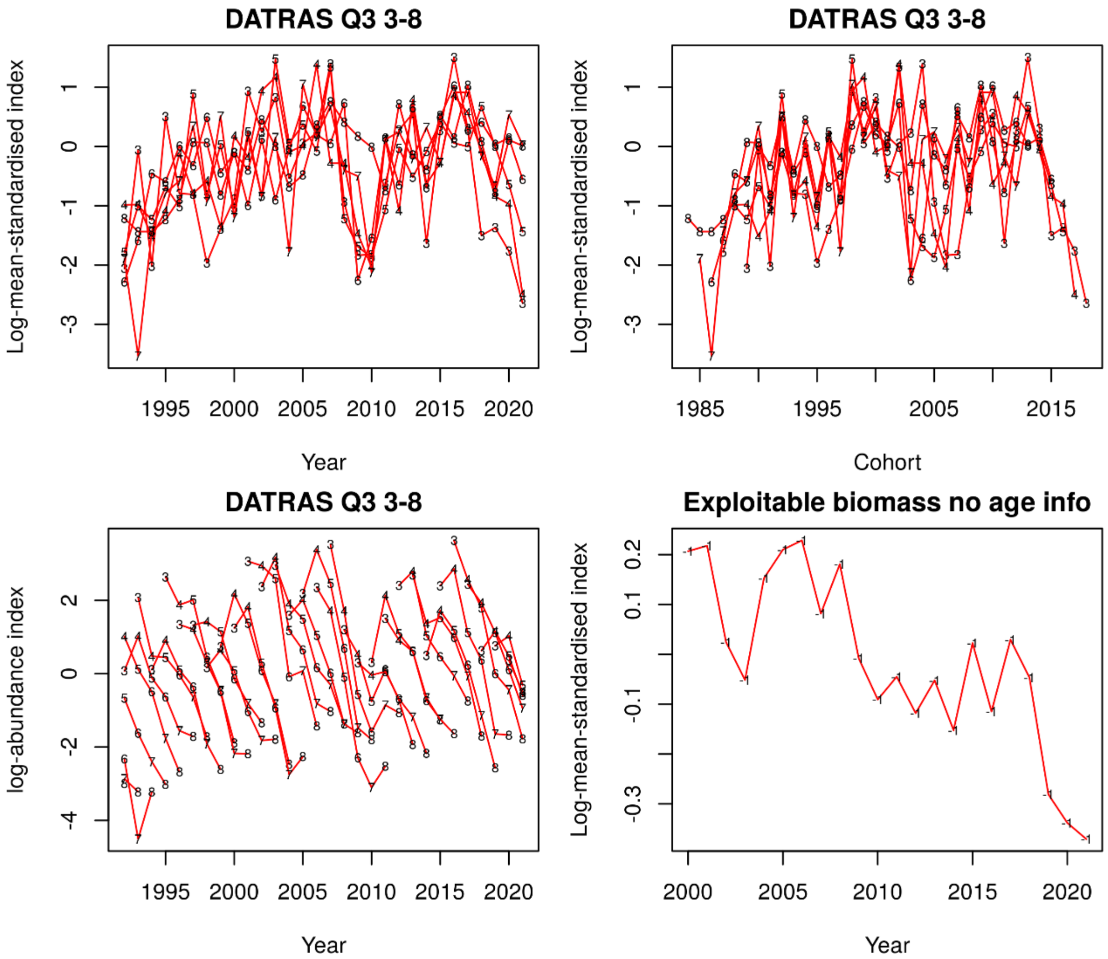

Figure 16.4.1. Saithe in subareas 4 and 6 and Division 3.a: Research survey index, IBTS–Q3, for ages 3 to 8, 1992–2021 is shown in terms of indices by age and year (top-left panel), indices by age and cohort (top-right panel), and log-catch curves by cohort (bottom-left panel). Commercial catch-per-unit-effort (CPUE) is shown in the bottom-right panel.

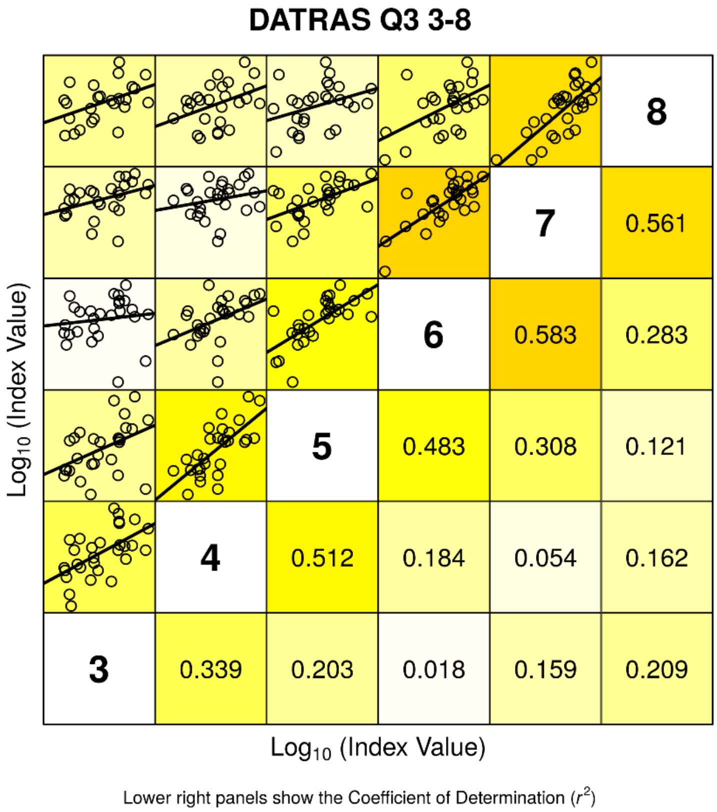

Figure 16.4.2. Saithe in subareas 4 and 6 and Division 3.a.: Internal consistencies for IBTS–Q3, 1992–2021 ages 3 to 8.

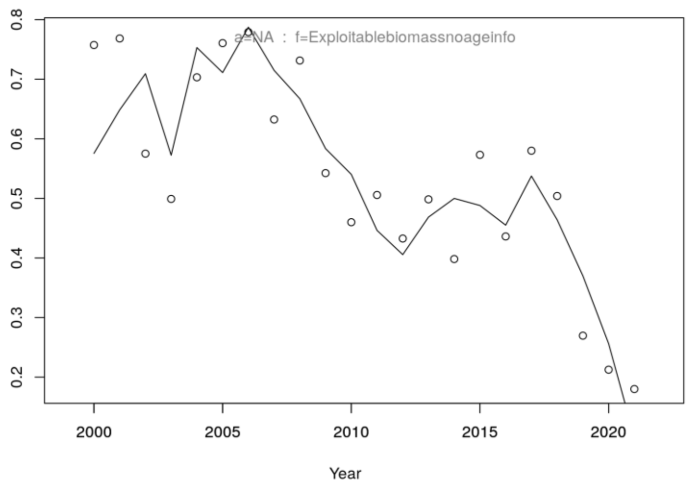

Figure 16.4.3. Saithe in subareas 4 and 6 and Division 3.a. Standardized combined CPUE index (year effects, open circles) and fit of model after tuning to the exploitable biomass (solid line), 2000–2021.

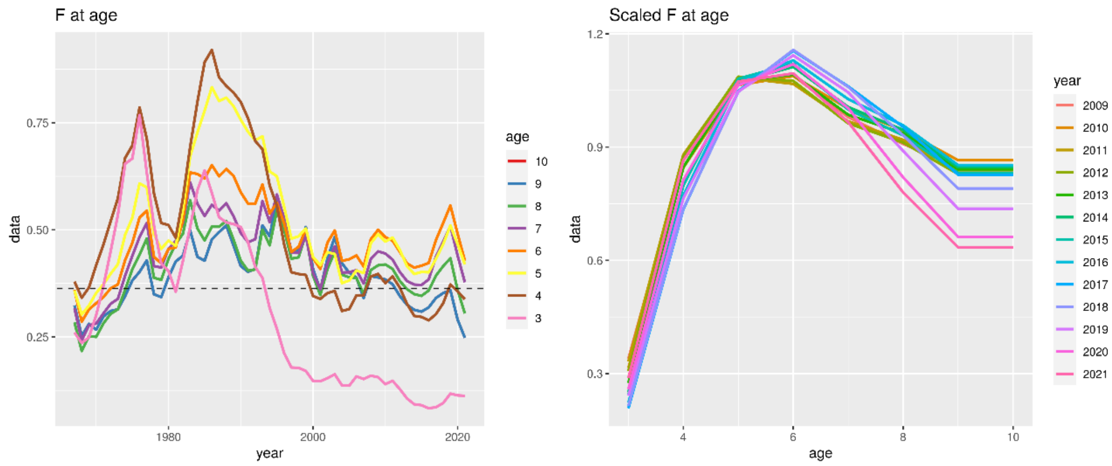

Figure 16.4.4. Saithe in subareas 4 and 6 and Division 3.a. Fishing mortality at age for the final assessment model. Time series (left panel) and scaled at $F_{4\text{-}7}$ for the last 13 years (right panel). F at age 9 and 10+, which are coupled in the model (9+), perfectly overlap.

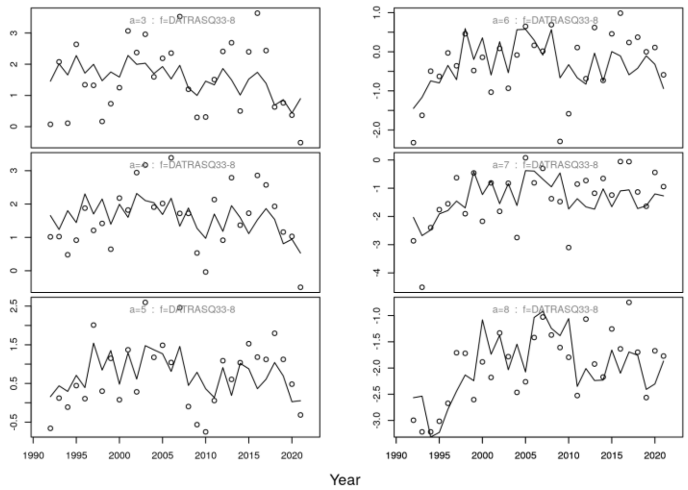

Figure 16.4.5. Saithe in subareas 4 and 6 and Division 3.a. DATRAS Q3 index at age (age 3-8, open circles) and model fit (solid line), 1992–2021.

Figure 16.4.6. Saithe in subareas 4 and 6 and Division 3.a. One-step ahead (serially independent) residual patterns of observations for the final SAM model. Plus-group: age 10+ for catch. Age:-1 indicates no age information.

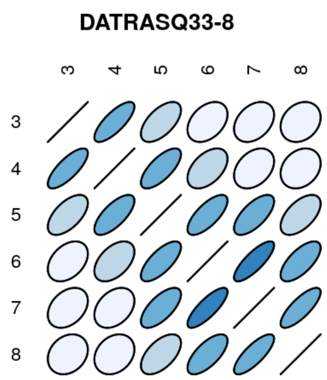

Figure 16.4.7. Saithe in subareas 4 and 6 and Division 3.a. Correlation between age classes within years for IBTS Q3 (ages 3–8). The darker the blue colour, the stronger the correlation.

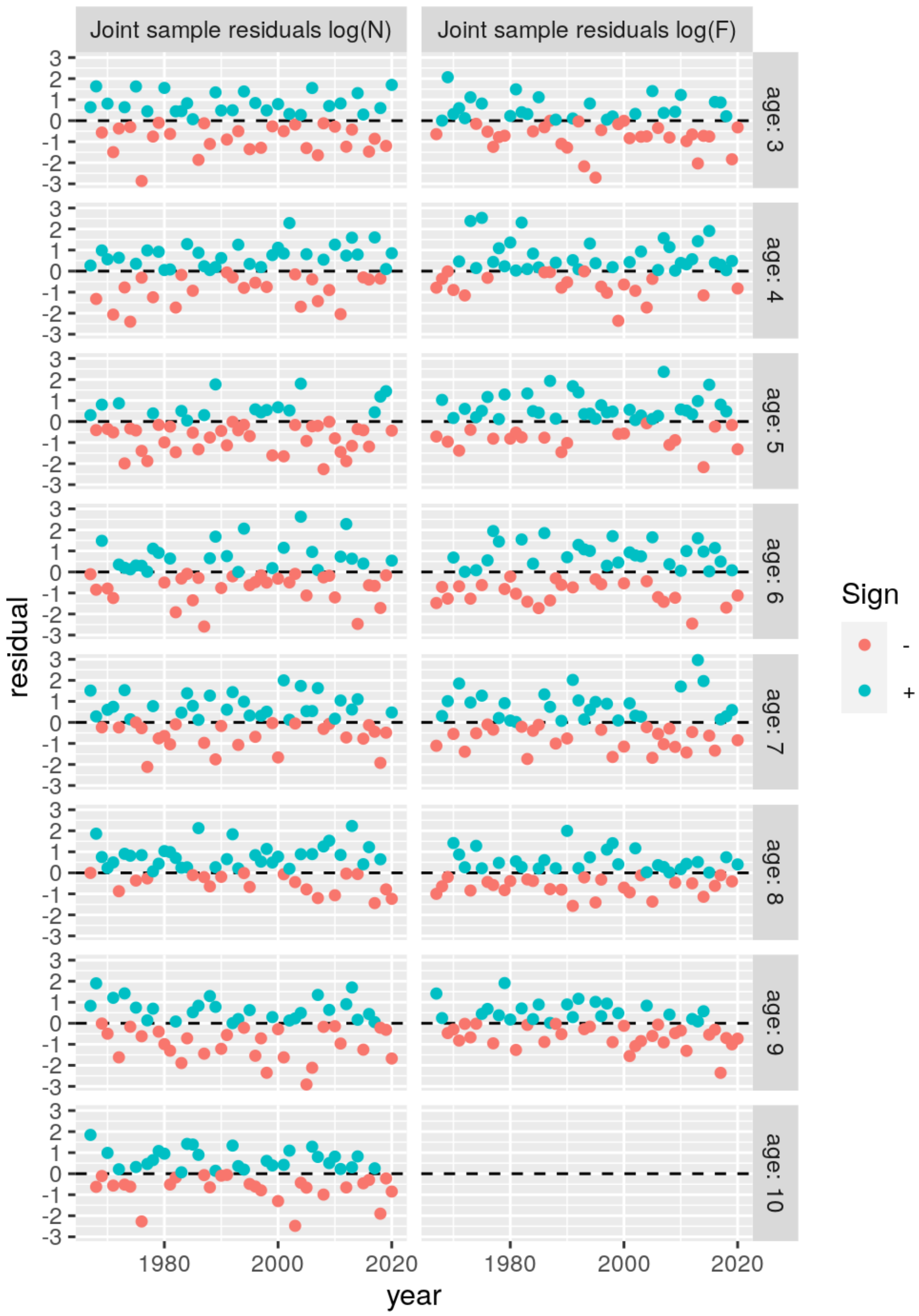

Figure 16.4.8. Saithe in subareas 4 and 6 and Division 3.a. One-step ahead (serially independent) process error. Plus-groups: age 10+ for N, 9+ for F

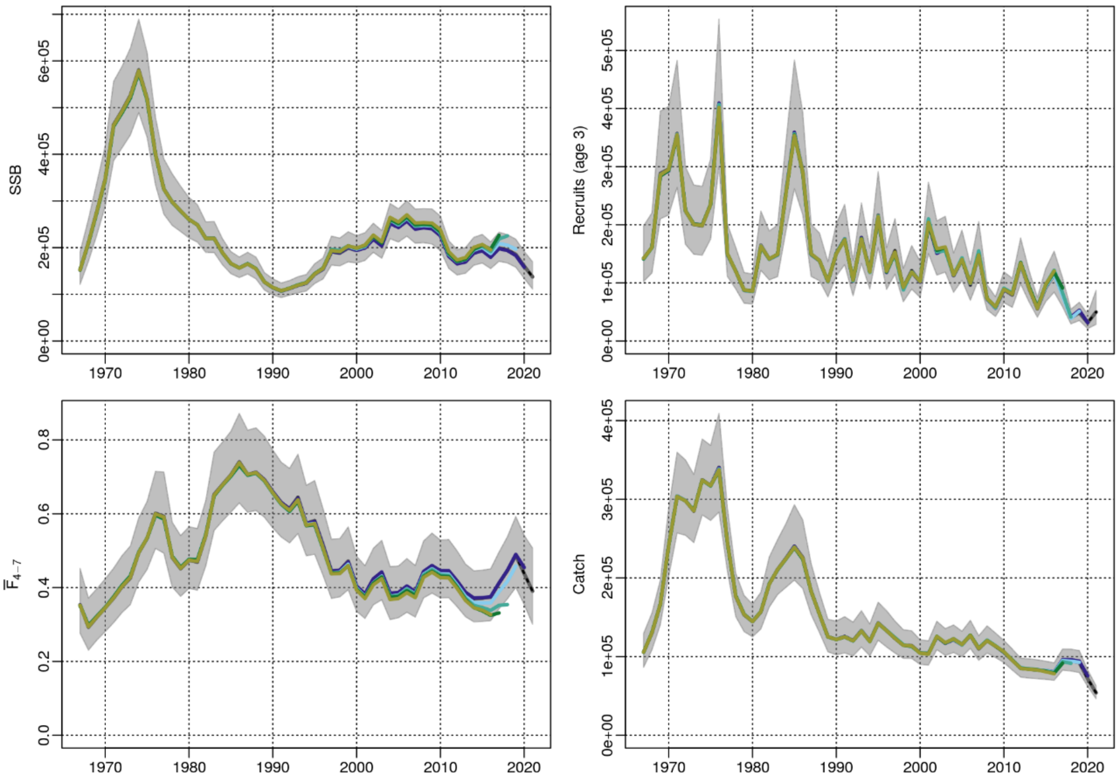

Figure 16.4.9. Saithe in subareas 4 and 6 and Division 3.a. Five-year retrospective pattern in SSB, F_{4-7}, recruitment, and catches for the final assessment.

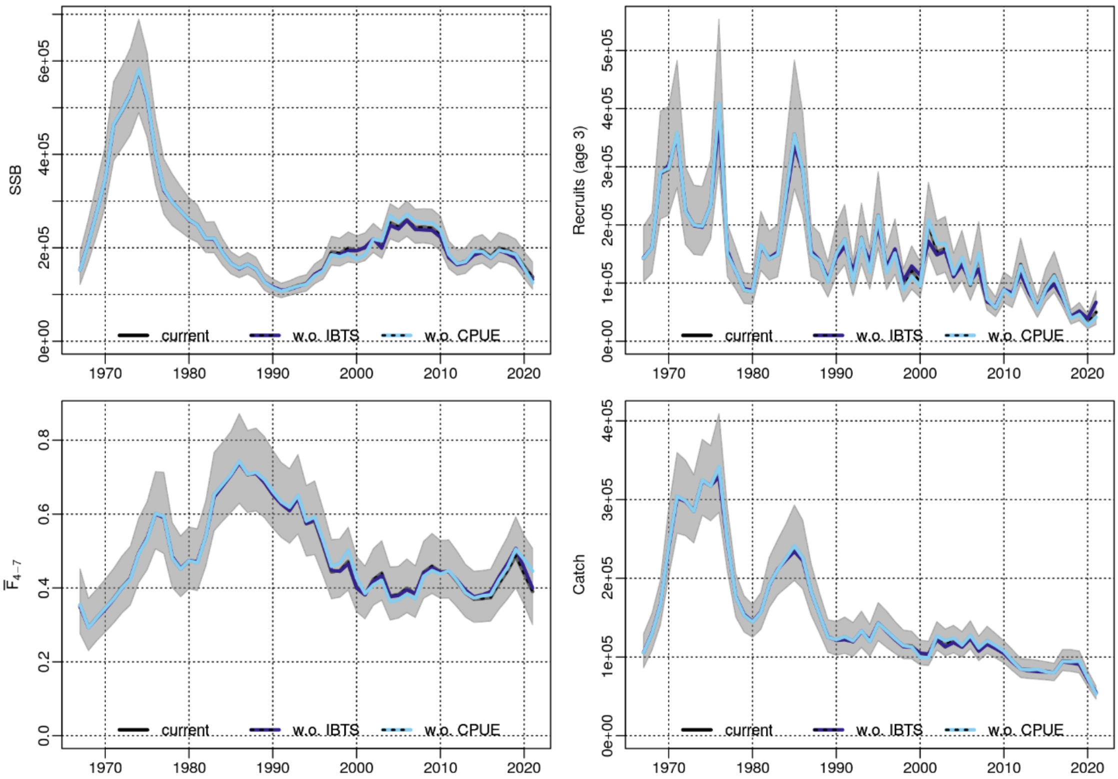

Figure 16.4.10. Saithe in subareas 4 and 6 and Division 3.a. Stock summary of trends in SSB, F_{4-7}, recruitment, and catches for the final assessment model. Black lines and grey-shaded confidence interval indicate the final assessment model, including the IBTS Q3 indices for ages 3–8 and the CPUE index. The light blue line is the assessment with only the IBTS Q3 tuning series, while the dark blue one is the assessment with only the CPUE index.

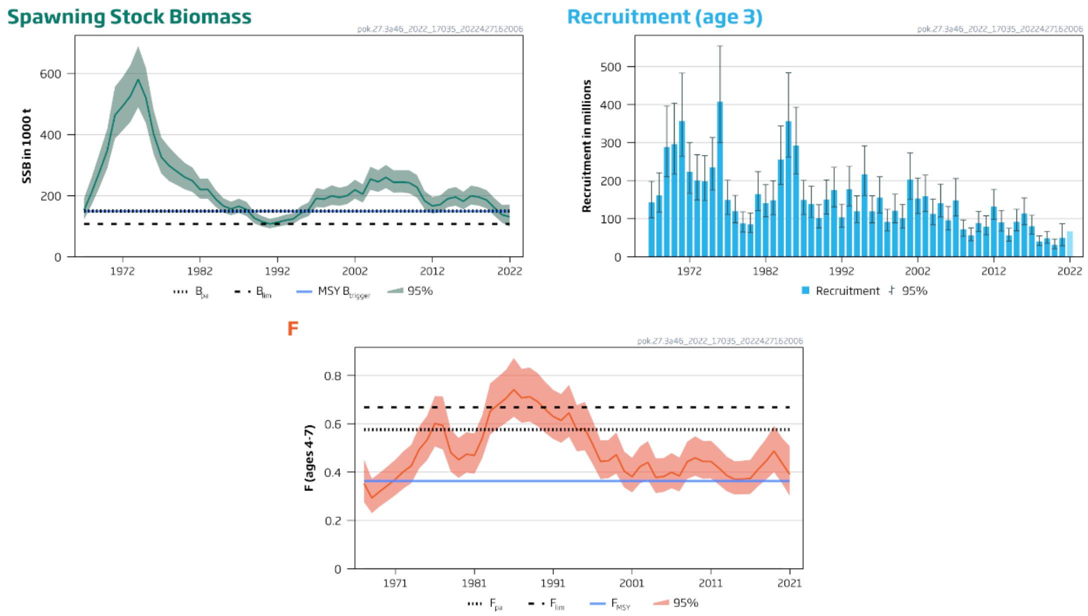

Figure 16.5.1. Saithe in subareas 4 and 6 and Division 3.a. Summary of stock assessment in relation to reference points for SSB and F. Predicted recruitment values are light shaded. Shaded areas (F, SSB) and error bars (R) indicate point-wise 95% confidence intervals.

17 Sole (*Solea solea*) in Subarea 27.4 (North Sea)

17.1 General

The assessment of sole in Subarea 27.4 is an update of last year's model run. This is the result of applying the methodology agreed at the last benchmark, carried out in February 2020 (ICES WKFLATNSCS, 2020). The adopted assessment model is the AAP statistical catch-at-age model of Aarts & Poos (2009). The model uses two indices of abundance: The Sole Net Survey (SNS), covering the coastal areas of the Southern North Sea, and a combined index based on the BTS Q3 survey, including data from The Netherlands, Belgium and Germany. This index covers the full area of distribution of the stock. Further details about the implementation of the BTS survey and changes to the stock assessment model can be found in the benchmark report (ICES WKFLATNSCS, 2020).

The benchmark agreed on the settings to be applied to the AAP model for the assessment of sol.27.4 and for the forecasts providing annual advice on catch limits. North Sea sole has been defined as a category 1 stock according to ICES guidelines, and the advice presented in this section refers to catch limits for 2023.

17.1.1 Stock structure and definition

North Sea sole is assumed to consist of a single stock unit.

17.1.2 Ecosystem aspects

North Sea sole is commonly distributed along the Southern half of the North Sea. Spawning takes place in shallow waters on the Southern coasts of the North Sea. Episodic large recruitment events take place at irregular intervals, the most recent being the strong 2018 year class.

17.1.3 Fisheries

Many vessels in the beam trawl fleet, targeting sole in the North Sea, transitioned in the past decade to using electrical pulse gears. In 2011, approximately 30 derogation licenses for pulse trawls were taken into operation, the number then increased to 42 in 2012.

The catch composition of these gears has been found to be different from the traditional beam trawl (ICES, 2018). The impact of this gear transition on the North Sea ecosystem has been evaluated by ICES (ICES, 2018). ICES recommended that further studies aimed at investigating catch composition of these innovative gears in comparison to traditional beam trawls were undertaken.

Between 2014 and 2017 the use of pulse trawls in the main fishery operating in the North Sea increased and less vessels were operating with traditional beam trawls. The pulse gear allows fishing of softer grounds and as a result the spatial distribution of the main fisheries has changed to the southern part of Division 4.c. As a consequence a larger proportion of the sole catch is now taken in this area (ICES, 2018).

In 2019 the European Parliament decided to ban pulse fisheries in European waters. This ban on pulse fishing implied that ultimately only 5% of the fleet of each member state could continue its fishing activities with the pulse trawl until 1 July 2021, after which a total ban has been applied.

The precise response of the fleet to the ban appears to be more varied than simply a return to the gear configurations in use before the advent of pulse. The choice of gear has also been affected by the increase in fuel prices. Overall selectivity has thus been in a dynamic state over the last decade.

BMS landings of sole reported to ICES are currently much lower than the estimates of catch below the minimum conservation reference size (MCRS), 4.4% of the total catch from observer programs.

17.1.4 Management regulations

ICES is requested to provide advice based on the MSY approach. As the stock biomass is estimated to be below MSYBtrigger, ICES advises that when the MSY approach is applied, total catch in 2023 should equal that corresponding to the level expected to impose a fishing mortality equal to 91% of F_{MSY}, 9152 tonnes.

17.2 Fisheries data

17.2.1 Official catches

For 2021, the official landings are presented next to the landings and discards data submitted to Intercatch in Figure 1. A time-series of the official landings by country and overall total, the officially reported BMS landings, the landings reported to ICES and the agreed TAC are presented in Table 2.

17.2.2 Intercatch processing

Data submitted on landings and discards at age by métier and quarter has been extracted from Intercatch. Figures 6, 7 and 8 show the coverage of the landings, as tonnage and as a cumulative percentage, and discards information, respectively, as available in Intercatch. The allocation of discards and age samples to unsampled strata has followed, in overall terms, the following grouping strategy:

- *TBB_DEF* and *OTB_DEF* < 100, separately and by quarter if possible.
- *TBB_DEF* and *OTB_DEF* > 100, separately and by quarter if possible.
- *TBB_CRU* and *OTB_CRU* < 100.
- *TBB_CRU* and *OTB_CRU* > 100.
- *GTR_DEF* and *GNS_DEF*.
- *FPO*, *LLS*, and *MIS*.

17.2.3 ICES estimates of landings and discards

Figure 2 presents the time series of total catches, landings and discards over the 1957-2021 period. Landings, in numbers by age, as used as input for the assessment, are presented in Table 3 and Figure 3. Total landings reported to ICES for sole in Subarea 27.4 in 2021 amounted to 9144 tonnes, a change of around -15% compared to the values reported for 2020.

Since 2016, small mesh beam trawlers (BT2) with discard rates of around 10%, are required to report BMS landings in Subarea 27.4. The official reported BMS landings in 2021 were 43 tonnes. For incorporation in the assessment, BMS landings are merged with the estimated discards.

Discards, in numbers at age, as used as input for the assessment, are presented in Table 4 and Figure 4. The proportions of caught fish at age that are discarded over the 2002-2021 period, over which data on discards is available, is presented in Figure 5.

In 2021, official catches amounted to 57.5% of the TAC, while landings reported to ICES were 53.4% of the TAC. If both landings and discards estimates are used, total catch in 2021 was 59.6% of the agreed TAC.

17.3 Weights-at-age

Weights-at-age in the landings of sole in Subarea 27.4 can be found in Table 5 and Figure 9. These are measured weights from the various national catch and market sampling programs. Discard weights at age (Table 6) are derived from the various national catch and discard programs (both observer and self-sampling).

Mean weight-at-age in the discards for the 1957-2002 period, when discards-at-age are reconstructed by the AAP model, are the average over the years 2006 to 2013. Sampling levels were substantially lower before 2006.

Mean weights-at-age in the stock (Table 7) are the average weights from the 2nd quarter landings and discards as constructed by Intercatch. The mean stock weights-at-age have shown a continuous downward trend, returning to values similar to those observed at the start of the time series (Figure 10). Mean weights at age for younger ages have also been decreasing in recent years.

17.4 Maturity and natural mortality

A knife-edged maturity-ogive with full maturation at age 3 is assumed for sole in Subarea 27.4 (Table 8). No new data was presented at the working group in 2022. Natural mortality at age is assumed to be constant at 0.1, except for the year 1963 where a value of 0.9 was used to take into account the effect of the severe winter of 1962-1963. The estimate of 0.9 was based on an analysis of the CPUE in the fisheries targeting sole before and after that period (ICES FWG, 1979).

17.5 Survey data

Two survey series are used in the assessment of North Sea sole:

- Quarter 3 Beam Trawl Survey (BTS), covering the 1985-2021 period and containing samples for ages 1 to 10+.
- Quarter 3 Sole Net Survey (SNS), extending from 1970 to 2021, with the exception of 2003, and with samples including ages 1 to 6.

An index of abundance is assembled based on the BTS Q3 samples collected by The Netherlands, Belgium and Germany (Figure 12), available in the Datras database. A standardized age-based index is calculated using a delta-lognormal GAM model, using the methodology presented in Berg *et al.* (2014). Please refer to the WKFlatNSCS report (ICES, 2020) for further details on the analysis[1]. This index substitutes the previous one that only utilized samples taken by RV-Isis and, since 2016, by RV-Tridens on the same locations and with the same gear. Ages included in the index are 1 to 10, the last one being a plusgroup.

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[1] Input data, source code and output of the index standardization is available at the https://github.com/ices-taf/2022_sol.27.4_survey/ TAF repository.

The SNS index is calculated by The Netherlands based on the mean densities across all sampled stations.

A standardized comparison of the two indices over the available time-series is presented in Figures 13, while Figures 14 and 17 present each individual index in their actual scales. The internal consistency plots of the year class cohorts of the two indices are presented in Figures 15 and 18. Changes over the last three decades on the internal consistency of the SNS survey are shown in Figure 19. The mean standardized indices per cohort and by year are shown on Figures 16 and 20. The actual values of the two survey indices used in the assessment are presented in Tables 9 and 10.

Internal consistency

A retrospective analysis was carried out for the standardization procedure used to generate the BTS Q3 index of abundances. The same model was applied to a total of five 1-year *peels*. The resulting indices (Figure 21, shown here in terms in total biomass) were then used in the stock assessment retrospective analysis.

17.6 Assessment

The model applied to North Sea sole is the Aarts and Poos statistical catch-at-age model (AAP; Aarts and Poos, 2009), in use for this stock since the 2015 benchmark (ICES WKNSEA, 2015). AAP models recruitment as an independent yearly factor, informed by the age-1 abundances of both surveys, and uses splines to model yearly patterns of the selectivity and fishing mortality-at-age. Discards-at-age are reconstructed through an estimate of changes in the discard fraction by age and year. The table below gives an overview of data and parameters used in the AAP model, as endorsed by the benchmark (ICES WKFlatNSCS, 2020).

Table 1. Sole in Subarea 4: Settings of the AAP stock assessment model.

Setting	Value
Plus group	10
First tuning year	1970
Catchability catches constant for age >=	9
Catchability surveys constant for ages >=	8
Spline for selectivity-at-age survey, no. knots	6
Tensor spline for F-at-age, ages, no. knots	8
Tensor spline for F-at-age, years, no. knots	28

A summary of the assessment results (recruitment, F and SSB, including confidence bounds) is presented in Figure 22. The estimates of spawning biomass and corresponding recruitment at age 1 are shown in Figure 23. The proportion of spawning biomass estimated to be accounted for by age and year is presented in Figure 24. A plot of log-standardized residuals of the model fit to the four data sources employed (the two indices of abundance, landings, and discards at age) is presented in Figure 25. The runs test for both indices (Carvalho et al, 2021) are presented in Figure 27 for the overall biomass, and Figure 28 for the numbers at age. Patterns were found to be non-random for ages 2 and 3 on the BTS survey only.

The retrospective patterns for recruitment, spawning biomass and fishing mortality are summarized in Figure 29. Figure 30 presents the results of an analysis of prediction skills by means of hindcasting cross-validation (carried out following Carvalho et al, 2021). A leave-one-out analysis of model fit over the two indices of abundance can be found in Figure 31. The estimated standard deviations of the lognormal likelihood for each age and data source are presented in Figure 32.

Yearly estimates of abundances and fishing mortality-at-age obtained by the model run are presented in Tables 11 and 12, respectively.

17.7 Recruitment estimates

The short term forecast for the stock requires an assumption about recruitment in the intermediate year, 2022. This has been set to the geometric mean of the 1957-2020 time series of recruitment estimates, 110 824 million fish.

17.8 Short-term forecasts

Short-term forecasts were carried out from the abundances estimated by the assessment model in 2021, with the following settings

- Natural mortality, maturity and weights-at-age in landings, discards and stock for 2022-2023 set as the average of the last three years (2019-2021).
- Selectivity-at-age for 2022-2023 set as the average of the last five years (2017-2021).
- Ratio of discards to landings at age as the average over the last three years (2019-2021).
- Recruitment in 2022 and 2023 set as 110 824 million fish, corresponding to the long-term geometric mean.
- Population numbers in the intermediate year for ages 2 and older are taken from the AAP survivors estimates.

Fishing mortality in the intermediate year, 2022, was scaled to that estimated for 2021.

Forecasts were carried out using the FLR toolset[2] (Kell *et al.*, 2007), and in particular the FLasher package[3] (Scott and Mosqueira, 2016). Source code for this analysis is available at the corresponding TAF repository[4]. Intermediate year assumptions and forecast results are summarized in Table 14.

The projections carried out were those necessary to populate the stock catch options table, as summarized here:

- F_{MSY}: F_{bar} (2023) = 0.207
- $F_{MSY\ lower}$: F_{bar} (2023) = 0.123
- $F_{MSY\ upper}$: F_{bar} (2023) = 0.311
- Zero catch: F_{bar} (2023) = 0
- F_{pa}: F_{bar} (2023) = 0.311
- F_{lim}: F_{bar} (2023) = 0.42
- B_{pa}: SSB (2023) = 42 838 t
- F_{lim}: SSB (2023) = 30 828 t
- MSY $B_{trigger}$: SSB (2023) = 42 838 t
- F2022: F_{bar} (2023) = 0.2076
- F_{mp}: F_{bar} (2023) = 0.20
- Roll-over TAC: Catch (2023) = 15 330 t

[2] https://flr-project.org

[3] https://flr-project.org/FLasher

[4] https://github.com/ices-taf/2022_sol.27.4_forecast/

17.9 Reference points

The reference points for sole in Subarea 4 were updated at the last benchmark (ICES WKFlatNSCS, 2020), following the procedures of ICES WKMSYREF3 (2014). All values are derived from the run of the AAP model including data up to 2018. The reference points in use for the stock are as follows:

Reference point	Value	Technical basis
MSY $B_{trigger}$	42 838 t	B_{pa}
F_{MSY}	0.21	EQsim analysis based on the recruitment period 1958–2015
B_{lim}	30 828 t	Break-point of hockey stick stock-recruit relationship, based on the recruitment period 19582018
B_{pa}	42 838 t	$B_{lim} \cdot \exp(1.645 \cdot 0.2)$
F_{lim}	0.42	EQsim analysis, based on the recruitment period 1958–2018
F_{pa}	0.31	$F_{lim}/\exp(1.645 \cdot 0.2)$
MSY $B_{trigger}$	42 838 t	MSY
MSY range F_{lower}	0.123–0.21	Consistent with ranges provided by ICES (2017a), resulting in no more than 5% reduction in long-term yield compared with MSY
MSY range F_{upper}	0.21–0.31	Consistent with ranges provided by ICES (2017a), resulting in no more than 5% reduction in long-term yield compared with MSY

17.10 Quality of the assessment

The assessment presents a strong retrospective pattern (SSB Mohn's rho = 0.38) for which a number of hypothesis have been explored, but no clear explanation has yet been found in Figure 29. The retrospective analysis has been carried out including retrospective fits of the GAM standardization of the BTS index of abundance (Figure 21). They were shown to have no effect on the assessment retrospective metric. Also, the model estimates of fleets selectivity at age show changes on the retrospective peels that are necessary to accommodate the discrepancies between catches of older ages and the information on those ages from the abundance indices in recent years.

In accordance with the decision tree of WKFORBIAS, a correction factor was calculated from ther fishing mortality Mohn's rho, 1 – 0.38. When this factor is applied to the fishing mortality corresponding to the MSY rule (F=0.188), the corrected value, 0.188 * (1 - 0.38) = 0.303, is still lower than that leading to a 5% risk of the biomass falling below B_{lim}, $F_{p.05}$ = 0.311. Therefore, F_{target} is assumed to be suffiently precautionary, and advice is given as usual this year.

The current model shows a low prediction skill for the main index of abundance (BTS), with projections based on reported catches generally overestimating the observed values. This indicates that stock productivity is likely lower than what the model estimates. The growth in stock abundance from the 2018 year class has been downwards corrected every year, as can be seen on the biomass retrospective pattern. This could be another indication of the misspecification of natural mortality in the younger ages.

An exploratory model run applied a larger natural mortality value for age 1 fish, 0.4, as well as setting the start of the data series after the large mortality event of the winter of 1963. Such sudden increase in natural mortality at the start of the time series, and before any index of abundance is available, could be expected to create difficulties for model estimation. This test run resulted in a very low retrospective pattern, of less than 0.02 for SSB, but also provided a quite different estimate of stock productivity and past biomass and fishing mortality levels. A new stock assessment model will have to be developed for this stock, possibly focusing on the natural mortality of younger ages, and the recent changes in fleet selectivity, so as to obtain more consistent estimates of stock status.

The uncertainty in the forecasted values of biomass, that form the basis for advice, was quantified by carrying out an stochastic forecast (Figure 33). The uncertainty in current status, introduced by parameter estimation, was incorporated through a Markov chain Monte Carlo (McMC) run of the stock assessment model. A single McMC chain was run for 100,000 iterations, thinned down every hundred. The probability quantiles obtained were comparable to those computed from the model estimated variances. Uncertainty in future recruitment was then added by resampling with replacement over the recruitment estimates of the last ten years.

17.11 Status of the stock

The stock appears to have increased notably in size in 2021, as the 2018 large cohort has entered the adult population. Fishing mortality has decreased as catches have also decreased. The spawning biomass in 2021, 45 001 t, is estimated to be above $MSY\ B_{trigger}$. Recruitment in both 2020 and 2021 are estimated to be lower than average, 45 and 44 million fish, respectively.

17.12 Management considerations

17.13 Issue for future benchmarks

The stock went through the benchmark process in 2020 (ICES WKFLATNSCS, 2020), when work concentrated on the two main issues in the ICES WGNSSK (2019) issue list: develop an index of abundance that includes samples from multiple countries of the BTS Q3 survey, and improvements on the residual patterns of the model fit. Limitations on time and data did now allow any work on the effect and suitability of the current assumptions on natural mortality.

The limited exploration carried out prior to WGNSSK showed how influential the current assumption on natural mortality, especially for the younger ages, could be in both the estimates of stock productivity, and on the stability of the retrospective runs.

Substantial changes have taken place over the last 10 years on the operation of the main fleet targeting sole, the Dutch Beam trawlers: from the traditional beam gear to pulse fishing, and then back. These changes might require a modelling approach in which selectivities for these fleet segments are estimated separately.

17.14 References

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Table 2. Sole in Subarea 4: Time-series of the official landings by country and overall total, the official BMS landings, the landings reported to ICES and the total TAC (figures rounded to the nearest tonne).

Year	BE	DK	FR	DE	NL	UK	Other	Official	BMS	ICES	TAC
1982	1900	524	686	266	17686	403	2.00	21467		21579	21000
1983	1740	730	332	619	16101	435	0.00	19957		24927	20000
1984	1771	818	400	1034	14330	586	1.00	18940		26839	20000
1985	2390	692	875	303	14897	774	3.00	19934		24248	22000
1986	1833	443	296	155	9558	647	2.00	12934		18201	20000
1987	1644	342	318	210	10635	676	4.00	13829		17368	14000
1988	1199	616	487	452	9841	740	28.00	13363		21590	14000
1989	1596	1020	312	864	9620	1033	50.00	14495		21805	14000
1990	2389	1427	352	2296	18202	1614	263.00	26543		35120	25000
1991	2977	1307	465	2107	18758	1723	271.00	27608		33513	27000
1992	2058	1359	548	1880	18601	1281	277.00	26004		29341	25000
1993	2783	1661	490	1379	22015	1149	298.00	29775		31491	32000
1994	2935	1804	499	1744	22874	1137	298.00	31291		33002	32000
1995	2624	1673	640	1564	20927	1040	312.00	28780		30467	28000
1996	2555	1018	535	670	15344	848	229.00	21199		22651	23000
1997	1519	689	99	510	10241	479	204.00	13741		14901	18000
1998	1844	520	510	782	15198	549	339.00	19742		20868	19100
1999	1919	828		1458	16283	645	501.00	21634		23475	22000
2000	1806	1069	362	1280	15273	600	539.00	20929		22641	22000
2001	1874	772	411	958	13345	597	394.00	18351		19944	19000
2002	1437	644	266	759	12120	451	292.00	15969		16945	16000
2003	1605	703	728	749	12469	521	363.00	17138		17920	15900
2004	1477	808	655	949	12860	535	544.00	17828		18757	17000
2005	1374	831	676	756	10917	667	357.00	15579		16355	18600
2006	980	585	648	475	8299	910	0.00	11933		12594	17700
2007	955	413	401	458	10365	1203	5.00	13800		14635	15000
2008	1379	507	714	513	9456	851	15.00	13435		14071	12800
2009	1353	476		555	12038	951	1.00	14898		13952	14000
2010	1268	406	621	537	8770	526	1.38	12129		12603	14100
2011	857	346	539	327	8133	786	2.00	10990		11485	14100
2012	593	418	633	416	9089	599	3.00	11752		11602	16200
2013	697	497	680	561	9987	867	0.00	13291		13137	14000
2014	920	314	675	642	9569	840	0.00	12547		13060	11900
2015	933	271	532	765	8899	804	0.00	12203		12867	11900
2016	767	355	362	861	9600	705	0.00	12651		14127	13262
2017	556	432	393	731	9155	513	0.00	11781	30	12370	16123
2018	408	368	432	717	8412	431	2.00	10771	57	11199	15694
2019	259	116	110	616	7212	334	1.00	8292	47	10607	12555
2020	240	123	37	914	6675	540	0.00	8808	43	10490	17545
2021	1184	172	166	643	6167	476	0.00	8808	43	9144	15330

Table 3. Sole in Subarea 4: Time-series of landings at age (in thousands).

year	1	2	3	4	5	6	7	8	9	10+
1957	0.0	1472	10556	13150	3913	3041	6780.0	1803.0	529.0	6541.0
1958	0.0	1863	8482	14240	9547	3501	3023.0	4461.0	2264.0	6590.0
1959	0.0	3694	12139	10499	9060	5823	1217.0	2044.0	2598.0	5668.0
1960	0.0	11965	14043	16691	9248	8313	4815.0	1583.0	1049.0	7851.0
1961	0.0	972	50470	19403	12574	4760	3998.0	4338.0	847.0	7355.0
1962	0.0	1584	6173	58836	15254	10478	4797.0	4087.0	2074.0	7450.0
1963	0.0	670	8271	8485	45823	8420	6603.0	2403.0	3365.0	8316.0
1964	53.0	150	2041	5518	3680	16749	3020.0	1749.0	790.0	2913.0
1965	0.0	45180	1045	1534	4798	2381	11990.0	1494.0	1463.0	3077.0
1966	0.0	12145	132170	979	1168	3649	736.0	6255.0	694.0	2424.0
1967	0.0	3769	26260	87039	1998	548	1962.0	777.0	5160.0	2978.0
1968	1034.0	17093	13852	24894	48417	461	244.0	1639.0	323.0	6502.0
1969	404.0	24404	21884	5433	12638	25646	338.0	249.0	1214.0	5379.0
1970	1299.0	6141	25996	8236	1784	3231	11961.0	246.0	140.0	5234.0
1971	425.0	33765	14596	12909	4538	1459	2355.0	7300.0	194.0	4649.0
1972	354.0	7511	36356	6997	4911	1548	517.0	1218.0	4654.0	2772.0
1973	716.0	12459	13025	16493	4101	2368	1013.0	779.0	1241.0	5899.0
1974	100.0	15171	21248	5412	6965	1896	1563.0	649.0	396.0	4750.0
1975	267.0	23193	28833	11839	2110	3870	798.0	916.0	513.0	3481.0
1976	1064.0	3619	28571	14316	4923	987	1950.0	562.0	434.0	2721.0
1977	1780.0	22747	12299	15593	7580	1812	325.0	1133.0	261.0	2155.0
1978	27.0	24921	29163	6102	6610	4231	1730.0	608.0	643.0	1595.0
1979	9.0	8280	41681	16259	3033	3262	1769.0	826.0	244.0	1546.0
1980	650.0	1233	12762	18138	7444	1479	2241.0	1437.0	374.0	1227.0
1981	434.0	29983	3344	7046	8439	3757	973.0	909.0	786.0	932.0
1982	2697.0	26799	46375	1868	3584	4855	1701.0	623.0	613.0	1295.0
1983	391.0	34545	41551	21273	626	1383	1958.0	982.0	388.0	1181.0
1984	192.0	30839	44081	22631	8821	744	857.0	1047.0	526.0	897.0
1985	163.0	16449	42773	20079	9307	3520	207.0	375.0	631.0	965.0
1986	372.0	9304	18381	17591	7698	5480	2256.0	109.0	281.0	1671.0
1987	93.0	28896	21927	8851	6477	3102	1559.0	898.0	81.0	690.0
1988	10.0	13206	47135	15217	4377	3878	1549.0	890.0	523.0	317.0
1989	115.0	45652	17973	22295	4551	1627	1414.0	637.0	451.0	459.0
1990	854.0	11816	103380	9667	9099	3315	1032.0	1186.0	548.0	837.0
1991	118.0	12938	24985	76580	6609	3612	1706.0	707.0	718.0	1072.0
1992	965.0	6730	43713	15961	37745	2440	2995.0	730.0	393.0	1163.0
1993	53.0	49870	16575	31047	13709	23758	1472.0	1170.0	456.0	833.0
1994	709.0	7710	86349	13387	18513	5642	11174.0	458.0	905.0	897.0
1995	4766.0	12674	16700	68073	6262	7254	1981.0	5971.0	293.0	665.0
1996	170.0	18609	16005	16770	26946	3814	4725.0	932.0	3267.0	976.0

year	1	2	3	4	5	6	7	8	9	10+
1997	1574.0	5987	23418	7253	5058	12667	1189.0	2303.0	330.0	1672.0
1998	242.0	56162	15011	14806	3466	1924	4727.0	787.0	1022.0	838.0
1999	284.0	15601	71730	8103	6049	1200	657.0	1964.0	328.0	804.0
2000	2329.0	14929	32425	42394	3257	2453	796.0	431.0	922.0	708.0
2001	857.0	25045	20925	19260	16211	1383	808.0	266.0	163.0	701.0
2002	1046.0	10958	32570	12185	8145	6393	667.0	592.0	88.0	362.0
2003	1047.0	32295	17479	16072	5814	3902	2427.0	400.0	128.0	451.0
2004	516.0	14960	48003	9531	7462	2167	902.0	962.0	389.0	389.0
2005	1131.0	7254	22633	28875	4168	3861	1491.0	602.0	768.0	392.0
2006	7008.0	9966	10397	9606	10943	1617	1577.0	724.0	373.0	553.0
2007	315.0	39643	10820	6407	5706	5479	819.0	725.0	498.0	541.0
2008	1959.0	6325	37427	5996	2928	2393	2613.0	448.0	491.0	459.0
2009	1630.0	10417	10771	26548	3278	1652	1591.0	1532.0	312.0	864.0
2010	371.0	11659	13354	8530	13623	1817	907.0	809.0	1196.0	690.0
2011	44.0	11992	19788	8379	5070	6436	983.0	431.0	283.0	765.0
2012	1.0	6439	28605	11069	4285	2146	4072.0	587.0	286.0	1028.0
2013	0.0	2741	28189	21500	5643	2042	1532.0	2246.0	242.0	471.0
2014	371.0	8111	6916	22942	11440	2591	1808.0	620.0	840.0	459.0
2015	201.0	10512	16589	4738	14756	6157	1470.0	562.0	393.0	545.0
2016	119.0	6151	24249	11489	4475	8994	4495.0	774.0	278.0	854.0
2017	416.0	4928	17641	16818	5909	2118	3745.0	2005.0	443.0	498.0
2018	331.0	11141	9184	11994	10095	3918	1096.0	1942.0	804.0	436.0
2019	488.4	6238	15757	6237	5383	4784	1485.1	695.6	1623.2	472.7
2020	121.8	18091	10055	10650	2648	2131	1499.0	562.4	152.2	1258.5
2021	337.3	2317	23740	7573	4330	1245	826.2	702.7	249.1	262.0

Table 4. Sole in Subarea 4: Time-series of discards at age (in thousands).

year	1	2	3	4	5	6	7	8	9	10+
2002	6461	12606	5212	1029	272.0	0.0	0.0	0.00	0.00	0.000
2003	1156	7152	5059	1212	381.0	0.0	0.0	0.00	0.00	0.000
2004	293	12832	7449	1719	518.0	12.0	0.0	0.00	0.00	0.000
2005	2256	5622	4796	1258	375.0	63.0	22.0	0.00	0.00	0.000
2006	2390	5727	2705	654	197.0	28.0	18.0	7.00	0.00	0.000
2007	818	4923	3010	619	226.0	57.0	4.0	0.00	0.00	0.000
2008	1230	2704	1764	371	106.0	0.0	8.0	0.00	0.00	0.000
2009	2695	6480	3652	999	266.0	5.0	9.0	0.00	0.00	0.000
2010	5687	12164	6670	1544	493.0	31.0	10.0	2.00	2.00	0.000
2011	3457	10298	5482	1273	354.0	33.0	0.0	0.00	0.00	0.000
2012	1132	19556	9444	984	230.0	232.0	36.0	4.00	7.00	1.000
2013	4653	5733	12558	3649	340.0	125.0	19.0	3.00	0.00	0.000
2014	7162	5836	2371	3488	1366.0	238.0	198.0	6.00	0.00	0.000
2015	9454	9166	3913	1991	1528.0	415.0	15.0	50.00	8.00	1.000
2016	5145	5338	5048	1393	291.0	536.0	226.0	4.00	1.00	1.000
2017	6083	4171	3633	2712	469.0	89.0	342.0	138.00	0.00	0.000
2018	2928	7760	1704	1448	1186.0	98.0	15.0	125.00	36.00	0.000
2019	12596	8610	5486	1640	788.6	793.9	233.1	18.53	79.48	0.812
2020	2454	17136	2126	1175	308.98	68.01	61.19	11.94	5.24	0.00
2021	2323	2034	5549	938.22	478.94	39.35	8.27	20.32	2.59	0.00

Table 5. Sole in Subarea 4: Time-series of the mean weights-at-age in the landings.

year	1	2	3	4	5	6	7	8	9	10+
1957	0.15	0.15	0.18	0.20	0.25	0.28	0.29	0.34	0.44	0.41
1958	0.15	0.14	0.18	0.22	0.25	0.27	0.31	0.32	0.39	0.41
1959	0.15	0.16	0.19	0.23	0.26	0.30	0.33	0.32	0.37	0.43
1960	0.15	0.15	0.18	0.23	0.25	0.28	0.30	0.31	0.38	0.42
1961	0.15	0.15	0.17	0.21	0.26	0.29	0.32	0.30	0.35	0.42
1962	0.15	0.15	0.17	0.21	0.24	0.29	0.32	0.32	0.33	0.41
1963	0.15	0.16	0.17	0.22	0.26	0.31	0.32	0.39	0.38	0.48
1964	0.15	0.17	0.21	0.25	0.27	0.31	0.33	0.35	0.39	0.48
1965	0.15	0.17	0.21	0.25	0.29	0.28	0.34	0.38	0.40	0.48
1966	0.15	0.18	0.19	0.18	0.30	0.33	0.43	0.40	0.45	0.50
1967	0.15	0.19	0.20	0.25	0.28	0.39	0.42	0.34	0.42	0.49
1968	0.16	0.19	0.21	0.27	0.33	0.34	0.35	0.46	0.47	0.51
1969	0.15	0.19	0.20	0.26	0.31	0.37	0.55	0.40	0.47	0.52
1970	0.15	0.21	0.22	0.28	0.35	0.40	0.44	0.46	0.44	0.53
1971	0.14	0.19	0.24	0.32	0.36	0.42	0.42	0.49	0.53	0.55
1972	0.17	0.20	0.25	0.33	0.43	0.42	0.53	0.48	0.56	0.63
1973	0.15	0.21	0.24	0.35	0.40	0.45	0.55	0.57	0.51	0.59
1974	0.16	0.19	0.23	0.34	0.42	0.45	0.52	0.56	0.61	0.65
1975	0.13	0.18	0.23	0.32	0.41	0.46	0.53	0.59	0.63	0.67
1976	0.14	0.19	0.22	0.31	0.39	0.44	0.51	0.56	0.67	0.66
1977	0.15	0.19	0.24	0.31	0.37	0.42	0.43	0.52	0.56	0.62
1978	0.15	0.20	0.23	0.31	0.37	0.43	0.47	0.42	0.57	0.67
1979	0.14	0.21	0.25	0.32	0.39	0.45	0.53	0.54	0.61	0.76
1980	0.14	0.20	0.24	0.33	0.37	0.42	0.50	0.55	0.60	0.68
1981	0.14	0.19	0.23	0.32	0.38	0.42	0.44	0.52	0.54	0.63
1982	0.14	0.19	0.22	0.31	0.37	0.41	0.44	0.49	0.58	0.66
1983	0.13	0.18	0.22	0.30	0.39	0.42	0.47	0.49	0.51	0.64
1984	0.15	0.17	0.22	0.29	0.36	0.39	0.47	0.56	0.57	0.63
1985	0.12	0.19	0.22	0.29	0.36	0.43	0.45	0.54	0.61	0.64
1986	0.14	0.18	0.21	0.30	0.36	0.41	0.48	0.54	0.57	0.61
1987	0.14	0.18	0.20	0.28	0.36	0.38	0.43	0.48	0.39	0.66
1988	0.13	0.17	0.22	0.27	0.35	0.43	0.48	0.52	0.56	0.71
1989	0.12	0.17	0.22	0.29	0.34	0.38	0.46	0.49	0.47	0.61
1990	0.12	0.18	0.23	0.29	0.37	0.41	0.41	0.51	0.48	0.62
1991	0.13	0.19	0.21	0.26	0.32	0.44	0.44	0.47	0.51	0.56
1992	0.15	0.18	0.21	0.26	0.30	0.38	0.41	0.46	0.49	0.56
1993	0.10	0.17	0.20	0.24	0.26	0.30	0.34	0.44	0.50	0.60
1994	0.14	0.18	0.20	0.23	0.26	0.30	0.32	0.43	0.41	0.51
1995	0.15	0.19	0.20	0.25	0.27	0.32	0.34	0.36	0.44	0.59
1996	0.16	0.18	0.20	0.23	0.27	0.28	0.32	0.37	0.39	0.59

year	1	2	3	4	5	6	7	8	9	10+
1997	0.15	0.18	0.21	0.24	0.27	0.30	0.32	0.31	0.38	0.44
1998	0.13	0.18	0.19	0.25	0.26	0.29	0.34	0.29	0.34	0.50
1999	0.16	0.18	0.21	0.23	0.29	0.32	0.35	0.37	0.37	0.45
2000	0.14	0.17	0.20	0.25	0.29	0.30	0.32	0.37	0.40	0.43
2001	0.14	0.18	0.20	0.27	0.28	0.33	0.39	0.41	0.43	0.49
2002	0.14	0.18	0.21	0.24	0.28	0.31	0.37	0.32	0.57	0.54
2003	0.14	0.18	0.21	0.26	0.27	0.32	0.34	0.34	0.50	0.43
2004	0.13	0.18	0.21	0.25	0.26	0.28	0.38	0.37	0.33	0.42
2005	0.17	0.18	0.21	0.24	0.24	0.28	0.27	0.38	0.32	0.40
2006	0.16	0.19	0.22	0.26	0.29	0.32	0.29	0.36	0.40	0.40
2007	0.15	0.18	0.20	0.24	0.25	0.27	0.29	0.30	0.28	0.33
2008	0.15	0.18	0.22	0.24	0.27	0.32	0.31	0.30	0.31	0.42
2009	0.14	0.18	0.20	0.26	0.28	0.28	0.33	0.33	0.30	0.40
2010	0.16	0.18	0.22	0.24	0.27	0.31	0.28	0.31	0.36	0.38
2011	0.15	0.16	0.19	0.23	0.24	0.27	0.27	0.29	0.34	0.35
2012	0.10	0.17	0.18	0.23	0.26	0.23	0.27	0.26	0.28	0.27
2013	0.12	0.17	0.18	0.22	0.25	0.27	0.30	0.28	0.31	0.47
2014	0.15	0.19	0.21	0.23	0.26	0.27	0.25	0.28	0.32	0.35
2015	0.14	0.17	0.20	0.24	0.26	0.27	0.30	0.29	0.33	0.32
2016	0.14	0.17	0.20	0.24	0.27	0.28	0.27	0.29	0.33	0.30
2017	0.11	0.17	0.19	0.23	0.28	0.27	0.31	0.31	0.28	0.35
2018	0.12	0.17	0.20	0.23	0.26	0.26	0.24	0.26	0.27	0.28
2019	0.14	0.16	0.18	0.22	0.23	0.22	0.25	0.23	0.21	0.31
2020	0.15	0.16	0.18	0.21	0.24	0.24	0.21	0.24	0.22	0.21
2021	0.13	0.16	0.18	0.21	0.24	0.25	0.27	0.24	0.22	0.35

Table 6. Sole in Subarea 4: Time-series of the mean weights-at-age in the discards.

year	1	2	3	4	5	6	7	8	9	10+
1957	0.06	0.08	0.10	0.10	0.11	0.11	0.12	0.13	0.14	0.14
1958	0.06	0.08	0.10	0.10	0.11	0.11	0.12	0.13	0.14	0.14
1959	0.06	0.08	0.10	0.10	0.11	0.11	0.12	0.13	0.14	0.14
1960	0.06	0.08	0.10	0.10	0.11	0.11	0.12	0.13	0.14	0.14
1961	0.06	0.08	0.10	0.10	0.11	0.11	0.12	0.13	0.14	0.14
1962	0.06	0.08	0.10	0.10	0.11	0.11	0.12	0.13	0.14	0.14
1963	0.06	0.08	0.10	0.10	0.11	0.11	0.12	0.13	0.14	0.14
1964	0.06	0.08	0.10	0.10	0.11	0.11	0.12	0.13	0.14	0.14
1965	0.06	0.08	0.10	0.10	0.11	0.11	0.12	0.13	0.14	0.14
1966	0.06	0.08	0.10	0.10	0.11	0.11	0.12	0.13	0.14	0.14
1967	0.06	0.08	0.10	0.10	0.11	0.11	0.12	0.13	0.14	0.14
1968	0.06	0.08	0.10	0.10	0.11	0.11	0.12	0.13	0.14	0.14
1969	0.06	0.08	0.10	0.10	0.11	0.11	0.12	0.13	0.14	0.14
1970	0.06	0.08	0.10	0.10	0.11	0.11	0.12	0.13	0.14	0.14
1971	0.06	0.08	0.10	0.10	0.11	0.11	0.12	0.13	0.14	0.14
1972	0.06	0.08	0.10	0.10	0.11	0.11	0.12	0.13	0.14	0.14
1973	0.06	0.08	0.10	0.10	0.11	0.11	0.12	0.13	0.14	0.14
1974	0.06	0.08	0.10	0.10	0.11	0.11	0.12	0.13	0.14	0.14
1975	0.06	0.08	0.10	0.10	0.11	0.11	0.12	0.13	0.14	0.14
1976	0.06	0.08	0.10	0.10	0.11	0.11	0.12	0.13	0.14	0.14
1977	0.06	0.08	0.10	0.10	0.11	0.11	0.12	0.13	0.14	0.14
1978	0.06	0.08	0.10	0.10	0.11	0.11	0.12	0.13	0.14	0.14
1979	0.06	0.08	0.10	0.10	0.11	0.11	0.12	0.13	0.14	0.14
1980	0.06	0.08	0.10	0.10	0.11	0.11	0.12	0.13	0.14	0.14
1981	0.06	0.08	0.10	0.10	0.11	0.11	0.12	0.13	0.14	0.14
1982	0.06	0.08	0.10	0.10	0.11	0.11	0.12	0.13	0.14	0.14
1983	0.06	0.08	0.10	0.10	0.11	0.11	0.12	0.13	0.14	0.14
1984	0.06	0.08	0.10	0.10	0.11	0.11	0.12	0.13	0.14	0.14
1985	0.06	0.08	0.10	0.10	0.11	0.11	0.12	0.13	0.14	0.14
1986	0.06	0.08	0.10	0.10	0.11	0.11	0.12	0.13	0.14	0.14
1987	0.06	0.08	0.10	0.10	0.11	0.11	0.12	0.13	0.14	0.14
1988	0.06	0.08	0.10	0.10	0.11	0.11	0.12	0.13	0.14	0.14
1989	0.06	0.08	0.10	0.10	0.11	0.11	0.12	0.13	0.14	0.14
1990	0.06	0.08	0.10	0.10	0.11	0.11	0.12	0.13	0.14	0.14
1991	0.06	0.08	0.10	0.10	0.11	0.11	0.12	0.13	0.14	0.14
1992	0.06	0.08	0.10	0.10	0.11	0.11	0.12	0.13	0.14	0.14
1993	0.06	0.08	0.10	0.10	0.11	0.11	0.12	0.13	0.14	0.14
1994	0.06	0.08	0.10	0.10	0.11	0.11	0.12	0.13	0.14	0.14
1995	0.06	0.08	0.10	0.10	0.11	0.11	0.12	0.13	0.14	0.14
1996	0.06	0.08	0.10	0.10	0.11	0.11	0.12	0.13	0.14	0.14

year	1	2	3	4	5	6	7	8	9	10+
1997	0.06	0.08	0.10	0.10	0.11	0.11	0.12	0.13	0.14	0.14
1998	0.06	0.08	0.10	0.10	0.11	0.11	0.12	0.13	0.14	0.14
1999	0.06	0.08	0.10	0.10	0.11	0.11	0.12	0.13	0.14	0.14
2000	0.06	0.08	0.10	0.10	0.11	0.11	0.12	0.13	0.14	0.14
2001	0.06	0.08	0.10	0.10	0.11	0.11	0.12	0.13	0.14	0.14
2002	0.05	0.07	0.08	0.09	0.10	0.11	0.12	0.14	0.14	0.14
2003	0.05	0.09	0.10	0.11	0.11	0.11	0.12	0.14	0.14	0.14
2004	0.07	0.09	0.10	0.11	0.12	0.10	0.12	0.14	0.14	0.14
2005	0.07	0.09	0.10	0.11	0.11	0.10	0.11	0.14	0.14	0.14
2006	0.07	0.08	0.10	0.11	0.11	0.12	0.11	0.12	0.14	0.14
2007	0.07	0.09	0.10	0.10	0.11	0.10	0.12	0.14	0.14	0.14
2008	0.06	0.09	0.10	0.11	0.12	0.11	0.11	0.14	0.14	0.14
2009	0.07	0.09	0.10	0.11	0.11	0.13	0.10	0.14	0.14	0.14
2010	0.07	0.08	0.10	0.10	0.11	0.11	0.11	0.12	0.12	0.12
2011	0.05	0.08	0.09	0.10	0.11	0.10	0.11	0.12	0.13	0.13
2012	0.06	0.07	0.09	0.10	0.11	0.08	0.12	0.12	0.12	0.12
2013	0.04	0.07	0.09	0.10	0.12	0.09	0.11	0.12	0.12	0.12
2014	0.05	0.08	0.09	0.10	0.11	0.10	0.12	0.10	0.15	0.15
2015	0.03	0.08	0.10	0.09	0.10	0.12	0.13	0.12	0.16	0.16
2016	0.02	0.07	0.09	0.10	0.11	0.11	0.12	0.22	0.21	0.21
2017	0.05	0.07	0.09	0.09	0.10	0.12	0.11	0.11	0.29	0.29
2018	0.04	0.07	0.09	0.09	0.10	0.10	0.10	0.10	0.01	0.01
2019	0.04	0.07	0.08	0.09	0.10	0.11	0.11	0.10	0.12	0.13
2020	0.05	0.07	0.08	0.09	0.09	0.10	0.11	0.13	0.11	0.11
2021	0.07	0.08	0.09	0.10	0.11	0.12	0.12	0.10	0.11	0.11

Table 7. Sole in Subarea 4: Time-series of the mean weights-at-age in the stock.

year	1	2	3	4	5	6	7	8	9	10+
1957	0.03	0.07	0.15	0.19	0.21	0.25	0.26	0.35	0.39	0.37
1958	0.03	0.07	0.16	0.20	0.23	0.23	0.30	0.32	0.39	0.42
1959	0.03	0.07	0.16	0.20	0.24	0.27	0.29	0.28	0.30	0.43
1960	0.03	0.07	0.16	0.21	0.23	0.24	0.27	0.24	0.36	0.43
1961	0.03	0.07	0.15	0.21	0.23	0.23	0.26	0.27	0.28	0.40
1962	0.03	0.07	0.15	0.19	0.24	0.30	0.29	0.28	0.27	0.44
1963	0.03	0.07	0.15	0.19	0.24	0.28	0.31	0.36	0.33	0.47
1964	0.03	0.07	0.16	0.21	0.24	0.29	0.30	0.31	0.36	0.47
1965	0.03	0.14	0.20	0.22	0.25	0.30	0.34	0.36	0.53	0.46
1966	0.03	0.07	0.16	0.15	0.39	0.31	0.41	0.38	0.39	0.50
1967	0.03	0.18	0.16	0.23	0.24	0.40	0.36	0.28	0.38	0.46
1968	0.03	0.12	0.17	0.25	0.31	0.28	0.63	0.42	0.41	0.49
1969	0.03	0.14	0.17	0.25	0.32	0.36	0.58	0.41	0.47	0.52
1970	0.03	0.14	0.20	0.28	0.34	0.37	0.42	0.46	0.39	0.55
1971	0.03	0.15	0.21	0.31	0.36	0.41	0.43	0.47	0.48	0.53
1972	0.04	0.15	0.22	0.31	0.42	0.44	0.44	0.44	0.51	0.60
1973	0.04	0.15	0.23	0.32	0.37	0.43	0.45	0.47	0.45	0.54
1974	0.04	0.15	0.22	0.33	0.41	0.43	0.50	0.56	0.54	0.62
1975	0.04	0.15	0.21	0.31	0.40	0.45	0.51	0.58	0.58	0.65
1976	0.04	0.14	0.20	0.30	0.38	0.46	0.51	0.52	0.64	0.66
1977	0.04	0.15	0.20	0.29	0.36	0.41	0.48	0.49	0.53	0.64
1978	0.04	0.14	0.21	0.29	0.36	0.43	0.43	0.39	0.54	0.64
1979	0.04	0.15	0.21	0.30	0.35	0.43	0.52	0.56	0.57	0.74
1980	0.04	0.16	0.20	0.30	0.34	0.39	0.49	0.54	0.58	0.65
1981	0.05	0.14	0.20	0.30	0.36	0.40	0.45	0.52	0.56	0.62
1982	0.05	0.13	0.19	0.27	0.36	0.41	0.43	0.48	0.58	0.64
1983	0.05	0.14	0.20	0.28	0.33	0.43	0.46	0.48	0.51	0.64
1984	0.05	0.13	0.20	0.27	0.35	0.39	0.49	0.59	0.57	0.66
1985	0.05	0.13	0.18	0.27	0.32	0.38	0.38	0.63	0.55	0.64
1986	0.05	0.13	0.19	0.28	0.34	0.42	0.49	0.49	0.59	0.69
1987	0.05	0.15	0.19	0.26	0.36	0.38	0.41	0.45	0.33	0.62
1988	0.05	0.13	0.19	0.26	0.34	0.41	0.42	0.47	0.49	0.65
1989	0.05	0.13	0.20	0.29	0.35	0.34	0.41	0.47	0.42	0.59
1990	0.05	0.15	0.20	0.29	0.36	0.45	0.40	0.49	0.48	0.65
1991	0.05	0.14	0.18	0.25	0.30	0.41	0.45	0.52	0.55	0.57
1992	0.05	0.16	0.19	0.26	0.31	0.40	0.41	0.47	0.50	0.54
1993	0.05	0.13	0.18	0.23	0.27	0.29	0.34	0.48	0.44	0.58
1994	0.05	0.14	0.17	0.21	0.26	0.33	0.35	0.40	0.49	0.46
1995	0.05	0.15	0.18	0.24	0.25	0.32	0.36	0.36	0.55	0.55
1996	0.05	0.15	0.18	0.21	0.27	0.27	0.32	0.38	0.40	0.55

year	1	2	3	4	5	6	7	8	9	10+
1997	0.05	0.15	0.19	0.23	0.25	0.30	0.32	0.33	0.36	0.42
1998	0.05	0.14	0.17	0.23	0.27	0.28	0.33	0.27	0.34	0.45
1999	0.05	0.13	0.19	0.22	0.26	0.30	0.34	0.32	0.37	0.46
2000	0.05	0.14	0.18	0.23	0.26	0.28	0.29	0.34	0.39	0.38
2001	0.05	0.14	0.18	0.22	0.26	0.32	0.33	0.42	0.41	0.53
2002	0.05	0.14	0.20	0.24	0.27	0.27	0.30	0.31	0.43	0.44
2003	0.05	0.15	0.19	0.24	0.26	0.29	0.33	0.31	0.51	0.47
2004	0.05	0.14	0.20	0.24	0.24	0.30	0.32	0.45	0.36	0.60
2005	0.05	0.15	0.19	0.23	0.24	0.26	0.28	0.40	0.37	0.43
2006	0.05	0.15	0.20	0.25	0.27	0.32	0.29	0.34	0.41	0.46
2007	0.05	0.15	0.18	0.22	0.24	0.24	0.28	0.25	0.26	0.36
2008	0.05	0.15	0.20	0.21	0.24	0.30	0.28	0.23	0.27	0.40
2009	0.05	0.14	0.18	0.23	0.26	0.28	0.28	0.33	0.30	0.39
2010	0.05	0.15	0.20	0.23	0.27	0.31	0.34	0.34	0.36	0.41
2011	0.05	0.14	0.18	0.22	0.26	0.28	0.32	0.36	0.44	0.39
2012	0.03	0.06	0.14	0.20	0.23	0.21	0.25	0.23	0.33	0.22
2013	0.03	0.07	0.12	0.19	0.25	0.26	0.31	0.24	0.33	0.56
2014	0.02	0.08	0.14	0.19	0.21	0.23	0.23	0.29	0.34	0.60
2015	0.07	0.07	0.14	0.15	0.23	0.24	0.26	0.29	0.37	0.39
2016	0.01	0.07	0.15	0.19	0.23	0.25	0.24	0.26	0.22	0.28
2017	0.02	0.07	0.13	0.17	0.23	0.24	0.25	0.22	0.23	0.37
2018	0.03	0.08	0.15	0.18	0.20	0.24	0.23	0.22	0.26	0.42
2019	0.03	0.07	0.13	0.15	0.19	0.17	0.18	0.22	0.19	0.25
2020	0.04	0.08	0.14	0.17	0.22	0.21	0.20	0.25	0.17	0.24
2021	0.05	0.09	0.14	0.18	0.20	0.23	0.28	0.18	0.20	0.37

Table 8. Sole in Subarea 4: Assumed values of maturity and natural mortality-at-age.

Age	Maturity	M
1	0.0	0.1
2	0.0	0.1
3	1.0	0.1
4	1.0	0.1
5	1.0	0.1
6	1.0	0.1
7	1.0	0.1
8	1.0	0.1
9	1.0	0.1
10+	1.0	0.1

Table 9. Sole in Subarea 4: Index of abundance, based on the BTS Q3 survey samples from The Netherlands, Germany and Belgium, used in the assessment.

year	1	2	3	4	5	6	7	8	9	10+
1985	917.87	695.19	633.67	347.03	163.82	76.89	0.00	0.00	20.74	40.65
1986	3179.56	1501.16	572.42	362.10	252.13	94.79	51.79	0.00	26.08	63.49
1987	913.81	2478.47	566.25	193.43	173.69	103.50	159.52	43.09	37.02	42.29
1988	9929.28	1425.94	1268.37	357.40	139.05	126.47	99.49	64.88	29.37	47.04
1989	3236.54	9329.23	869.58	826.17	129.15	73.54	63.12	23.46	6.37	60.83
1990	3642.10	3311.69	6329.24	462.19	277.81	150.15	48.95	38.41	24.88	34.00
1991	1603.07	4126.10	1738.58	2317.31	131.48	76.14	37.42	39.31	29.85	63.91
1992	14770.59	2773.15	3171.92	627.88	989.66	16.45	49.33	11.74	7.21	14.17
1993	3617.95	7638.62	440.25	1285.17	524.90	924.61	39.37	59.03	19.16	79.78
1994	3247.53	2327.80	5572.16	73.44	329.12	56.95	296.42	48.51	11.49	87.84
1995	6482.55	2076.46	1566.28	1726.19	182.67	246.41	72.19	138.13	23.34	42.90
1996	1475.51	2360.52	447.71	414.92	678.63	95.60	104.27	20.40	59.17	29.46
1997	14394.49	967.99	767.05	188.49	207.46	147.40	22.70	14.21	14.10	18.06
1998	2062.06	4552.93	187.38	253.14	65.68	64.19	97.20	7.82	15.01	32.98
1999	2548.52	1485.28	1890.70	56.61	126.82	23.16	13.01	66.26	10.04	33.73
2000	2445.62	790.61	620.49	344.25	59.64	23.12	12.42	2.47	25.71	15.76
2001	2139.83	1339.62	427.43	440.13	223.42	29.29	3.09	10.92	10.24	35.53
2002	2817.76	549.62	499.08	188.15	86.23	98.54	14.91	14.95	6.78	20.59
2003	2393.96	1219.98	332.77	225.13	67.61	50.78	54.46	4.99	4.96	9.31
2004	982.58	806.10	750.56	153.74	134.84	33.20	16.25	11.73	0.91	15.30
2005	1447.01	777.93	390.88	310.06	61.32	70.00	8.68	13.24	12.77	17.26
2006	3330.94	618.97	215.22	338.00	180.81	45.43	55.86	19.41	15.82	12.80
2007	1898.56	2447.03	277.10	110.35	125.25	119.71	26.18	23.76	12.48	14.95
2008	2222.35	1059.49	1179.09	206.84	60.47	64.09	82.97	11.57	22.52	16.14
2009	2654.86	991.77	503.22	695.67	89.25	28.50	54.49	44.16	11.99	29.91
2010	2560.67	1131.02	383.92	207.49	198.54	71.17	17.63	16.83	17.88	26.20
2011	2478.55	2295.72	592.64	203.85	166.07	161.41	25.00	12.30	18.40	25.75
2012	1181.11	3277.59	1276.54	299.91	144.83	85.62	45.75	18.00	6.20	21.69
2013	1404.78	763.31	1786.48	488.95	147.45	34.27	37.62	31.73	6.57	21.40
2014	3347.05	1882.47	427.12	801.79	351.09	81.12	26.36	28.69	18.68	6.80
2015	2608.75	2169.38	1178.22	324.48	589.47	195.44	87.11	21.63	17.64	28.10
2016	1378.56	1739.90	1187.50	603.72	179.84	314.71	89.18	19.91	2.42	29.72
2017	5733.46	1187.66	1096.36	553.82	234.50	78.24	104.67	47.74	2.22	15.94
2018	2996.16	1910.30	532.16	524.68	173.98	117.87	39.90	59.75	6.50	5.22
2019	12669.43	1526.96	1043.14	283.67	211.85	71.42	59.99	18.92	22.00	9.64
2020	1634.68	4770.22	968.37	479.72	117.26	114.51	45.55	20.99	11.78	23.68
2021	2255.55	632.53	1521.27	338.93	181.98	48.30	36.40	7.27	7.08	22.67

Table 10. Sole in Subarea 4: Index of abundance, based on the SNS survey, used in the assessment.

year	1	2	3	4	5	6
1970	5410.30	734.40	237.70	35.40	4.00	0.00
1971	902.70	1831.10	113.40	2.90	28.90	0.00
1972	1454.70	272.30	148.60	0.00	28.30	0.00
1973	5587.20	935.30	83.80	37.30	13.00	0.00
1974	2347.90	361.40	65.20	0.00	0.00	4.40
1975	525.40	864.50	177.00	17.50	0.00	17.10
1976	1399.40	73.60	229.10	26.70	5.70	0.00
1977	3742.90	776.10	103.80	43.10	31.70	3.90
1978	1547.70	1354.70	294.10	28.00	99.40	13.30
1979	93.80	408.30	300.80	76.90	0.00	16.70
1980	4312.90	88.90	109.30	61.30	3.30	0.00
1981	3737.20	1413.10	50.00	20.00	0.00	0.00
1982	5856.50	1146.20	227.80	6.70	10.00	0.00
1983	2621.10	1123.30	120.60	39.90	0.00	19.70
1984	2493.10	1099.90	318.30	74.40	8.00	0.00
1985	3619.40	715.60	167.10	49.30	4.40	0.00
1986	3705.10	457.60	69.20	31.40	16.70	0.00
1987	1947.90	943.70	64.80	21.30	0.00	0.00
1988	11226.70	593.80	281.60	81.50	10.20	15.50
1989	2830.70	5005.00	207.60	53.10	18.20	18.60
1990	2856.20	1119.50	914.30	100.40	49.60	12.50
1991	1253.60	2529.10	513.80	623.90	27.20	35.80
1992	11114.00	144.40	360.40	194.90	284.80	20.00
1993	1290.80	3419.60	153.80	212.80	0.00	191.70
1994	651.80	498.30	934.10	10.20	59.30	0.00
1995	1362.10	223.70	142.80	411.10	7.10	31.10
1996	218.40	349.10	29.60	35.50	90.00	10.00
1997	10279.30	153.60	189.80	26.50	58.10	230.00
1998	4094.60	3126.40	141.70	98.70	0.00	10.00
1999	1648.90	971.80	455.60	10.00	20.70	0.00
2000	1639.20	125.90	166.30	118.00	0.00	2.00
2001	970.30	655.40	106.70	35.50	56.20	0.00
2002	7547.50	379.00	195.30	0.00	30.80	19.20
2003						
2004	1369.50	624.40	393.00	68.90	53.10	7.50
2005	568.10	162.90	124.00	0.00	21.30	6.70
2006	2726.40	117.10	25.00	30.00	0.00	0.00
2007	848.60	911.00	33.30	39.50	14.40	0.00
2008	1259.10	258.50	325.30	0.00	10.00	0.00
2009	1931.60	344.40	61.70	102.70	0.00	0.00

year	1	2	3	4	5	6
2010	2636.90	237.10	67.10	42.20	23.20	0.00
2011	1248.00	883.90	211.30	111.80	0.00	38.00
2012	226.60	159.50	54.00	18.00	0.00	0.00
2013	967.40	426.60	490.50	179.30	50.80	7.60
2014	2849.00	448.20	44.80	60.00	33.60	0.00
2015	3192.00	2333.90	137.80	159.90	162.40	150.60
2016	733.80	623.30	494.60	109.80	16.70	42.90
2017	956.70	204.30	209.60	209.70	41.60	5.20
2018	1002.30	482.40	163.10	94.10	82.40	5.70
2019	7896.70	476.30	375.20	60.70	6.70	50.90
2020	294.70	2023.20	105.10	137.90	48.40	0.00
2021	210.60	87.70	365.40	44.80	3.60	0.00

Table 11. Sole in Subarea 4: Time series of abundances at age (in thousands) estimated by the AAP stock assessment.

year	1	2	3	4	5	6	7	8	9	10+
1957	138242	75702	86259	63112	17728	18506	35683.3	17076.0	2904.2	44887.0
1958	124971	125085	66079	63756	41784	11922	13296.5	25261.1	13633.2	34910.0
1959	442753	113077	109600	47657	44647	28361	8403.2	9624.7	19129.2	36988.7
1960	40657	400614	99096	76842	33943	29921	19505.7	6094.1	6782.7	43257.1
1961	65442	36787	348686	67236	52300	21428	19884.1	13635.0	3924.6	37142.6
1962	10643	59210	31579	229858	41429	30149	13688.7	12926.2	8166.9	27916.6
1963	12388	9629	50235	20684	133226	23187	18723.5	8363.6	7899.4	22887.2
1964	592798	11207	8155	33440	12622	79841	14340.4	11479.2	5659.5	20174.1
1965	147499	536316	9453	5457	21959	7975	50134.6	9331.4	8425.5	18370.9
1966	58474	133458	441789	6097	3685	13424	5133.6	35249.7	7040.3	20414.5
1967	97960	52909	104076	261742	4022	2056	8822.6	3789.0	26256.6	21611.5
1968	134264	88630	37634	54035	157810	2104	1358.6	6485.1	2684.8	37237.4
1969	87127	121187	56340	16791	27945	83324	1378.9	952.2	4278.5	29373.9
1970	199518	76004	71562	22966	7715	15332	54217.2	933.1	613.7	23219.7
1971	57467	170931	45501	29865	10822	4354	9992.4	37602.3	638.0	16175.1
1972	119773	50876	106988	19693	15031	6150	2826.2	7113.7	26927.1	11478.8
1973	155942	107457	32422	44096	9895	8366	3890.8	1962.1	4956.4	25811.7
1974	122768	140277	69001	12359	21032	5308	5079.7	2535.3	1260.5	20061.6
1975	60721	110083	93412	27506	5727	10968	3117.7	3198.4	1565.5	13809.5
1976	150553	53730	77326	43218	13117	2982	6394.5	2012.3	2052.9	10204.3
1977	188213	132241	38608	38564	21663	7005	1770.8	4224.9	1308.5	8291.9
1978	63038	168419	92425	17920	20066	12054	4305.3	1150.0	2538.2	6435.3
1979	17060	56846	112719	38129	9375	11392	7575.3	2700.4	623.3	5857.8
1980	186873	15389	38147	47276	19108	5146	7063.2	4695.2	1518.4	4129.4
1981	249598	167840	10673	17684	22116	9805	3044.0	4408.1	2975.5	3578.2
1982	218545	222528	116499	4953	8036	11061	5475.4	1876.8	2956.3	4247.8
1983	190580	194836	146528	46182	2329	4195	5893.3	3219.5	1223.6	4834.7
1984	89879	170248	120979	49041	22280	1253	2162.6	3284.1	1969.9	4073.3
1985	112116	80121	106529	42297	22829	11511	634.2	1181.9	1941.3	3806.1
1986	176515	100062	53120	43049	18681	11013	5841.2	352.9	710.1	3311.8
1987	87277	158977	70440	22932	19288	8967	5755.9	3380.7	224.0	2337.0
1988	650700	78895	116827	30043	11008	9857	4918.3	3478.7	2265.4	1635.2
1989	125940	588400	59383	50349	14974	5929	5685.9	3073.7	2367.2	2656.1
1990	226475	113670	445946	27893	24476	8094	3545.5	3601.4	2019.9	3431.0
1991	93233	203002	85834	233056	13213	12757	4834.1	2205.1	2253.8	3620.5
1992	502130	83862	151781	48594	114542	6450	7166.7	2815.0	1365.6	3788.7
1993	114370	453465	61468	88364	24969	52424	3277.8	3773.1	1766.2	3239.7
1994	82863	103147	319439	34034	43779	11256	24887.6	1585.6	2338.5	3049.3
1995	131169	72781	68811	154559	14780	20268	5315.0	11697.2	926.0	3153.4
1996	76352	106365	47298	28568	59709	6796	9519.7	2529.0	6188.5	2293.6

year	1	2	3	4	5	6	7	8	9	10+
1997	308852	66853	71347	18428	11252	25191	3039.3	4657.1	1192.8	4612.7
1998	141689	277865	46296	28291	7704	4324	10843.4	1519.5	2056.3	3045.4
1999	113828	127381	188841	19148	11619	3013	1949.1	5422.7	707.5	2547.4
2000	143400	99798	81961	81563	7381	4962	1470.7	966.8	2789.9	1610.4
2001	73288	118622	62974	36925	31991	3277	2466.6	739.1	516.5	2434.7
2002	209050	62244	78161	29392	16312	13718	1536.8	1289.1	379.8	1902.9
2003	97116	183634	42522	37144	14238	6837	6164.0	833.1	644.0	1553.6
2004	50811	85903	124081	20130	17999	6350	3263.8	3396.6	442.1	1361.0
2005	52313	44866	56593	58478	9369	8768	3334.6	1824.1	1974.9	916.4
2006	178625	46194	30002	27271	27150	4779	4847.1	1928.0	1123.5	1390.2
2007	68730	158111	32264	15208	13278	13932	2654.3	2903.5	1211.2	1387.5
2008	73420	60725	112709	17403	7812	6837	7641.4	1585.6	1821.9	1593.8
2009	90280	64236	42578	64001	9208	4098	3717.2	4322.3	980.1	2114.8
2010	171090	78240	44276	24401	33607	4899	2230.9	1985.2	2581.8	1844.0
2011	170820	149266	55103	24018	12144	17733	2701.2	1194.9	1116.4	2527.6
2012	46072	150475	108990	28385	11308	6290	9896.9	1479.0	629.3	2035.6
2013	87062	40533	111574	60381	13664	5835	3495.9	5217.5	758.6	1505.1
2014	147520	75303	29831	70669	31674	7183	3178.8	1660.4	2719.3	1312.7
2015	104254	123635	54875	19919	39238	17136	3846.5	1414.8	872.5	2336.1
2016	61454	85176	90288	34272	10914	21706	9135.4	1824.0	721.7	1759.1
2017	114585	50202	62440	49016	17715	5964	11391.4	4744.0	896.8	1241.1
2018	92578	95843	36558	31153	23724	8985	2969.4	6102.1	2337.6	983.8
2019	311889	79167	69401	19012	14875	11140	4302.5	1603.0	3193.3	1534.0
2020	44825	268337	58452	40489	9983	7442	5754.5	2471.9	933.6	2533.1
2021	43910	38124	207037	38619	25046	6062	4561.4	3719.8	1623.1	2286.8

Table 12. Sole in Subarea 4: Time series of fishing mortality at age estimated by the AAP stock assessment.

year	1	2	3	4	5	6	7	8	9	10+
1957	0.000	0.036	0.202	0.312	0.297	0.231	0.245	0.125	0.214	0.214
1958	0.000	0.032	0.227	0.256	0.287	0.250	0.223	0.178	0.172	0.172
1959	0.000	0.032	0.255	0.239	0.300	0.274	0.221	0.250	0.160	0.160
1960	0.000	0.039	0.288	0.285	0.360	0.309	0.258	0.340	0.198	0.198
1961	0.000	0.053	0.317	0.384	0.451	0.348	0.331	0.413	0.286	0.286
1962	0.000	0.064	0.323	0.445	0.480	0.376	0.393	0.392	0.355	0.355
1963	0.000	0.066	0.307	0.394	0.412	0.381	0.389	0.291	0.323	0.323
1964	0.000	0.070	0.302	0.321	0.359	0.365	0.330	0.209	0.241	0.241
1965	0.000	0.094	0.338	0.292	0.392	0.341	0.252	0.182	0.172	0.172
1966	0.000	0.149	0.423	0.316	0.483	0.320	0.204	0.195	0.139	0.139
1967	0.000	0.241	0.555	0.406	0.548	0.315	0.208	0.244	0.151	0.151
1968	0.002	0.353	0.707	0.559	0.539	0.323	0.255	0.316	0.207	0.207
1969	0.037	0.427	0.797	0.678	0.500	0.330	0.291	0.339	0.271	0.271
1970	0.055	0.413	0.774	0.652	0.472	0.328	0.266	0.280	0.288	0.288
1971	0.022	0.369	0.737	0.587	0.465	0.332	0.240	0.234	0.282	0.282
1972	0.009	0.351	0.786	0.588	0.486	0.358	0.265	0.261	0.297	0.297
1973	0.006	0.343	0.864	0.640	0.523	0.399	0.328	0.342	0.328	0.328
1974	0.009	0.307	0.820	0.669	0.551	0.432	0.363	0.382	0.334	0.334
1975	0.022	0.253	0.671	0.641	0.553	0.440	0.338	0.343	0.310	0.310
1976	0.030	0.230	0.596	0.591	0.527	0.421	0.314	0.330	0.291	0.291
1977	0.011	0.258	0.668	0.553	0.486	0.387	0.332	0.410	0.300	0.300
1978	0.003	0.302	0.785	0.548	0.466	0.364	0.366	0.512	0.327	0.327
1979	0.003	0.299	0.769	0.591	0.500	0.378	0.378	0.476	0.351	0.351
1980	0.007	0.266	0.669	0.660	0.567	0.425	0.371	0.356	0.356	0.356
1981	0.015	0.265	0.668	0.689	0.593	0.483	0.384	0.299	0.334	0.334
1982	0.015	0.318	0.825	0.655	0.550	0.530	0.431	0.328	0.299	0.299
1983	0.013	0.377	0.995	0.629	0.520	0.563	0.485	0.391	0.297	0.297
1984	0.015	0.369	0.951	0.665	0.560	0.581	0.504	0.426	0.362	0.362
1985	0.014	0.311	0.806	0.717	0.629	0.578	0.486	0.409	0.451	0.451
1986	0.005	0.251	0.740	0.703	0.634	0.549	0.447	0.355	0.443	0.443
1987	0.001	0.208	0.752	0.634	0.571	0.501	0.404	0.300	0.349	0.349
1988	0.001	0.184	0.742	0.596	0.519	0.450	0.370	0.285	0.284	0.284
1989	0.003	0.177	0.656	0.621	0.515	0.414	0.357	0.320	0.281	0.281
1990	0.009	0.181	0.549	0.647	0.552	0.415	0.375	0.369	0.309	0.309
1991	0.006	0.191	0.469	0.610	0.617	0.477	0.441	0.379	0.339	0.339
1992	0.002	0.211	0.441	0.566	0.682	0.577	0.542	0.366	0.364	0.364
1993	0.003	0.250	0.491	0.602	0.697	0.645	0.626	0.378	0.396	0.396
1994	0.030	0.305	0.626	0.734	0.670	0.650	0.655	0.438	0.436	0.436
1995	0.110	0.331	0.779	0.851	0.677	0.656	0.643	0.537	0.476	0.476
1996	0.033	0.299	0.843	0.832	0.763	0.705	0.615	0.651	0.509	0.509

year	1	2	3	4	5	6	7	8	9	10+
1997	0.006	0.267	0.825	0.772	0.856	0.743	0.593	0.717	0.545	0.545
1998	0.006	0.286	0.783	0.790	0.839	0.697	0.593	0.664	0.595	0.595
1999	0.032	0.341	0.740	0.853	0.751	0.617	0.601	0.565	0.604	0.604
2000	0.090	0.360	0.697	0.836	0.712	0.599	0.588	0.527	0.492	0.492
2001	0.063	0.317	0.662	0.717	0.747	0.657	0.549	0.566	0.339	0.339
2002	0.030	0.281	0.644	0.625	0.770	0.700	0.512	0.594	0.285	0.285
2003	0.023	0.292	0.648	0.625	0.707	0.639	0.496	0.534	0.379	0.379
2004	0.024	0.317	0.652	0.665	0.619	0.544	0.482	0.442	0.577	0.577
2005	0.024	0.302	0.630	0.667	0.573	0.493	0.448	0.385	0.632	0.632
2006	0.022	0.259	0.579	0.620	0.567	0.488	0.412	0.365	0.494	0.494
2007	0.024	0.238	0.517	0.566	0.564	0.501	0.415	0.366	0.389	0.389
2008	0.034	0.255	0.466	0.537	0.545	0.509	0.470	0.381	0.379	0.379
2009	0.043	0.272	0.457	0.544	0.531	0.508	0.527	0.415	0.418	0.418
2010	0.036	0.251	0.512	0.598	0.539	0.495	0.524	0.476	0.460	0.460
2011	0.027	0.214	0.563	0.653	0.558	0.483	0.502	0.541	0.482	0.482
2012	0.028	0.199	0.491	0.631	0.562	0.487	0.540	0.568	0.471	0.471
2013	0.045	0.207	0.357	0.545	0.543	0.507	0.645	0.552	0.445	0.445
2014	0.077	0.216	0.304	0.488	0.514	0.525	0.709	0.543	0.446	0.446
2015	0.102	0.214	0.371	0.502	0.492	0.529	0.646	0.573	0.501	0.501
2016	0.102	0.211	0.511	0.560	0.504	0.545	0.555	0.610	0.593	0.593
2017	0.079	0.217	0.595	0.626	0.579	0.597	0.524	0.608	0.676	0.676
2018	0.056	0.223	0.554	0.639	0.656	0.636	0.517	0.548	0.673	0.673
2019	0.050	0.203	0.439	0.544	0.592	0.561	0.454	0.441	0.524	0.524
2020	0.062	0.159	0.314	0.380	0.399	0.390	0.336	0.321	0.316	0.316
2021	0.090	0.115	0.214	0.240	0.230	0.239	0.227	0.222	0.167	0.167

Table 13. Sole in Subarea 4: Time series of spawning stock biomass and mean fishing mortality, plus lower and upper confidence intervals, estimated by the AAP stock assessment.

Year	SSB	SSB lower	SSB upper	F	F lower	F upper
1957	65786	57264	74308	0.216	0.175	0.256
1958	68123	59414	76832	0.211	0.184	0.237
1959	71875	63433	80317	0.220	0.189	0.252
1960	74984	66409	83559	0.256	0.223	0.289
1961	107430	96316	118544	0.311	0.271	0.350
1962	90031	80877	99185	0.338	0.293	0.383
1963	72286	64491	80081	0.312	0.275	0.349
1964	54228	47206	61250	0.283	0.242	0.325
1965	44095	37040	51150	0.291	0.252	0.331
1966	105570	91600	119540	0.338	0.291	0.386
1967	104560	93630	115490	0.413	0.357	0.469
1968	92398	83302	101494	0.496	0.436	0.556
1969	71925	64495	79355	0.546	0.467	0.626
1970	65431	58403	72459	0.528	0.465	0.591
1971	55794	49681	61907	0.498	0.428	0.568
1972	63500	56213	70787	0.514	0.452	0.576
1973	47538	42254	52822	0.554	0.487	0.620
1974	47015	41690	52340	0.556	0.489	0.623
1975	48328	42922	53734	0.511	0.459	0.564
1976	47283	42478	52088	0.473	0.415	0.531
1977	38735	35314	42156	0.470	0.420	0.520
1978	44998	39849	50147	0.493	0.429	0.557
1979	53582	47560	59604	0.507	0.449	0.566
1980	40139	36532	43746	0.517	0.465	0.570
1981	27099	24896	29302	0.539	0.480	0.599
1982	38947	33921	43973	0.575	0.521	0.630
1983	53048	44903	61193	0.616	0.541	0.692
1984	52755	46449	59061	0.625	0.564	0.687
1985	47284	41945	52623	0.608	0.544	0.672
1986	38970	35780	42160	0.575	0.519	0.631
1987	35159	31959	38359	0.533	0.484	0.583
1988	43949	38997	48901	0.498	0.443	0.553
1989	39805	36395	43215	0.477	0.434	0.520
1990	117490	100840	134140	0.469	0.418	0.520
1991	90858	81749	99967	0.473	0.431	0.515
1992	86633	79438	93828	0.495	0.449	0.541
1993	59130	54846	63414	0.537	0.485	0.589
1994	89494	78647	100341	0.597	0.548	0.647
1995	67997	60814	75180	0.659	0.591	0.726
1996	40288	37200	43376	0.688	0.635	0.742

Year	SSB	SSB lower	SSB upper	F	F lower	F upper
1997	33039	29595	36483	0.693	0.630	0.756
1998	23948	21819	26077	0.679	0.623	0.735
1999	47202	39855	54549	0.660	0.604	0.717
2000	39354	34882	43826	0.641	0.580	0.702
2001	31964	29109	34819	0.620	0.574	0.666
2002	32467	29159	35775	0.604	0.548	0.659
2003	26129	23955	28303	0.582	0.538	0.626
2004	38902	34051	43753	0.560	0.509	0.611
2005	31627	28699	34555	0.533	0.486	0.580
2006	24719	22857	26581	0.503	0.460	0.546
2007	17965	16661	19269	0.477	0.430	0.524
2008	33596	29942	37250	0.462	0.425	0.499
2009	29829	27187	32471	0.462	0.416	0.509
2010	28217	26156	30278	0.479	0.440	0.518
2011	26061	23829	28293	0.494	0.450	0.539
2012	28925	26169	31681	0.474	0.432	0.516
2013	32691	29967	35415	0.432	0.397	0.467
2014	28619	26465	30773	0.410	0.369	0.450
2015	26480	24601	28359	0.422	0.386	0.457
2016	31209	28215	34203	0.466	0.417	0.516
2017	26775	24405	29145	0.523	0.467	0.579
2018	20977	18903	23051	0.542	0.464	0.619
2019	18951	16265	21637	0.468	0.380	0.556
2020	21761	17713	25809	0.328	0.254	0.403
2021	45001	33348	56654	0.208	0.139	0.276

Table 14. Sole in Subarea 4: Intermediate year assumptions and forecast catch option table. All weights are in tonnes.

Variable	Value	Notes
$F_{ages\ 2–6}$ (2022)	0.21	Average exploitation pattern (2017–2021), scaled to $F_{ages\ 2–6}$ in 2021
SSB (2023)	38 776	Short-term forecast (STF), in tonnes.
$R_{age\ 1}$ (2022, 2023)	110 824	Geometric mean of recruitment (GM; 1957–2020), in thousands.
Total catch (2022)	10 429	STF, in tonnes.
Projected landings (2022)	9605	STF, assuming average landing ratio by age 2019–2021, in tonnes.
Projected discards (2022)	824	STF, assuming average discard ratio by age 2019–2021, in tonnes.

Basis	Total catch* (2023)	Projected landings (2023)	Projected discards ** (2023)	F_{total}[#] (ages 2–6) (2023)	$F_{projected\ landings}$ (ages 2–6) (2023)	$F_{projected\ discards}$ (ages 1–3) (2023)	SSB (2024)	% SSB change ^	% TAC change ^^	% advice change ^^
ICES advice basis										
MSY approach: F_{MSY} × SSB (2023) /MSY $B_{trigger}$	9152	8467	685	0.188	0.176	0.037	41078	5.9	-40	-40
Other scenarios										
F = F_{MSY}	10012	9260	752	0.207	0.195	0.041	40315	4.0	-35	-35
F = $F_{MSY\ lower}$	6207	5747	460	0.123	0.084	0.024	43695	12.7	-60	-60
F = $F_{MSY\ lower}$ × SSB (2023) /MSY $B_{trigger}$	5652	5234	418	0.111	0.076	0.022	44189	14.0	-63	-63
F = 0	0	0	0	0	0	0	49224	27	-100	-100
F_{pa}	14276	13185	1091	0.311	0.292	0.062	36539	-5.8	-6.9	-6.9
F_{lim}	18281	16858	1422	0.42	0.395	0.083	33005	-14.9	19.2	19.2
SSB (2024) = B_{pa}	7171	6638	533	0.144	0.135	0.029	42838	10.5	-53	-53
SSB (2024) = B_{lim}	20755	19121	1634	0.493	0.464	0.098	30828	-20	35	35
SSB (2024) = MSY $B_{trigger}$	7171	6638	533	0.144	0.135	0.029	42838	10.5	-53	-53
F = F_{2022}	10031	9277	754	0.208	0.195	0.041	40299	3.9	-35	-35
Rollover advice	15330	14153	1177	0.338	0.318	0.067	35608	-8.2	0.00	0.00

*** Differences between the total catch and the sum of projected landings and discards result from rounding.**

**** Including BMS landings, assuming recent discard rate.**

^ SSB 2024 relative to SSB 2023.

^^ Total catch in 2023 relative to the advice value 2022 and TAC (15 330 tonnes).

[#] $F_{projected\ landings}$ and $F_{projected\ discards}$ do not add up to F_{total} as they are calculated using different ages.

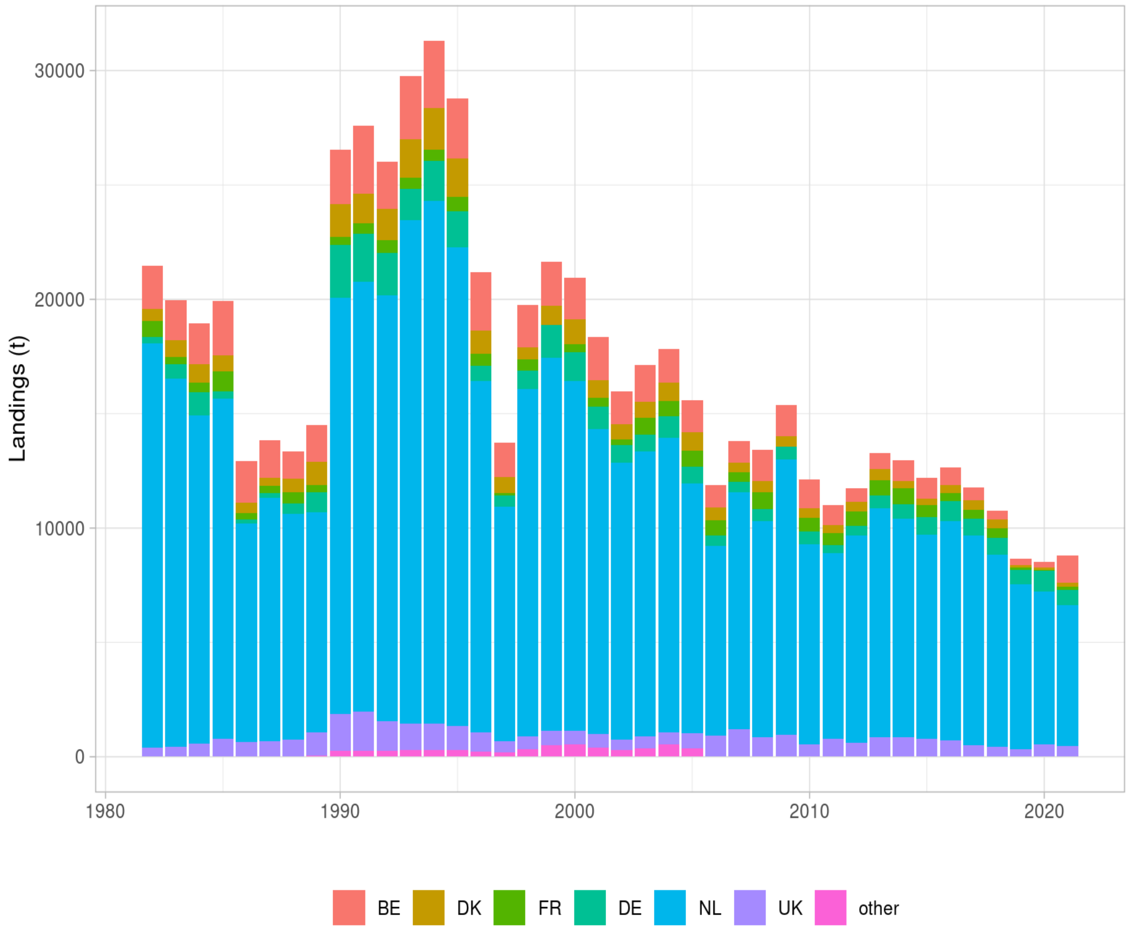


Figure 1. Sole in Subarea 4: Official landings reported to ICES by country.

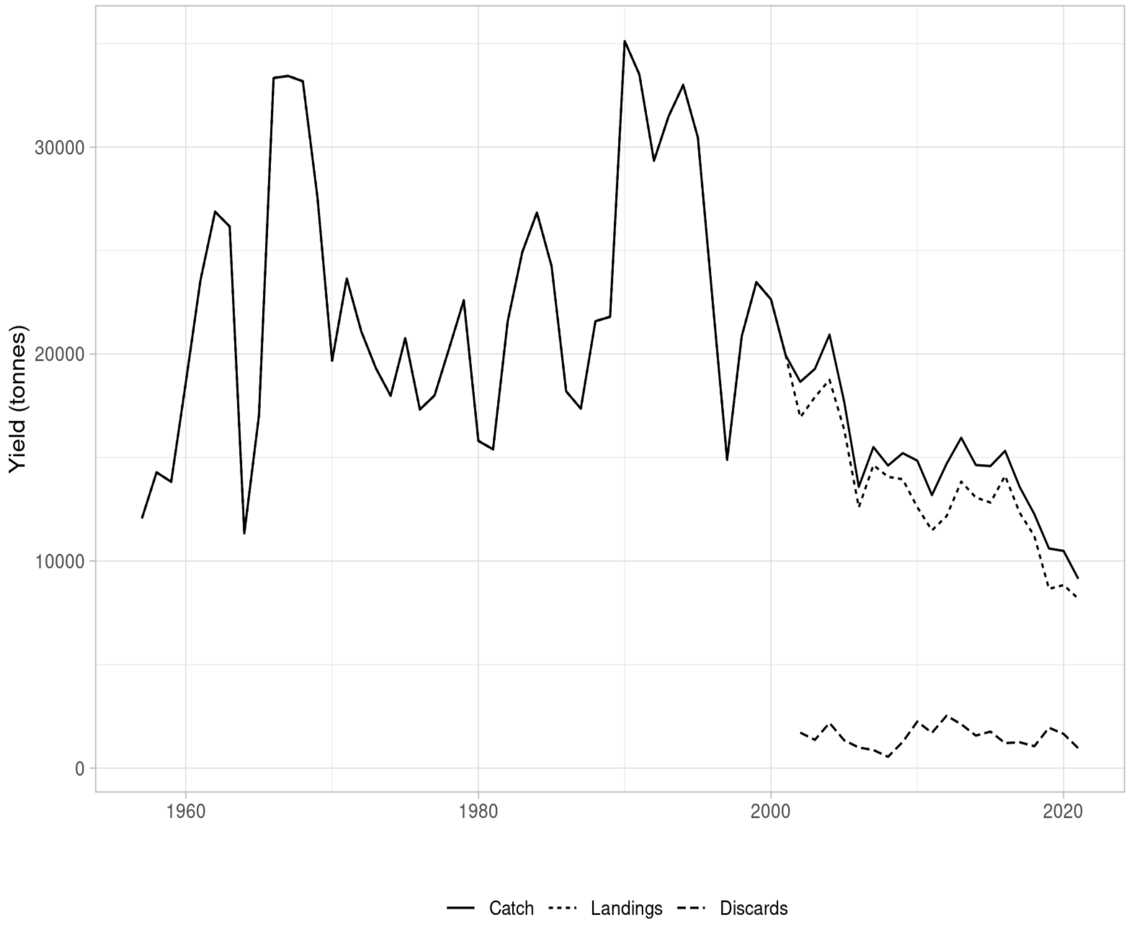


Figure 2. Sole in Subarea 4: Time series of catches, landings and discards (in tonnes) reported to ICES Intercatch.

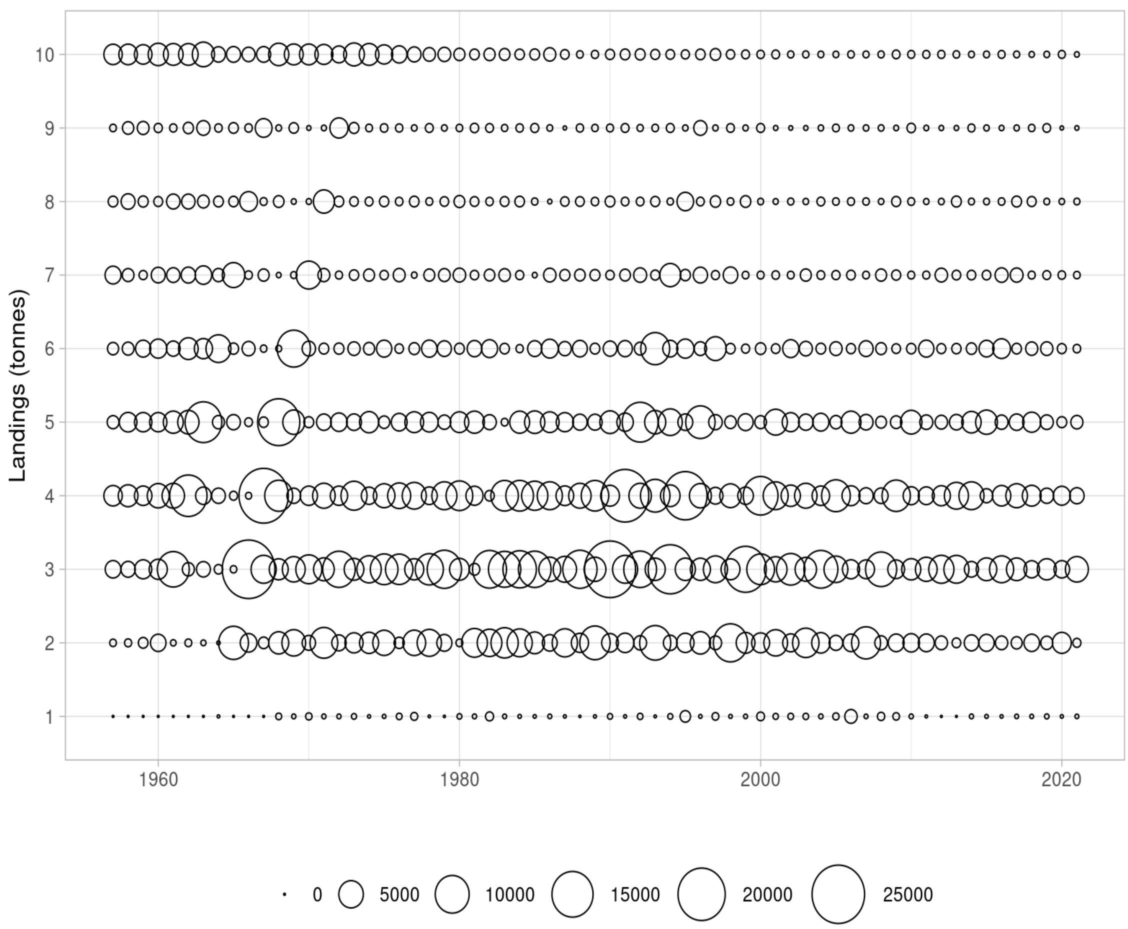


Figure 3. Sole in Subarea 4: Time series of landings at age (in thousands).

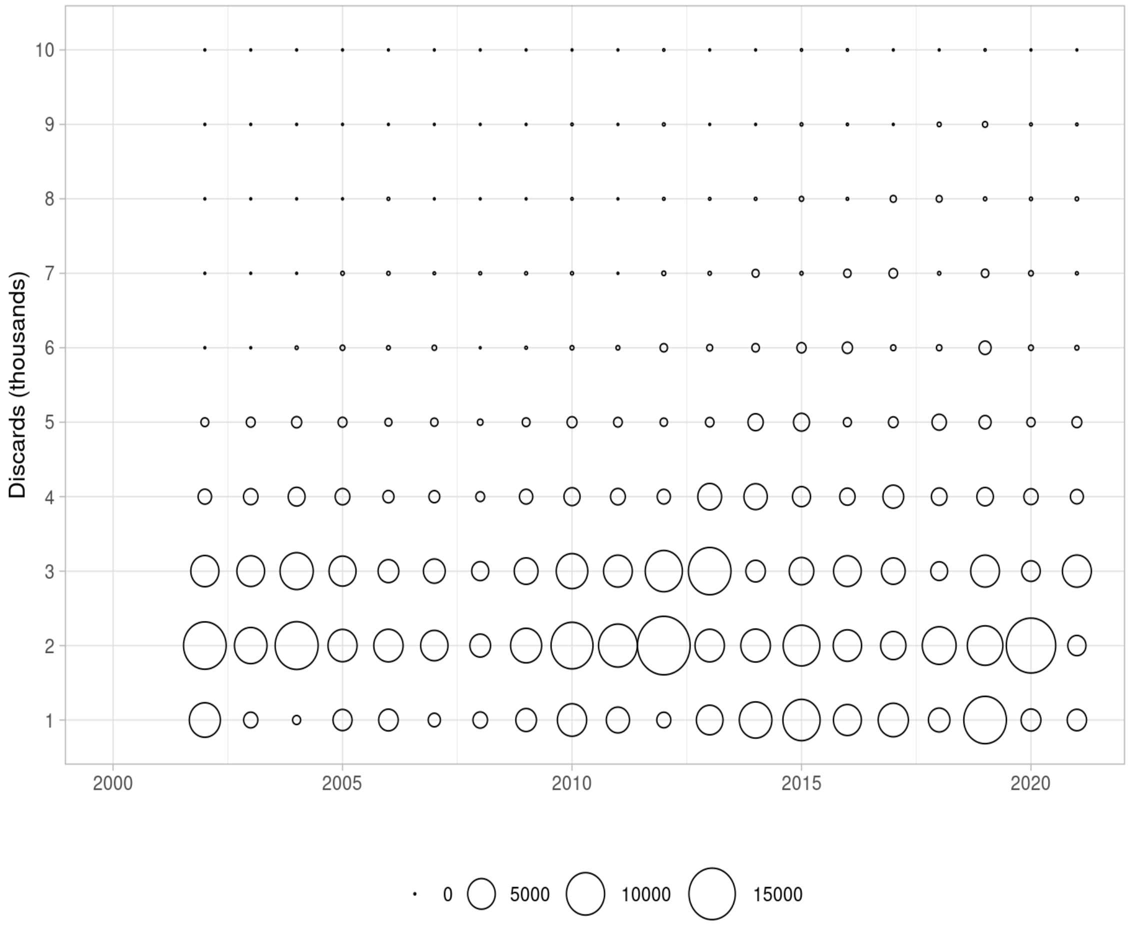


Figure 4. Sole in Subarea 4: Time series of discards at age (in thousands).

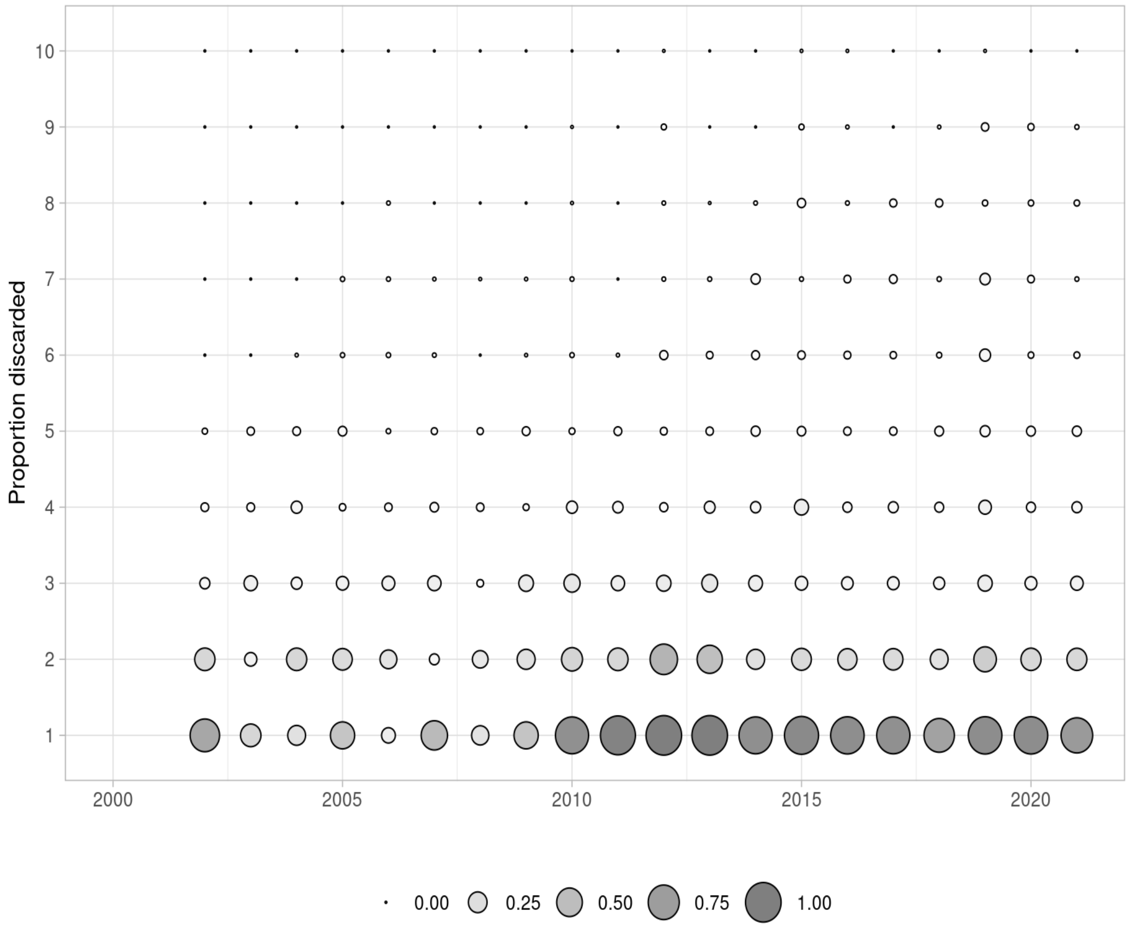


Figure 5. Sole in Subarea 4: Proportions of fish discarded by age over the 2002–2021 period.

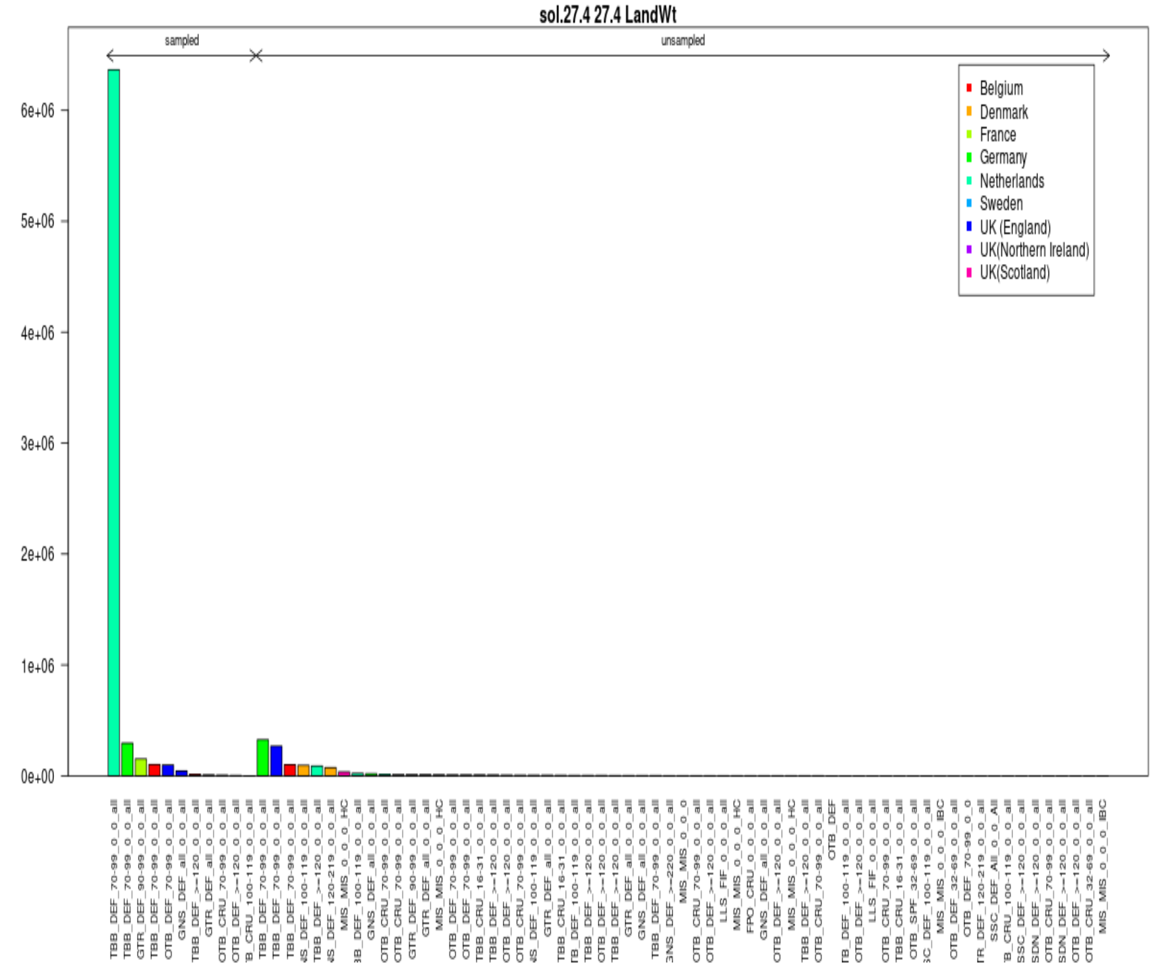


Figure 6. Sole in Subarea 4: InterCatch summary plots. Sampled and unsampled fleets for landings yield estimation (tonnes).

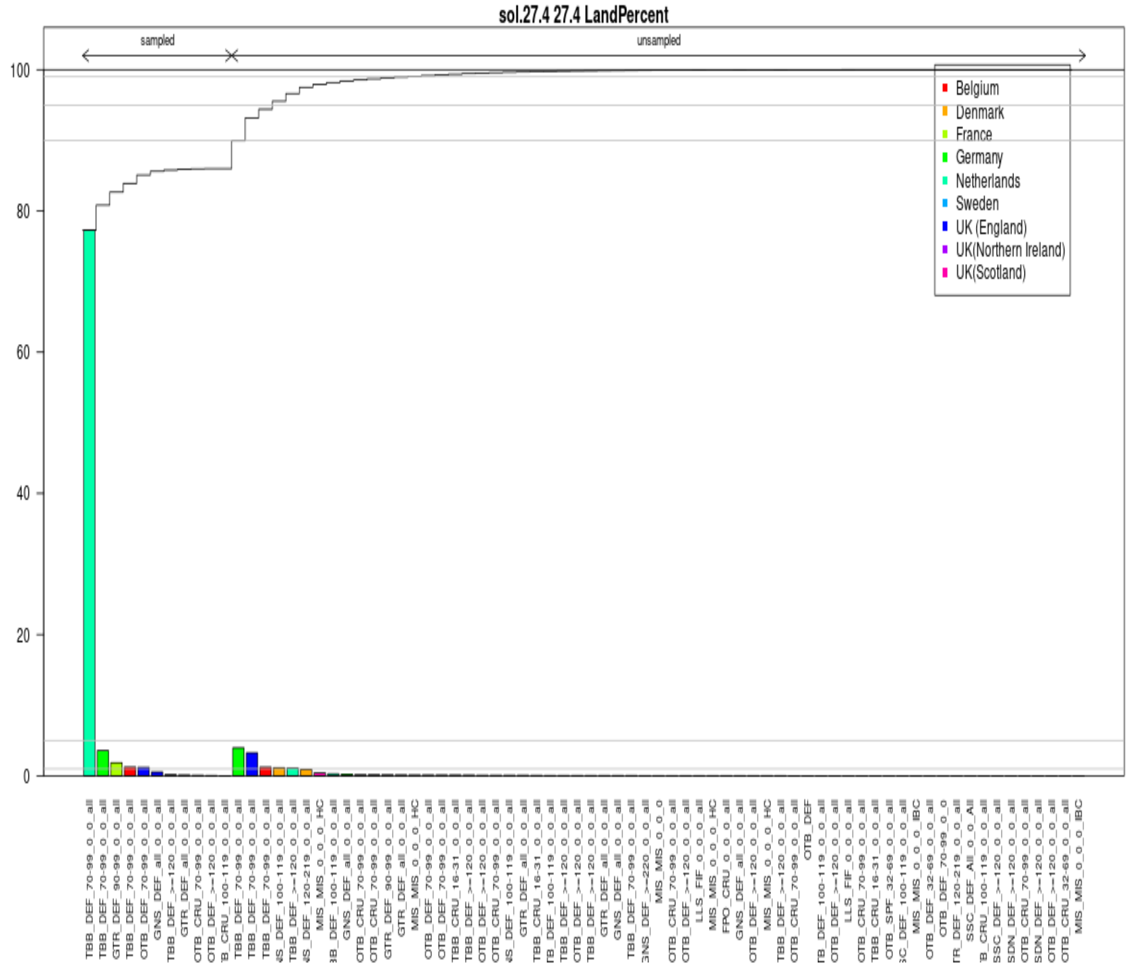


Figure 7. Sole in Subarea 4: InterCatch summary plots. Sampled and unsampled fleets for landings yield estimation (cumulative percentage).

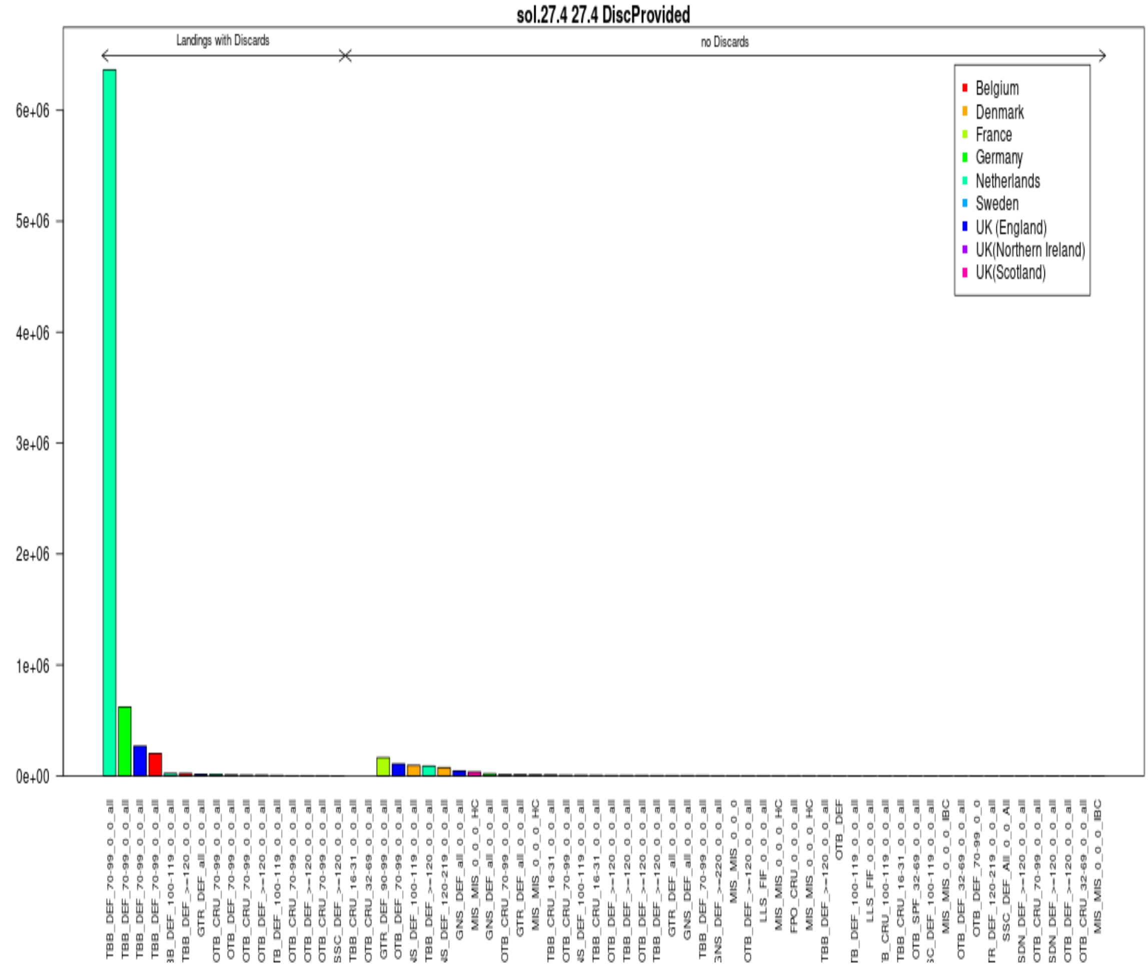


Figure 8. Sole in Subarea 4: InterCatch summary plots. Sampled and unsampled fleets for discards yield estimation (tonnes).

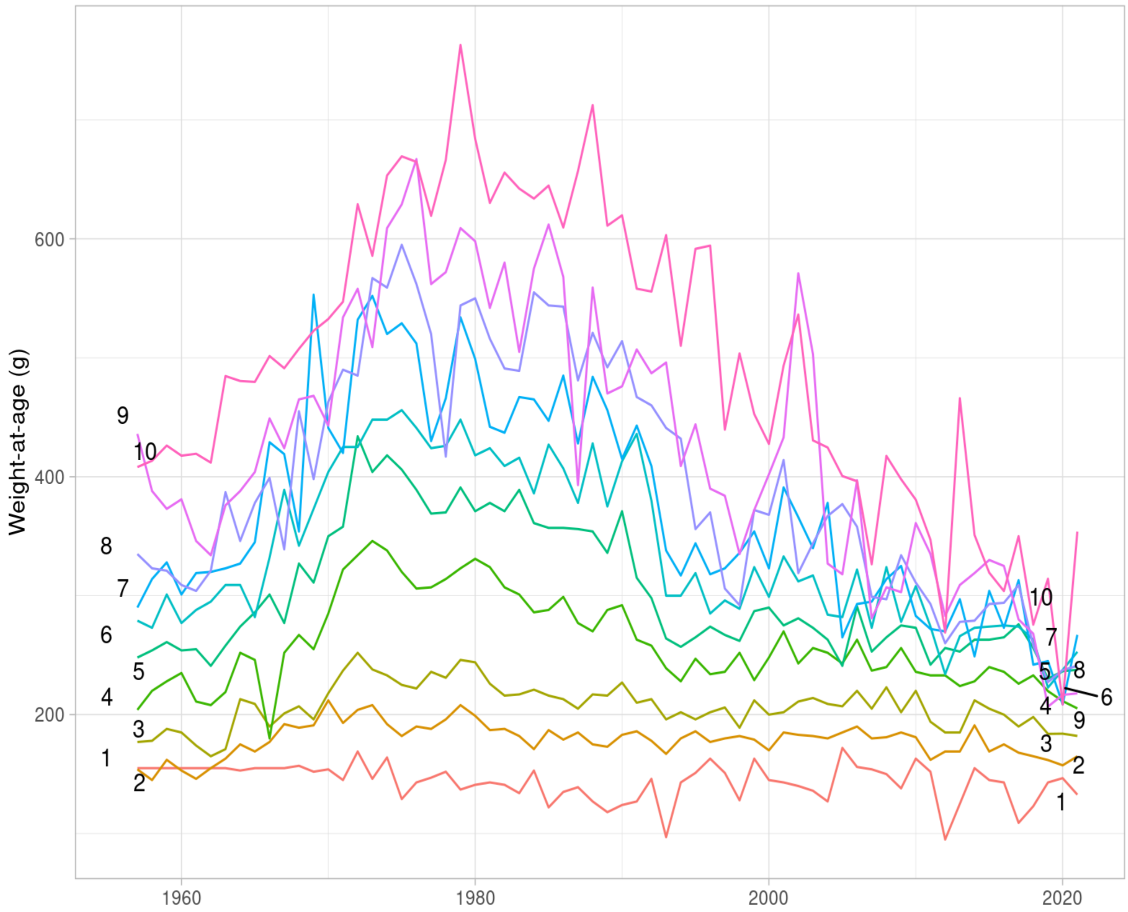


Figure 9. Sole in Subarea 4: Time series of mean weight-at-age in the landings (in grammes).

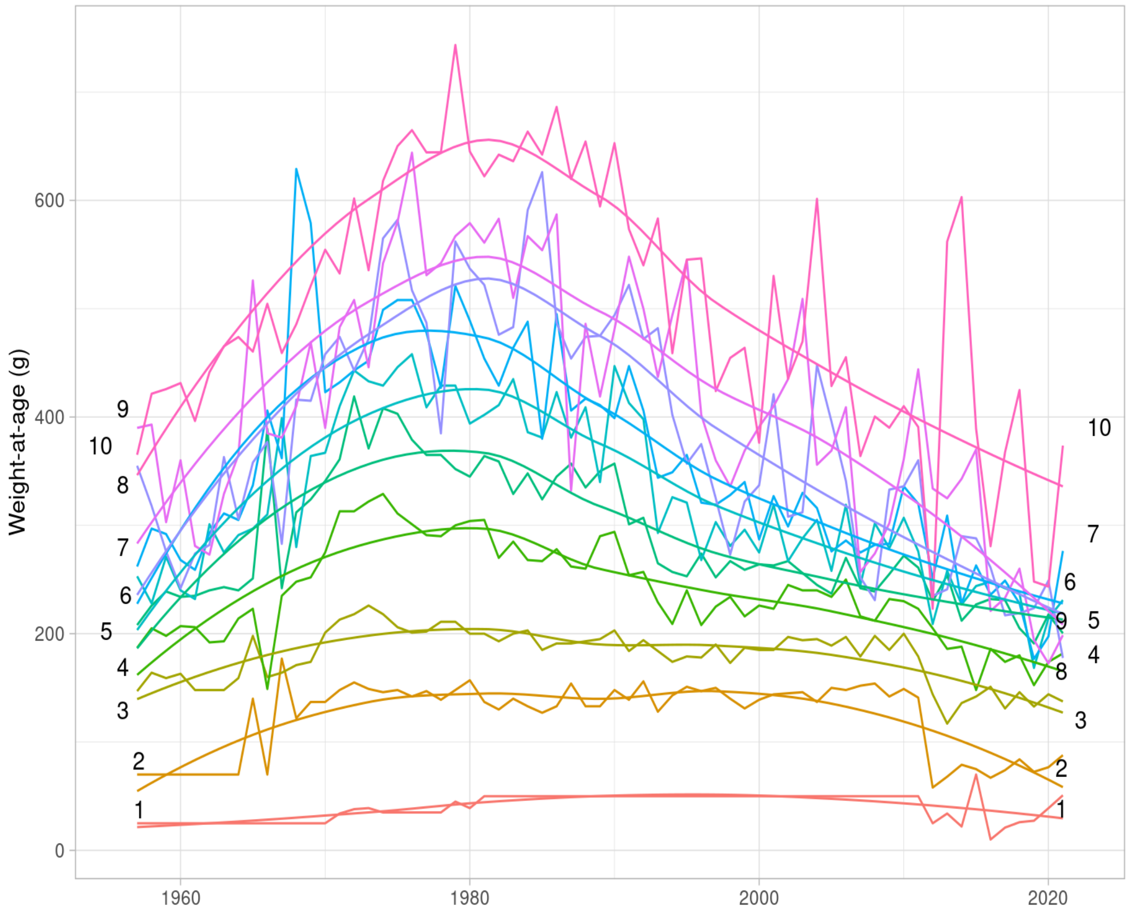


Figure 10. Sole in Subarea 4: Time series of mean weight-at-age in the stock (in grammes).

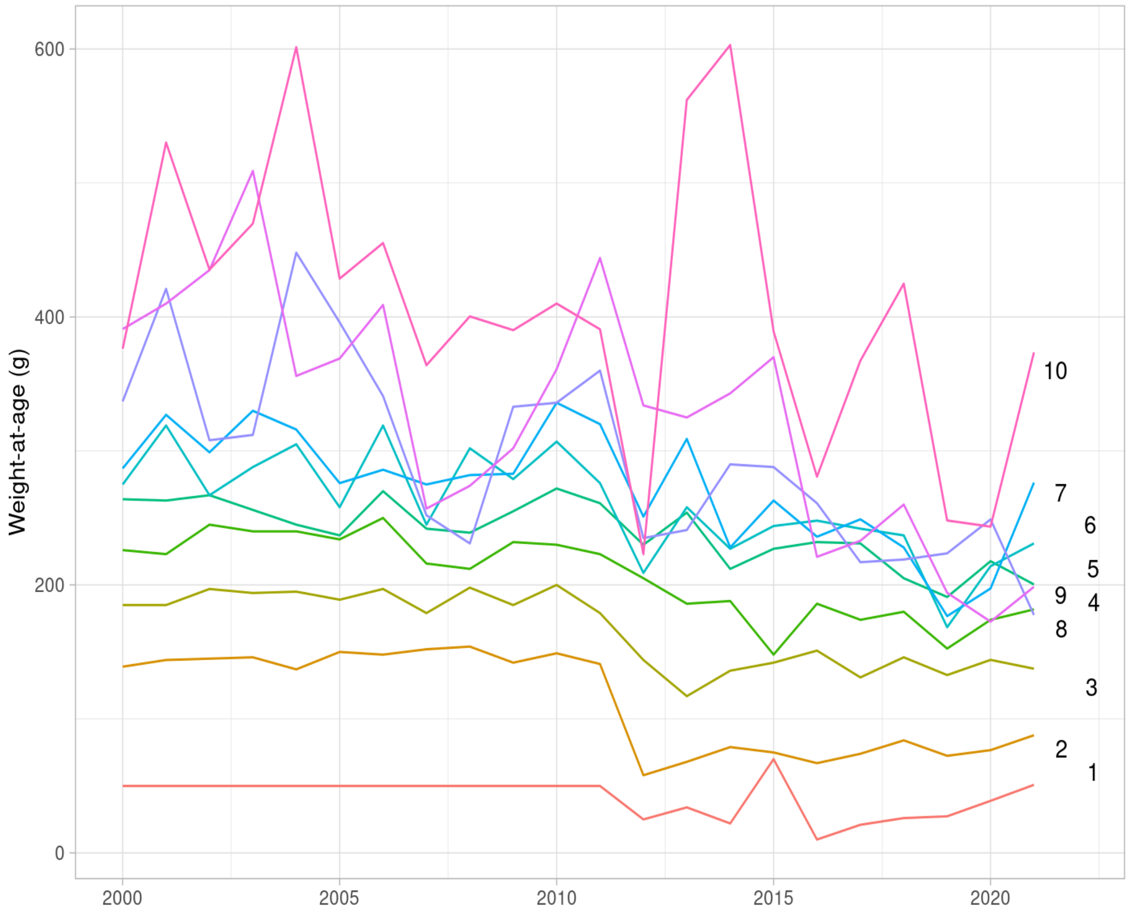


Figure 11. Sole in Subarea 4. Recent values of the time series of mean weight-at-age in the stock (in grammes).

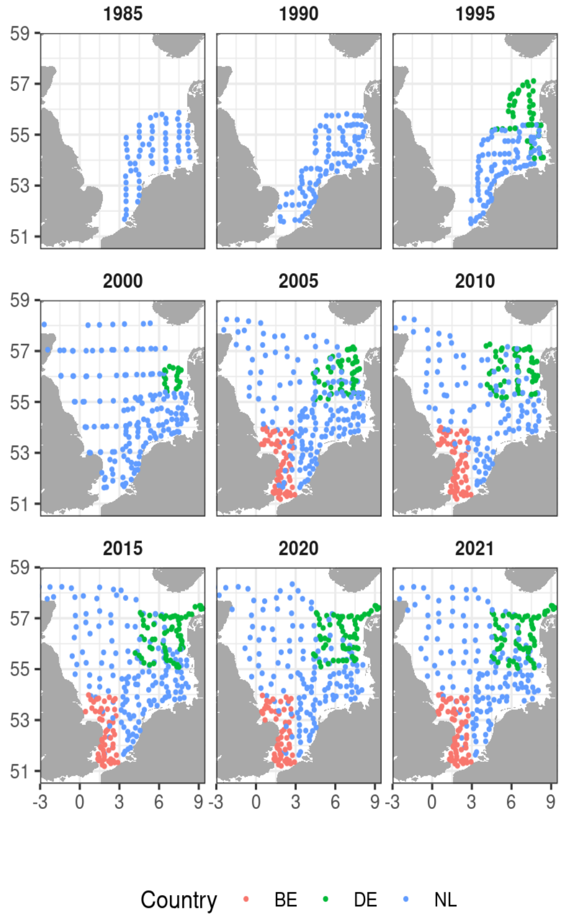


Figure 12. Sole in Subarea 4: Location of stations sampled during the BTS Q3 survey and included in the BTS index of abundance.

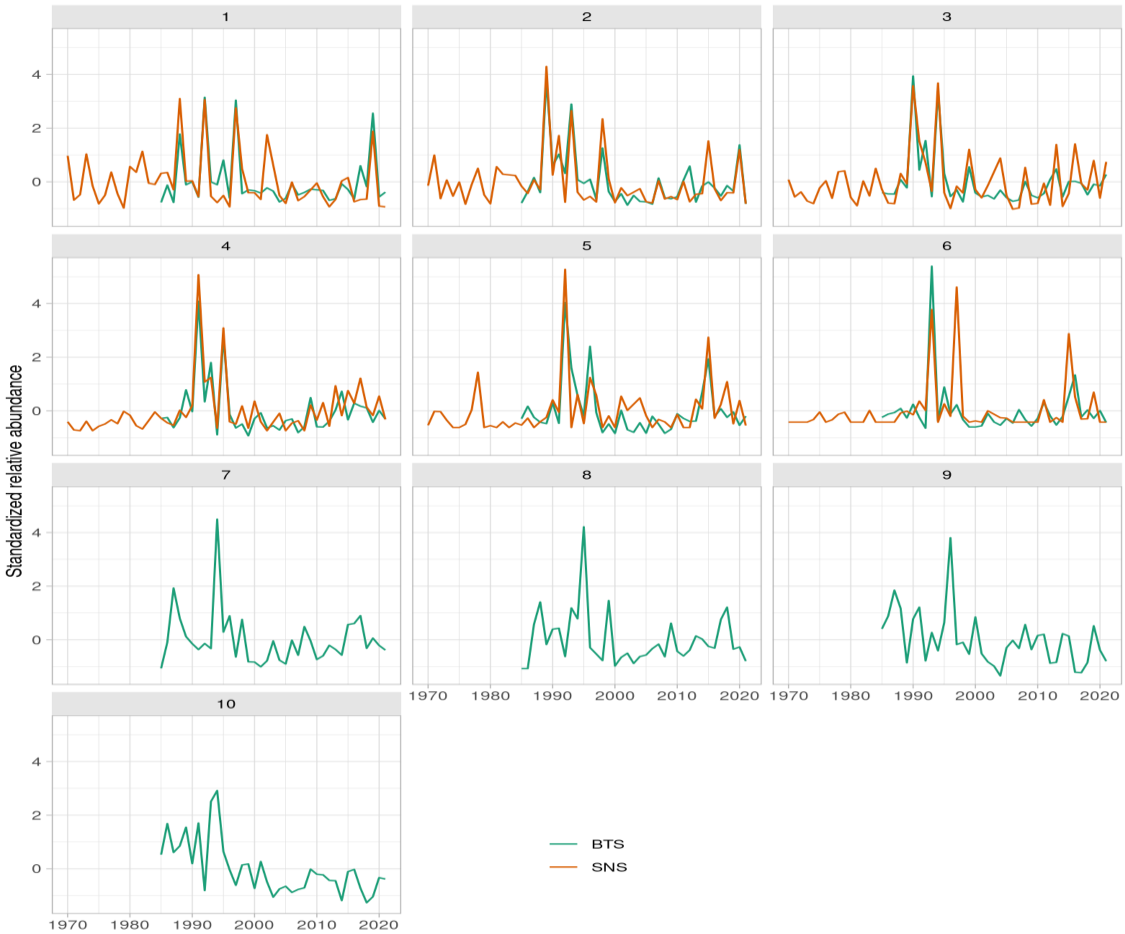


Figure 13. Sole in Subarea 4: Comparison of the time series of relative abundance at age from the BTS Q3 delta-lognormal GAM standardized (1985–2021) and SNS (1970–2021) indices of abundance.

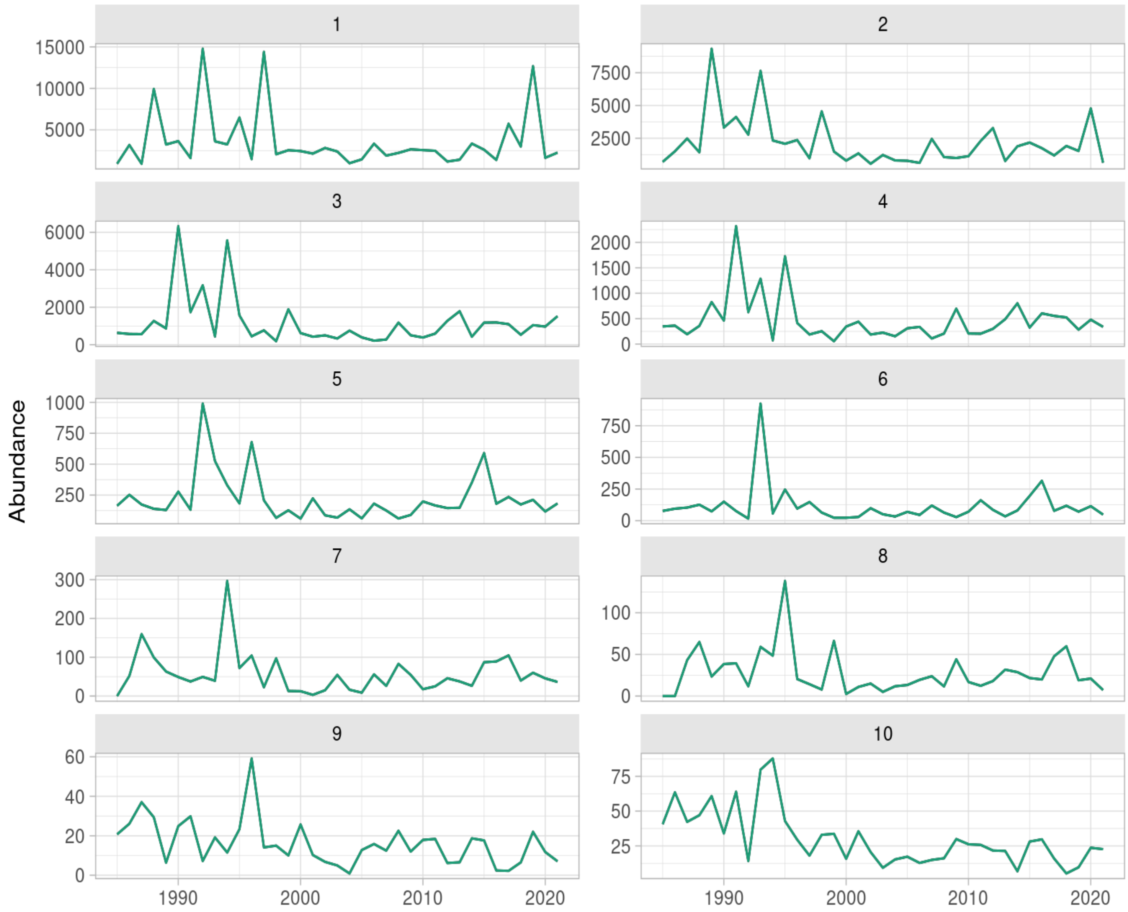


Figure 14. Sole in Subarea 4: Time series of relative abundance at age from the BTS Q3 delta-lognormal GAM standardized index of abundance (1985–2021).

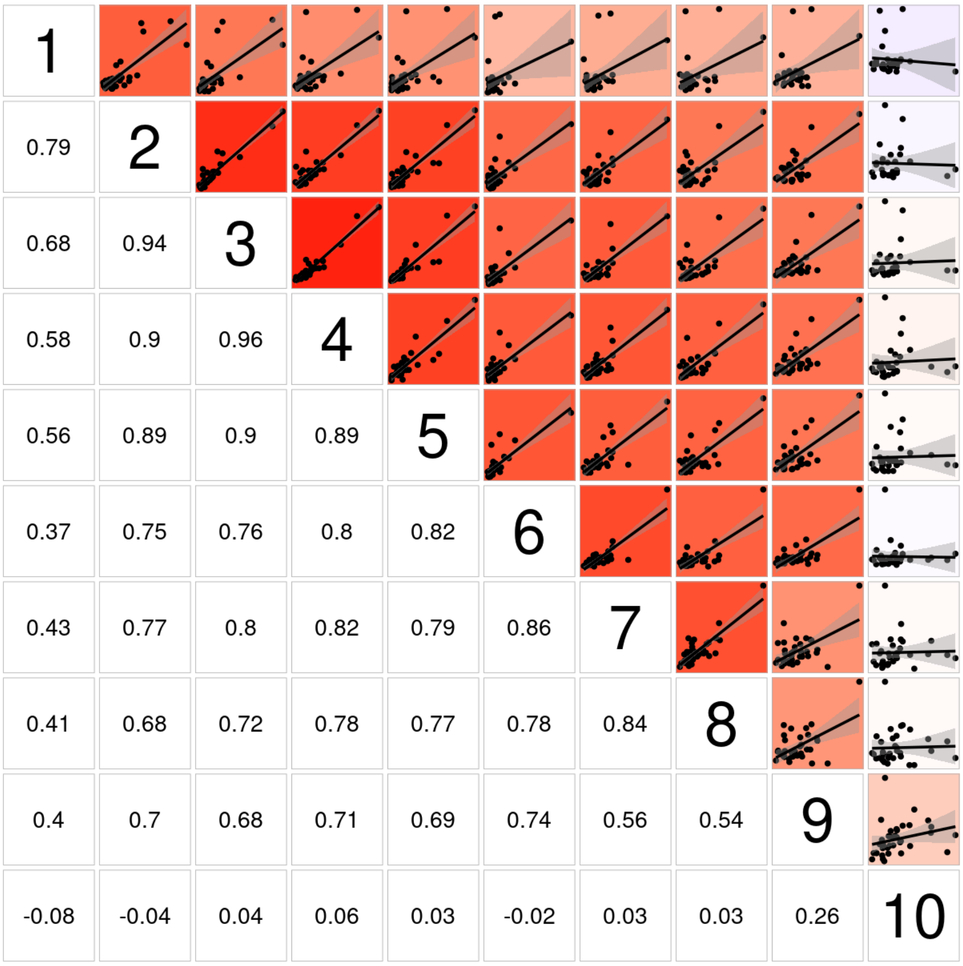


Figure 15. Sole in Subarea 4. Bivariate cross-correlation plots showing the internal consistency in signals by cohort for the BTS Q3 delta-lognormal GAM standardized index of abundance (1985–2021).

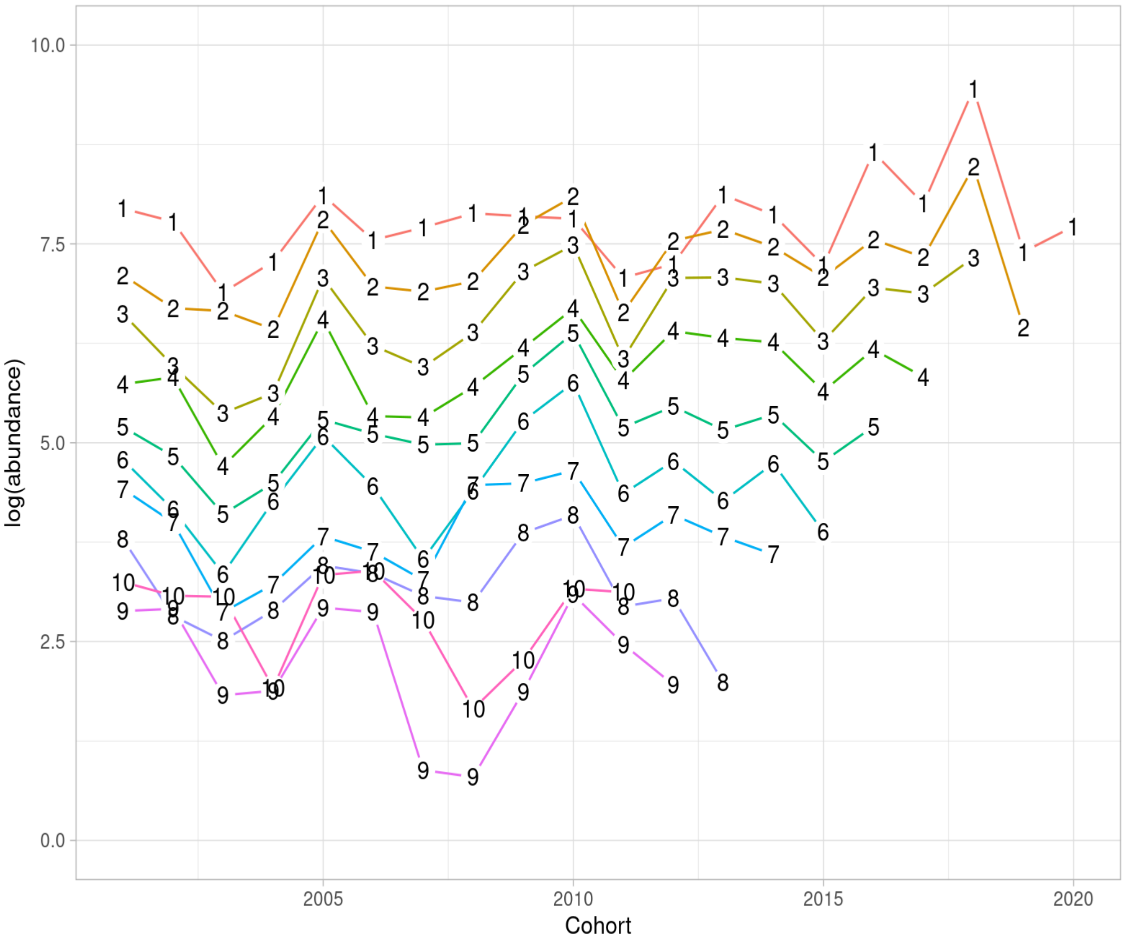


Figure 16. Sole in Subarea 4: Abundance in log scale by cohort (in the x axis) and age (coloured lines) for the BTS Q3 delta-lognormal GAM standardized index of abundance (2001–2021).

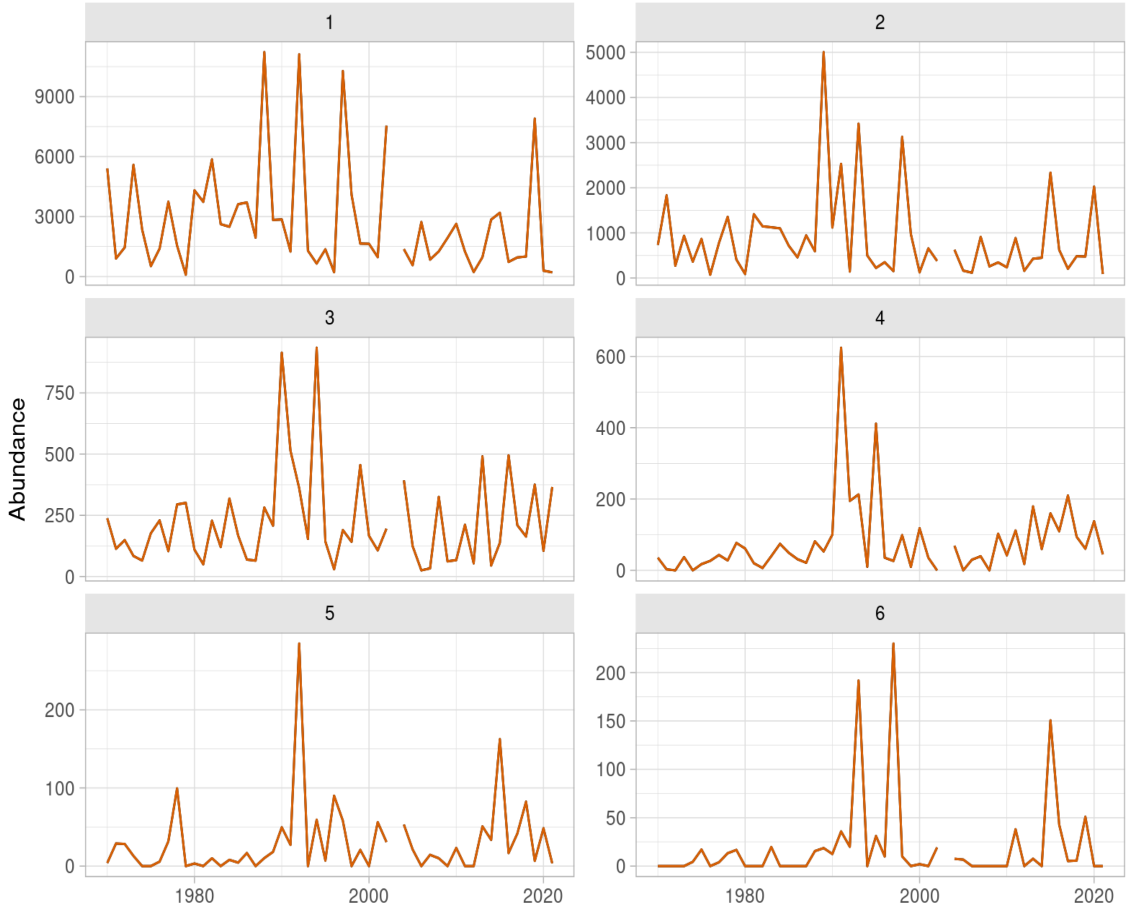


Figure 17. Sole in Subarea 4: Time series of relative abundance at age from the SNS index of abundance (1970–2021).

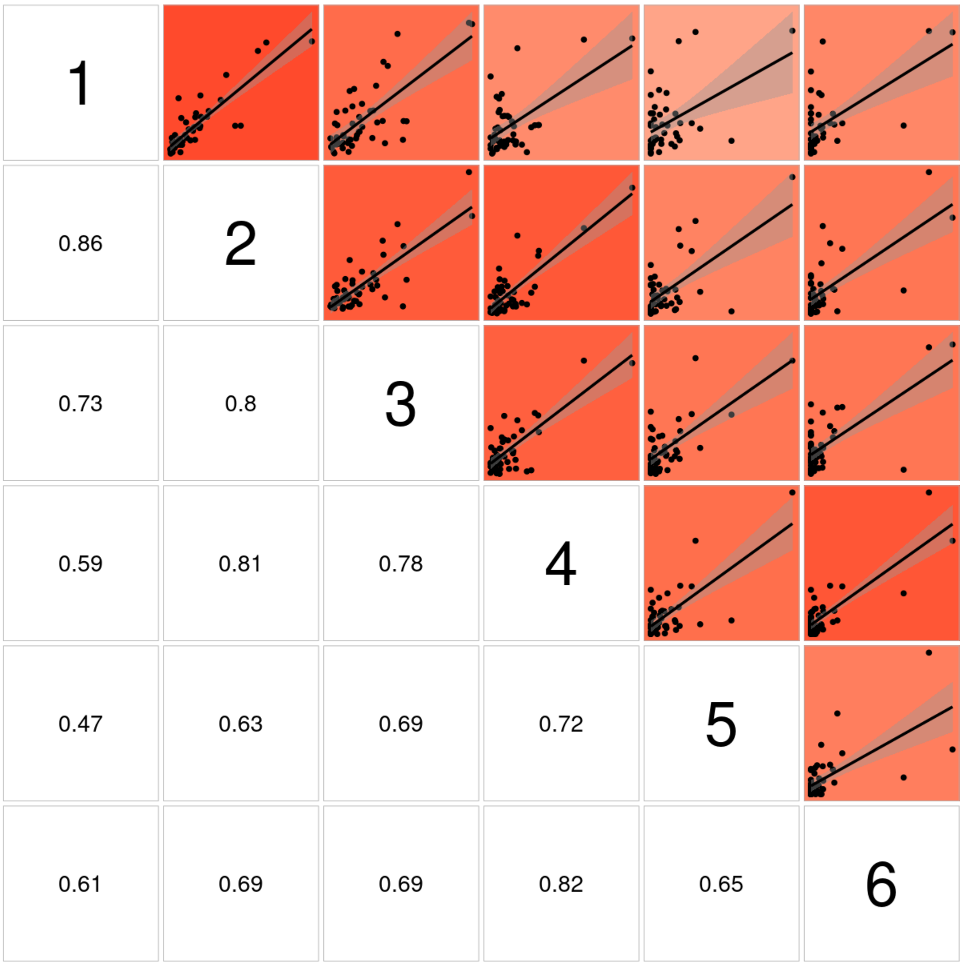


Figure 18. Sole in Subarea 4: Bivariate cross-correlation plots showing the internal consistency in signals by cohort for the SNS index of abundance (1970–2021).

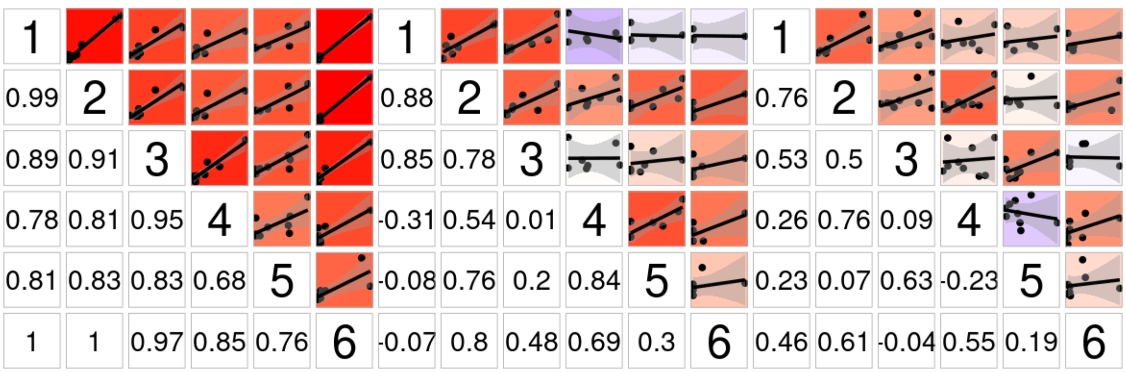


Figure 19. Sole in Subarea 4: Bivariate cross-correlation plots showing the internal consistency in signals by cohort for the SNS index of abundance, over the last three decades (left to right 1992–2001, 2002–2011 and 2012–2021).

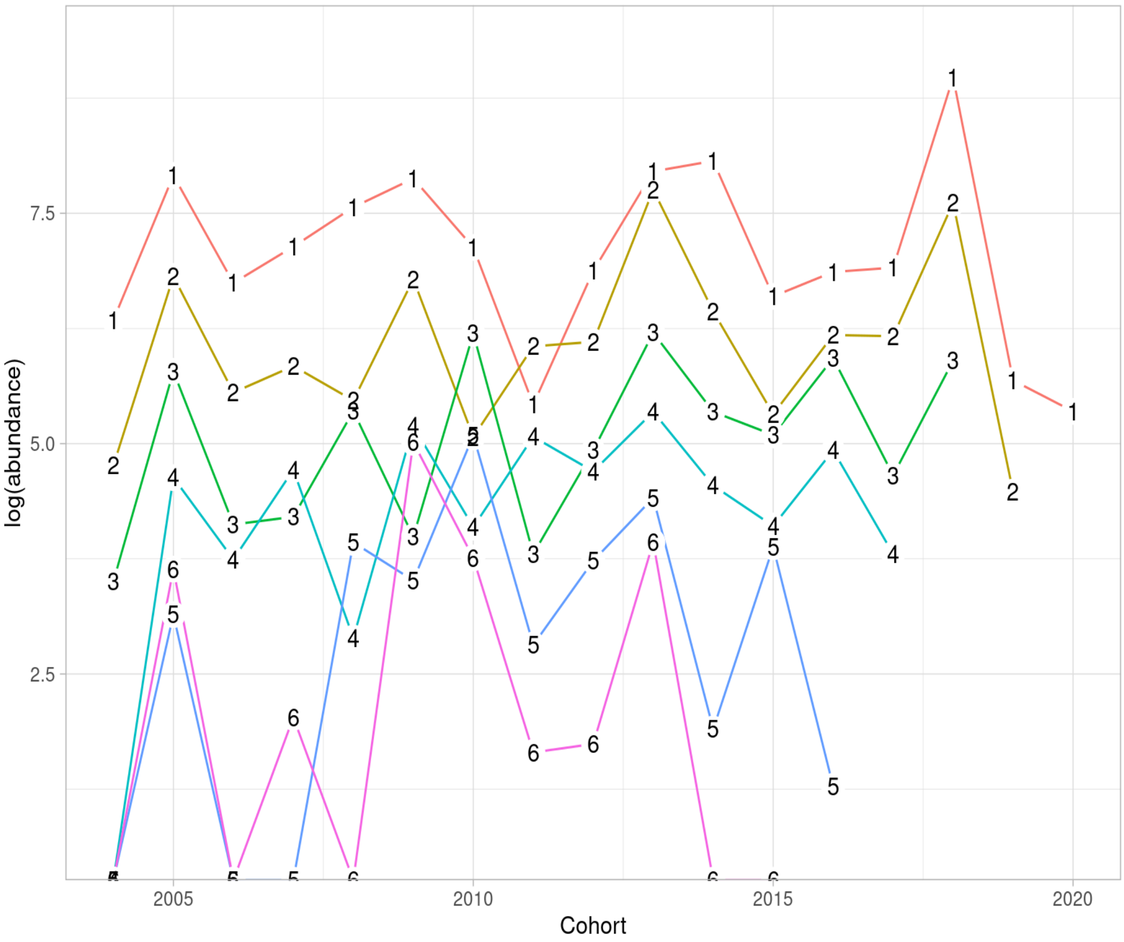


Figure 20. Sole in Subarea 4: Abundance in log scale by cohort (in the x axis) and age (coloured lines) for the SNS index of abundance (2004–2021).

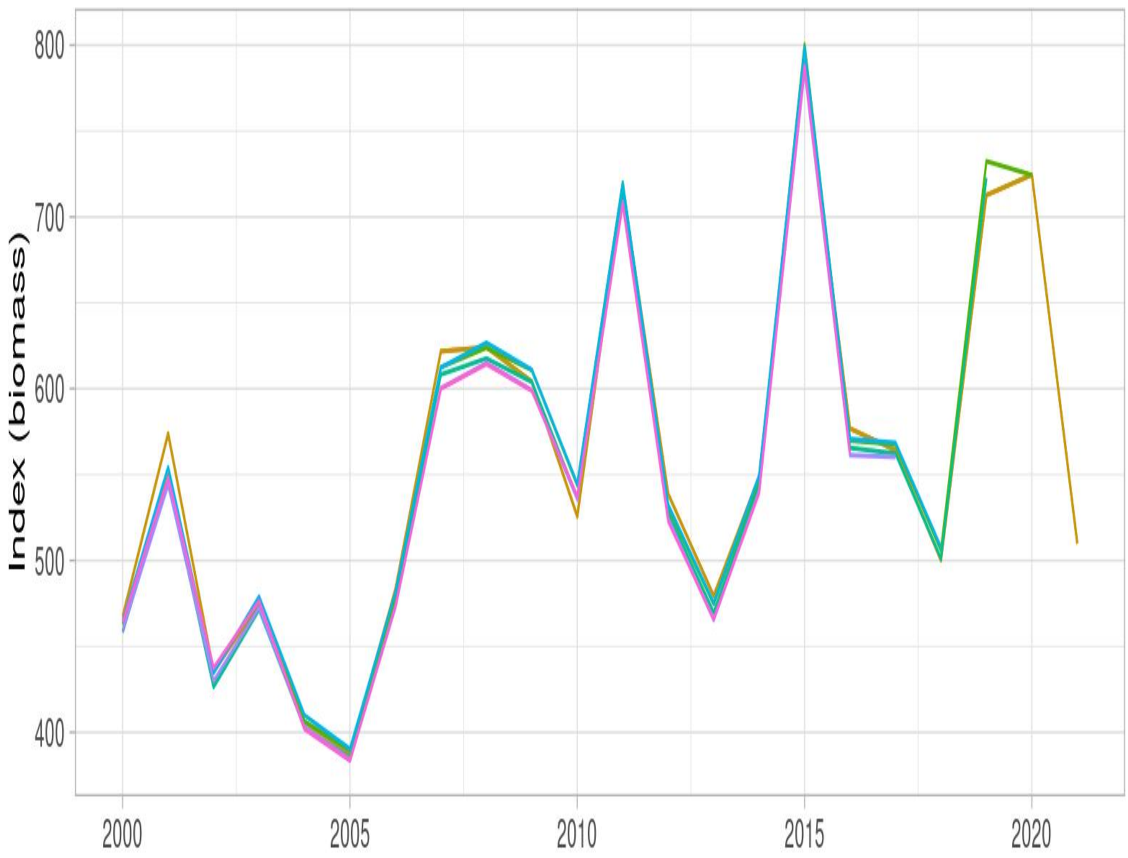


Figure 21. Sole in Subarea 4. Retrospective pattern in lognormal GAM-standardized BTS Q3 index of abundance.

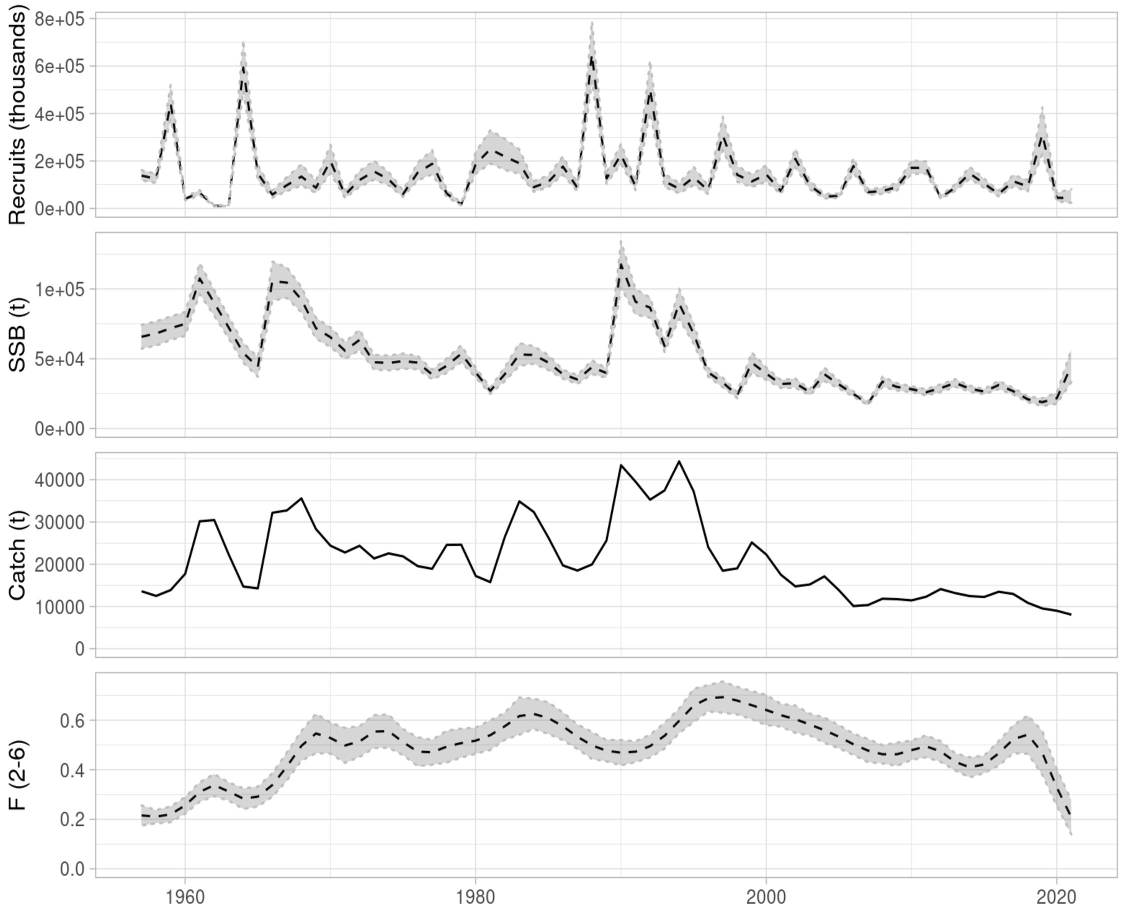


Figure 22. Sole in Subarea 4: Estimates time series of recruitment at age 1 (in thousands), spawning biomass (in tonnes) and fishing mortality (as average of ages 2 to 6), together with total catch (in tonnes). Grey bands show the 95% uncertainty estimate, computed as two times the standard deviation.

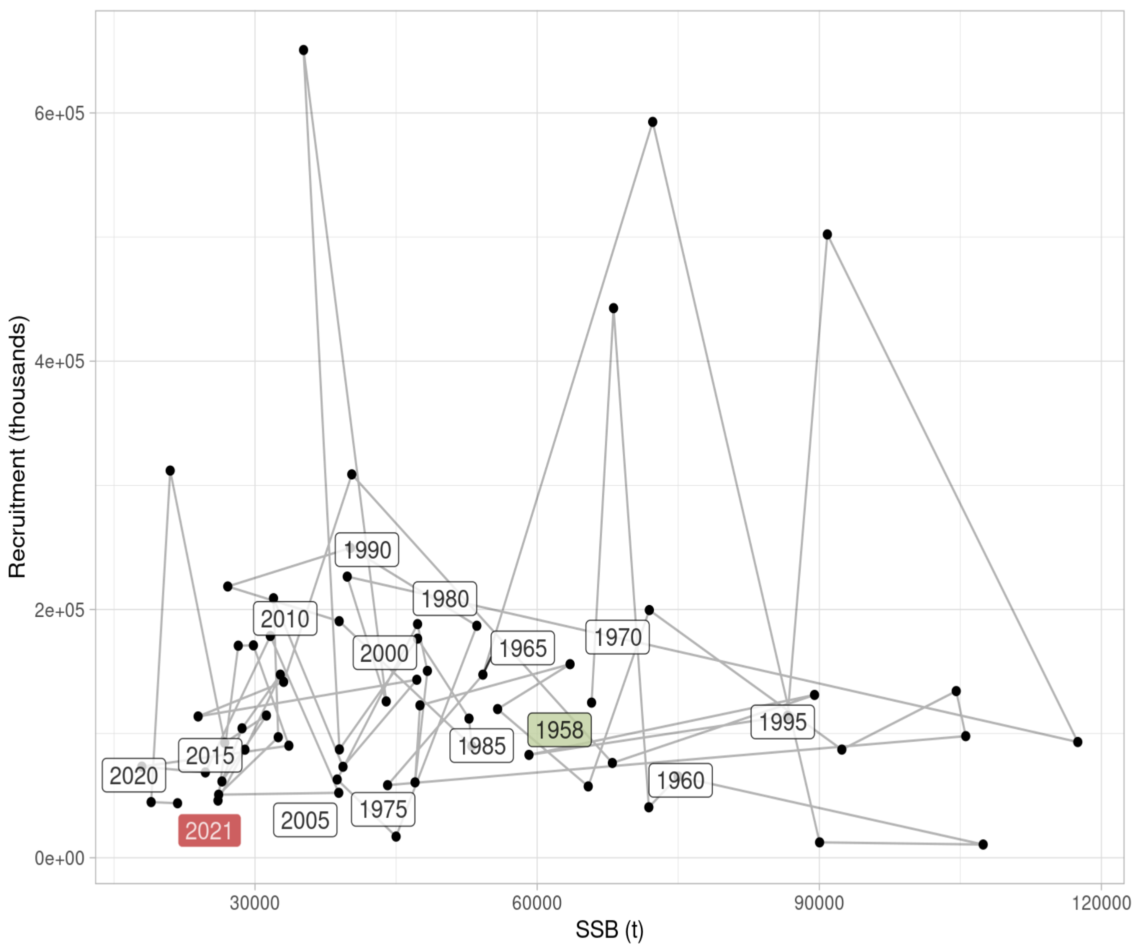


Figure 23. Sole in Subarea 4. Estimates of recruitment at age 1 (in thousands) and spawning biomass (in tonnes), connected in time. Labels refer to the year in which recruitment was observed.

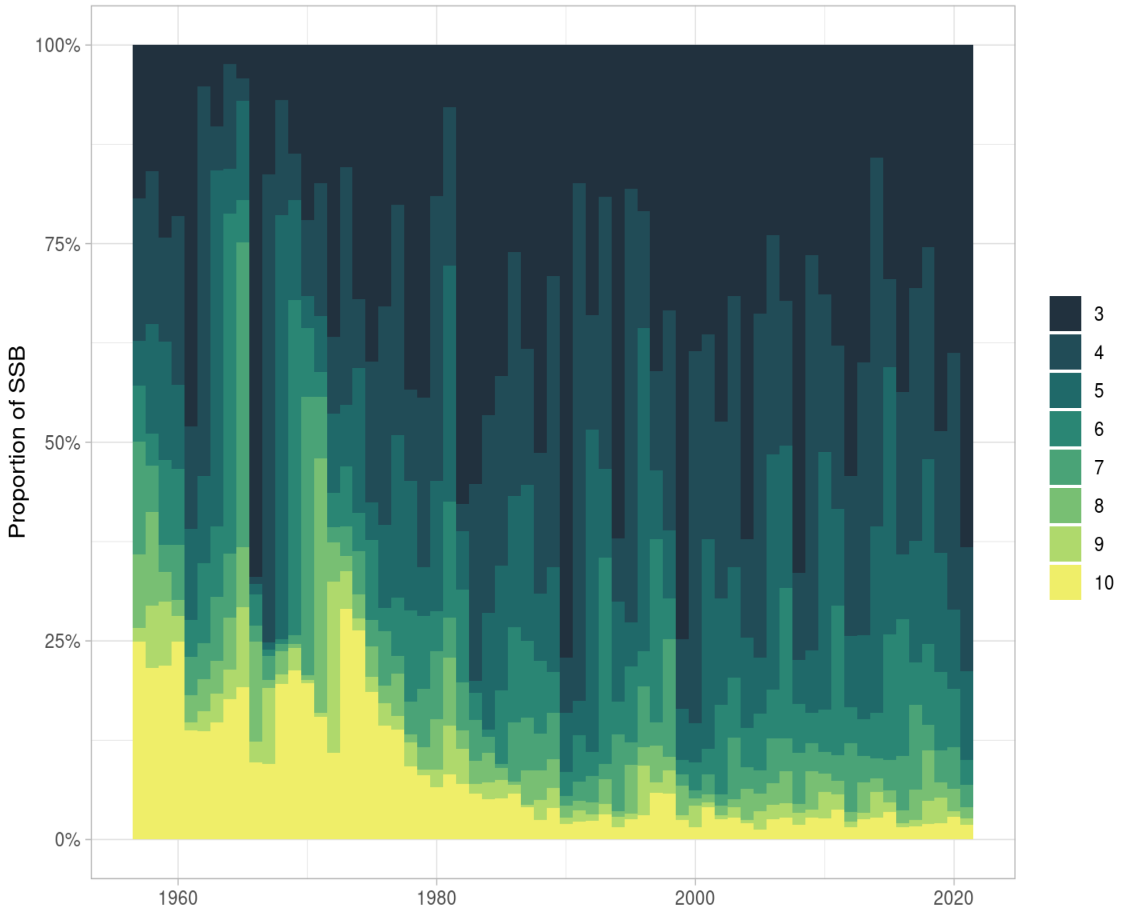


Figure 24. Sole in Subarea 4: Estimated proportions of spawning biomass by age and year.

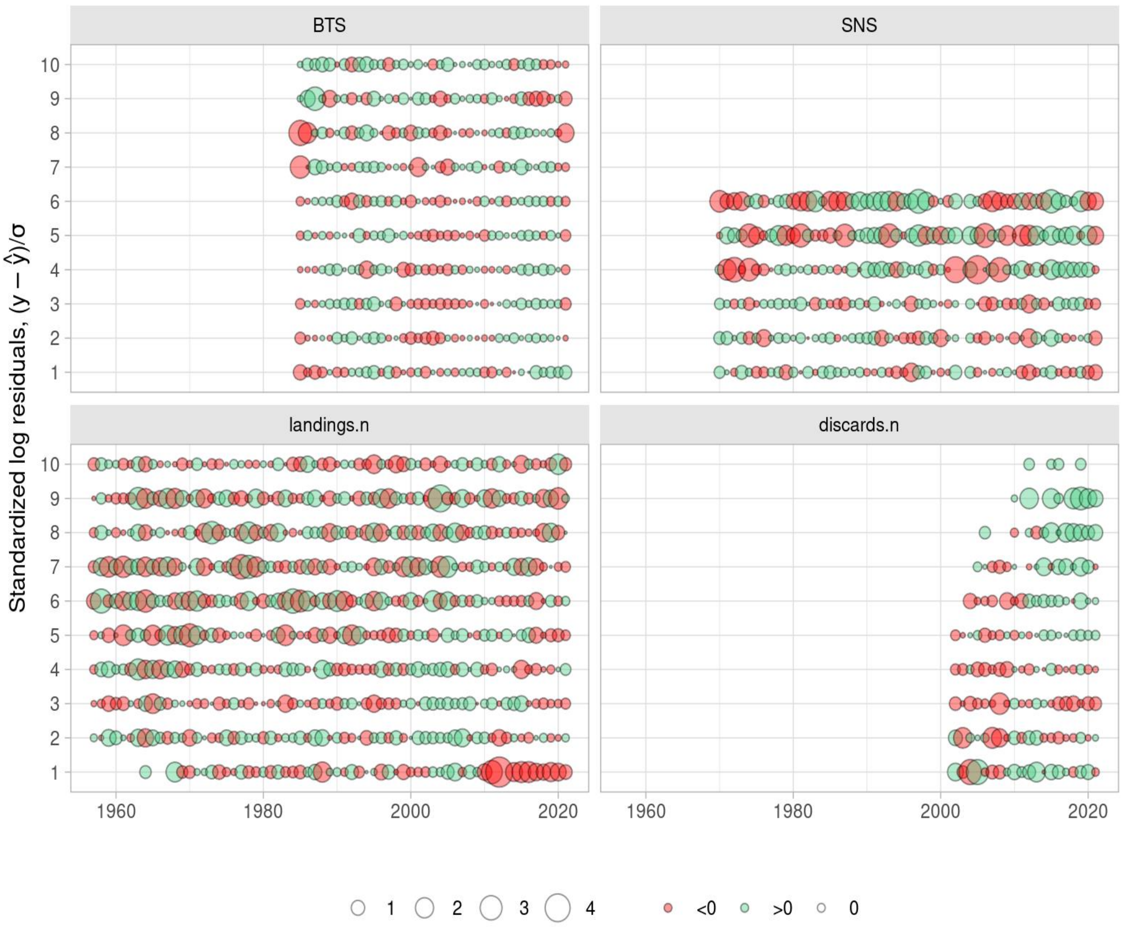


Figure 25. Sole in Subarea 4: Residuals of model fit to the four sources of data: BTS and SNS indices of abundance, landings-at-age (landings.n) and discards-ta-age (discards.n). Residuals in log scale are standardized by the estimated standard deviation.

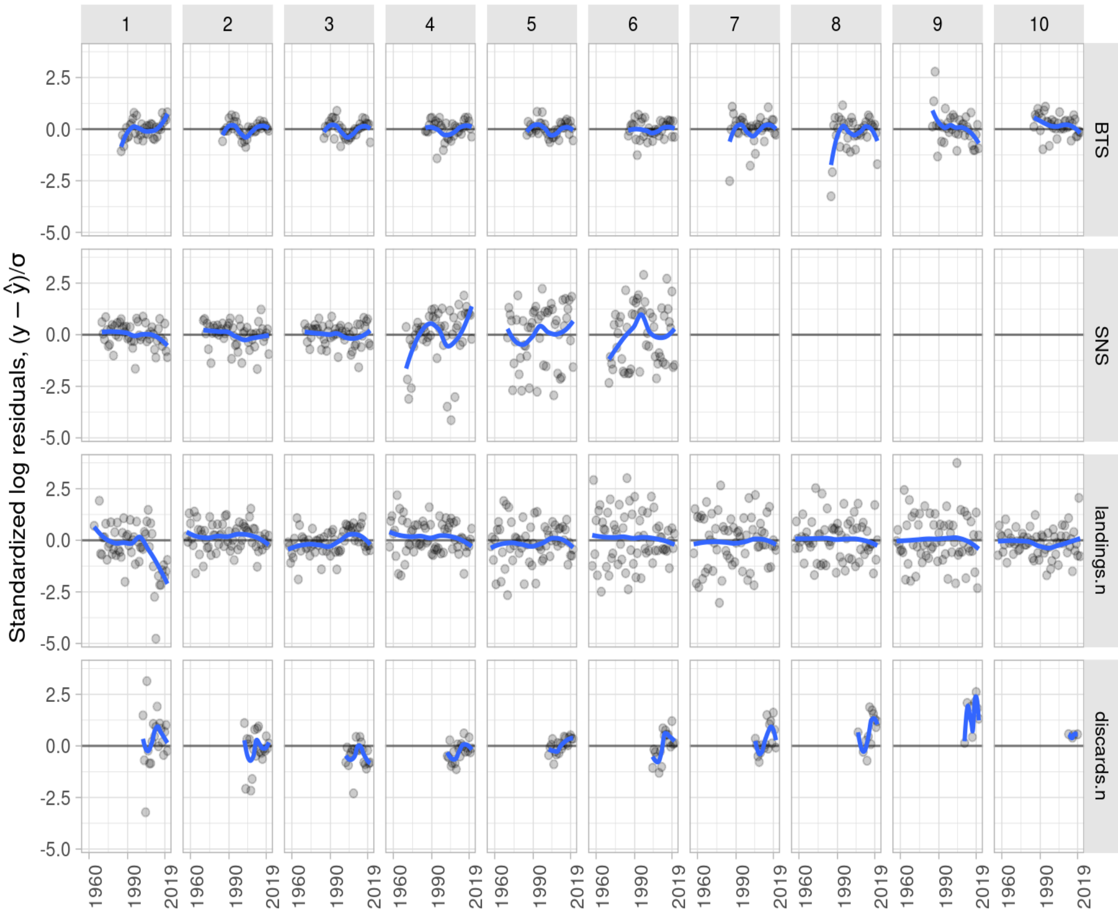


Figure 26. Sole in Subarea 4: Residuals of model fit to the four sources of data: BTS and SNS indices of abundance, landings-at-age (landings.n) and discards-ta-age (discards.n). Residuals in log scale are standardized by the estimated standard deviation.

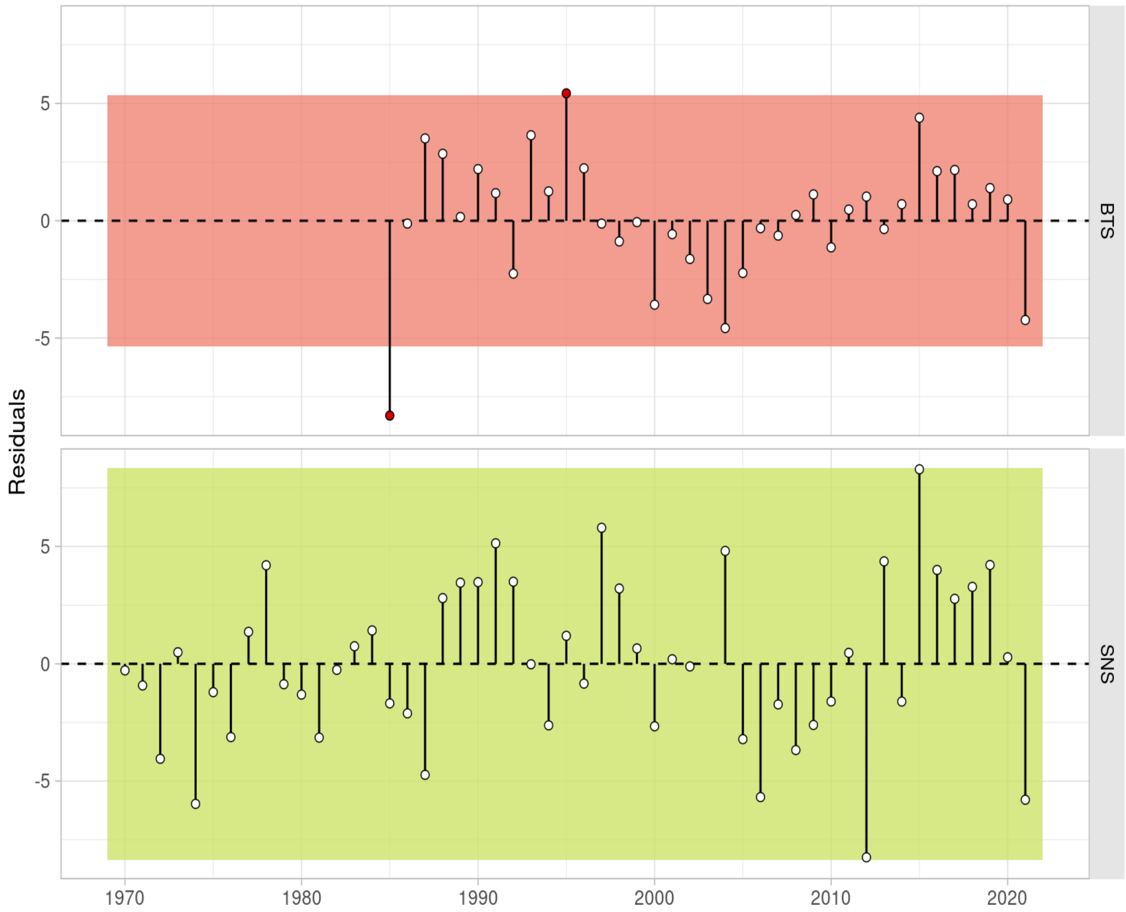


Figure 27. Sole in Subarea 4: Runs test of model fit to index vulnerable biomass for the two indices of abundance: BTS and SNS. Green shading indicates no evidence and red shading evidence to reject the hypothesis of a randomly distributed time-series of residuals, respectively. The shaded area spans three residual standard deviations to either site from zero, and the red points outside of the shading violate the 'three-sigma limits' for that series.

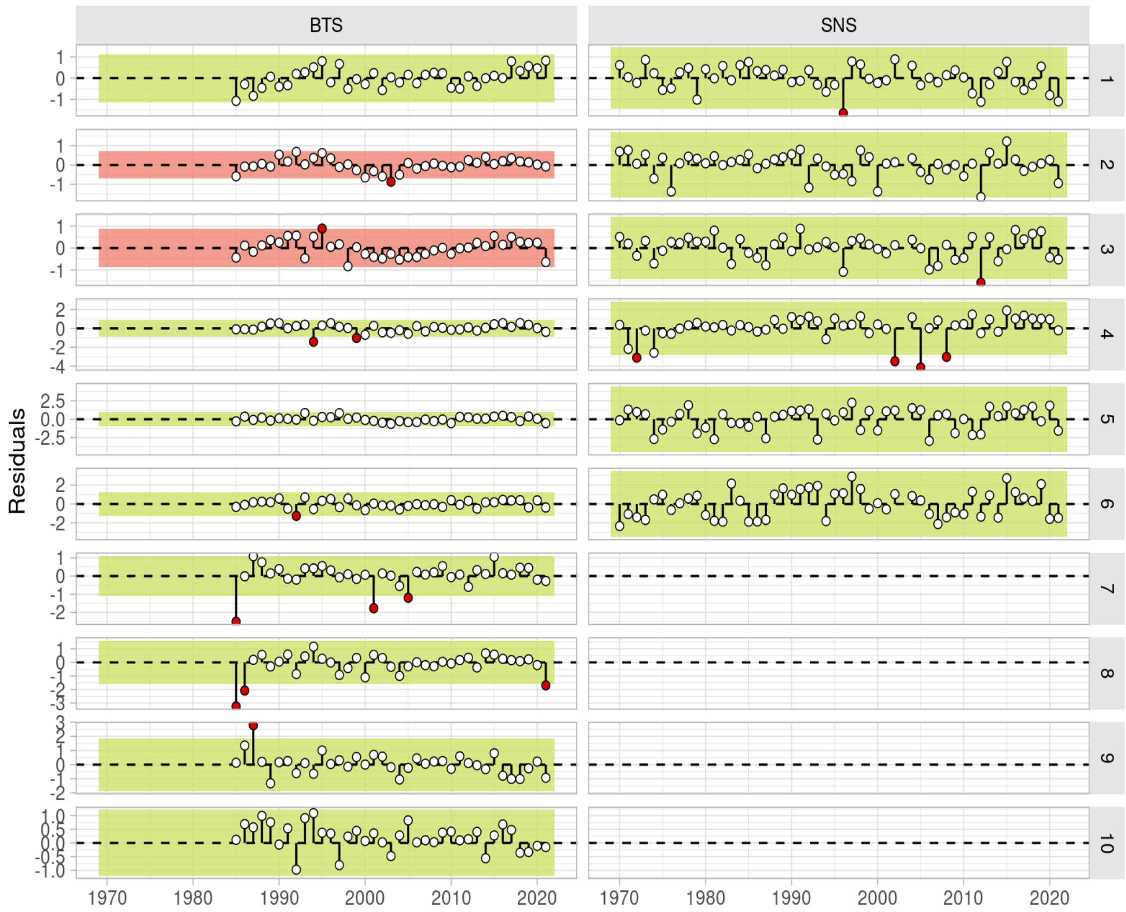


Figure 28. Sole in Subarea 4: Runs test of model fit to the sampled abundances at age for the two indices of abundance: BTS and SNS. Green shading indicates no evidence and red shading evidence to reject the hypothesis of a randomly distributed time-series of residuals, respectively. The shaded area spans three residual standard deviations to either site from zero, and the red points outside of the shading violate the 'three-sigma limits' for that series.

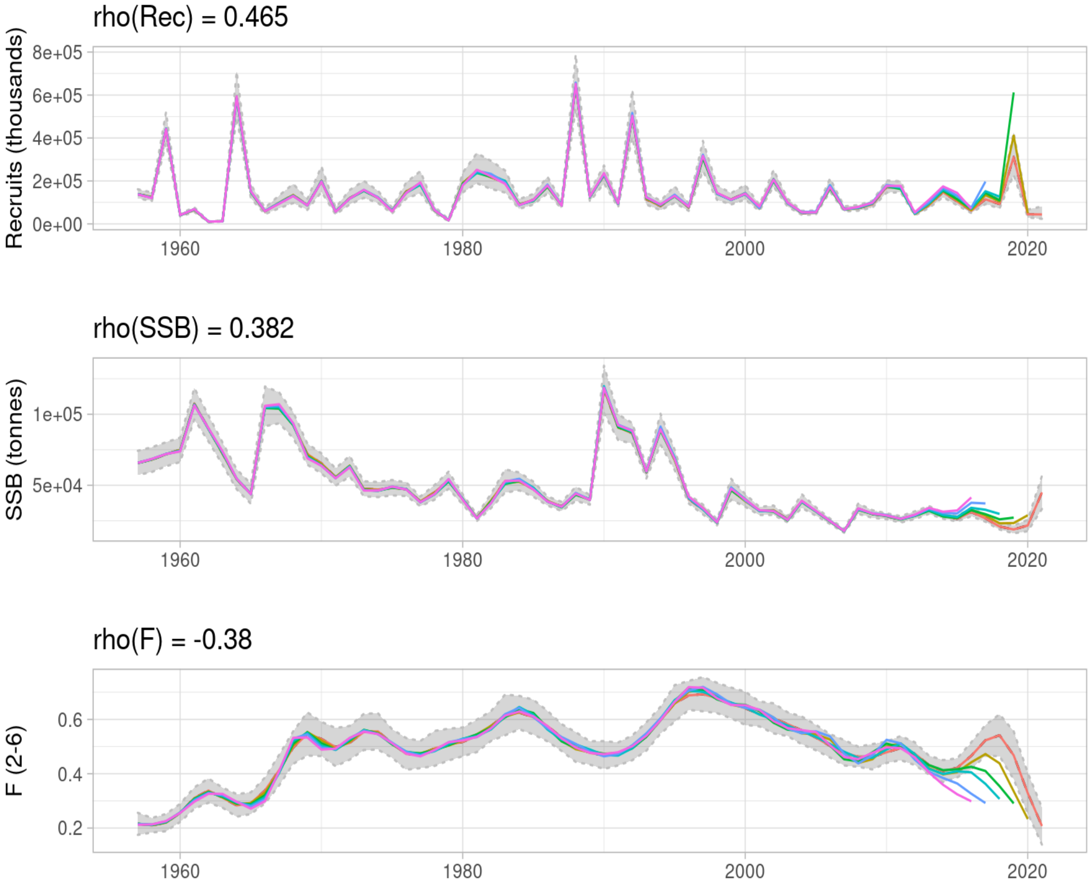


Figure 29. Sole in Subarea 4: Retrospective patterns in estimated age 1 recruitment, spawning biomass and mean fishing mortality, computed over five one-year steps.

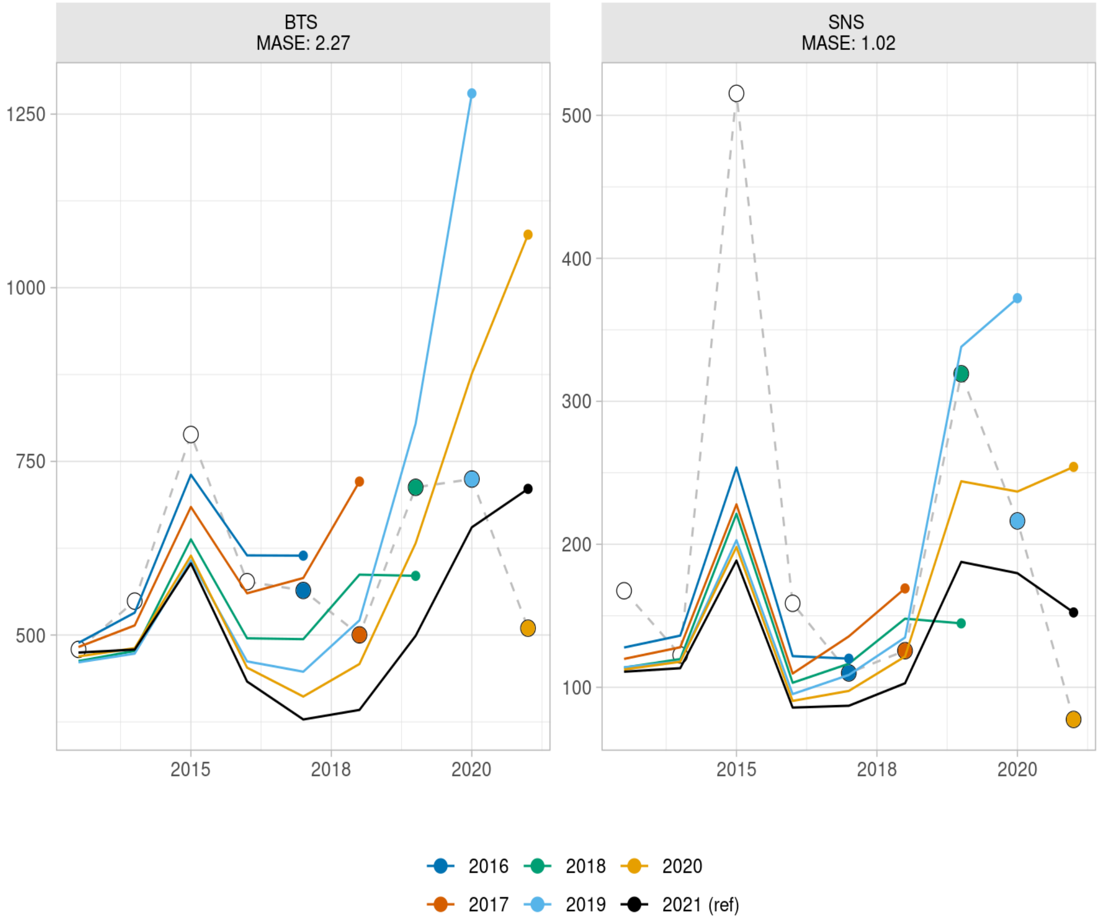


Figure 30. Sole in Subarea 4: Hindcasting cross-validation of indices of abundance to estimate assessment model prediction skill.

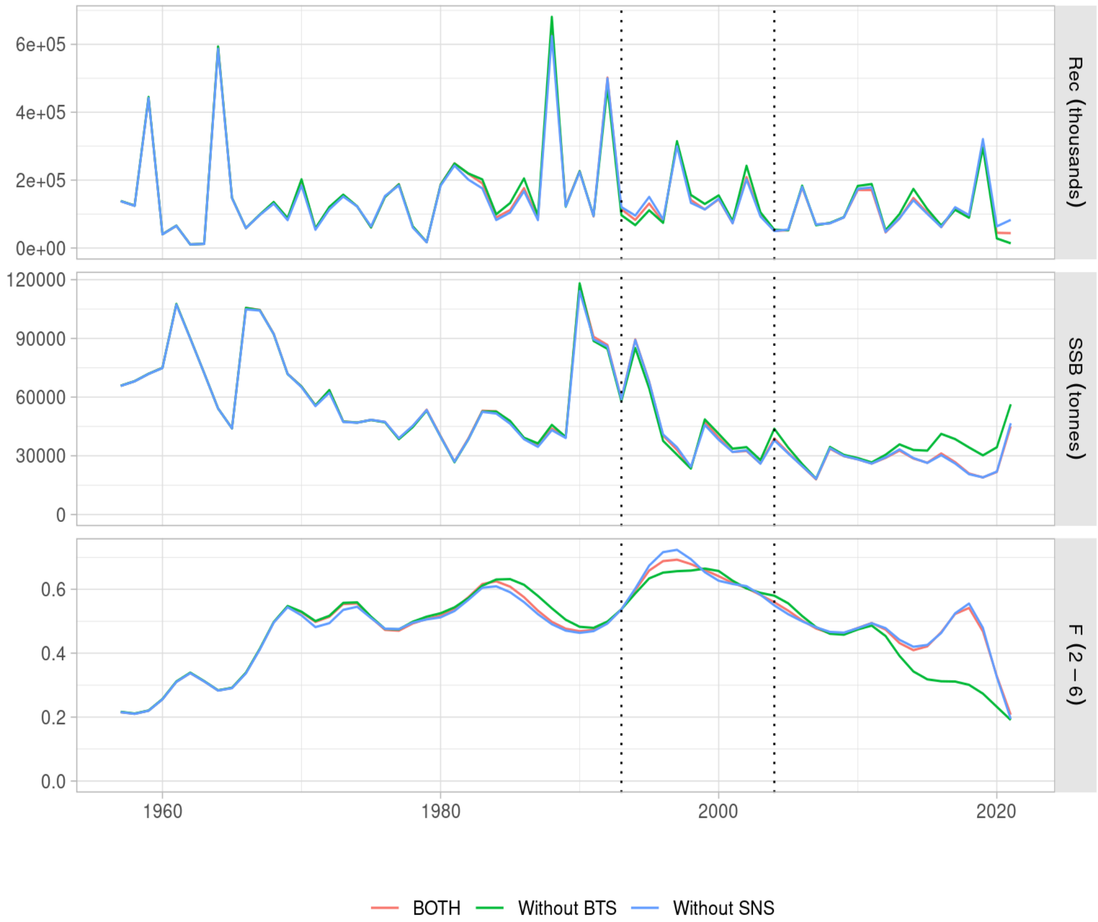


Figure 31. Sole in Subarea 4: Leave-one-out analysis of the AAP model run.

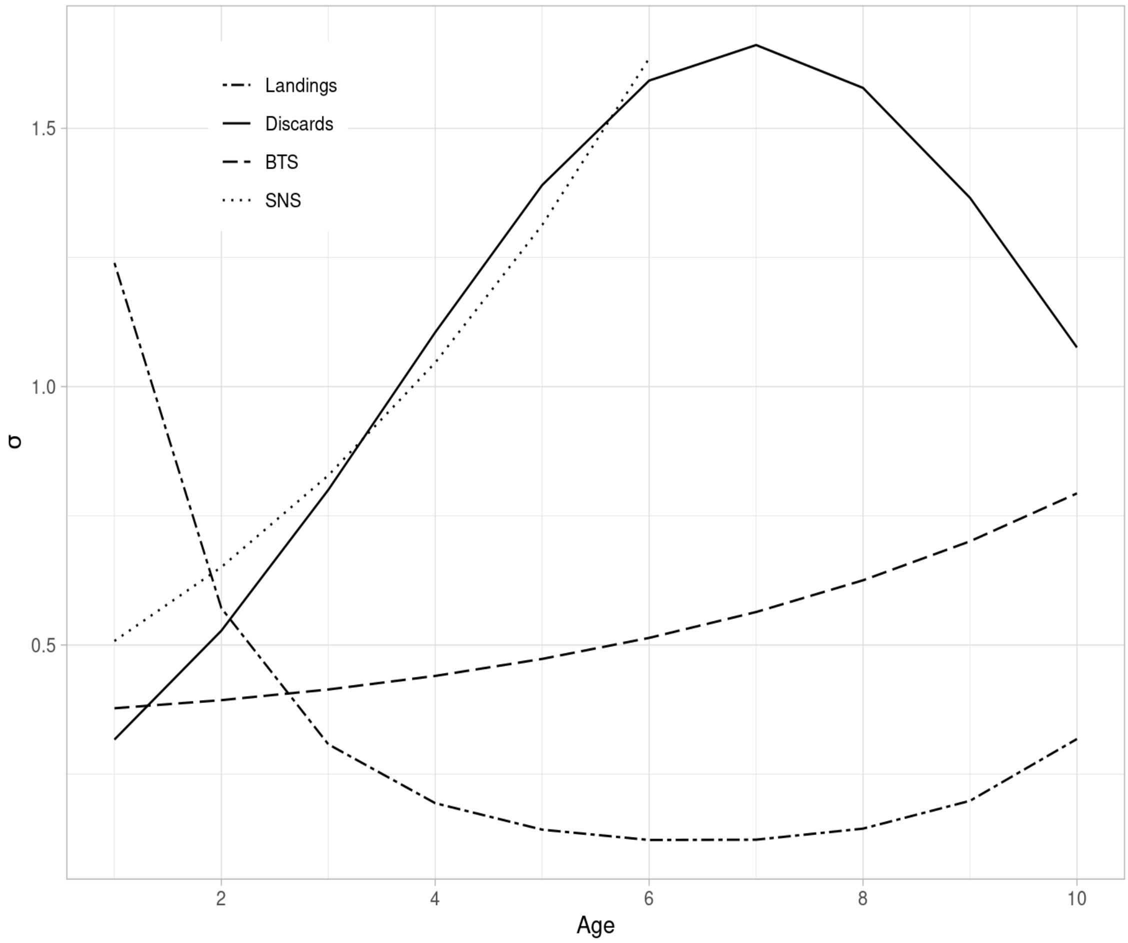


Figure 32. Sole in Subarea 4: Estimated standard deviations of the partial model likelihood by age and per each component.

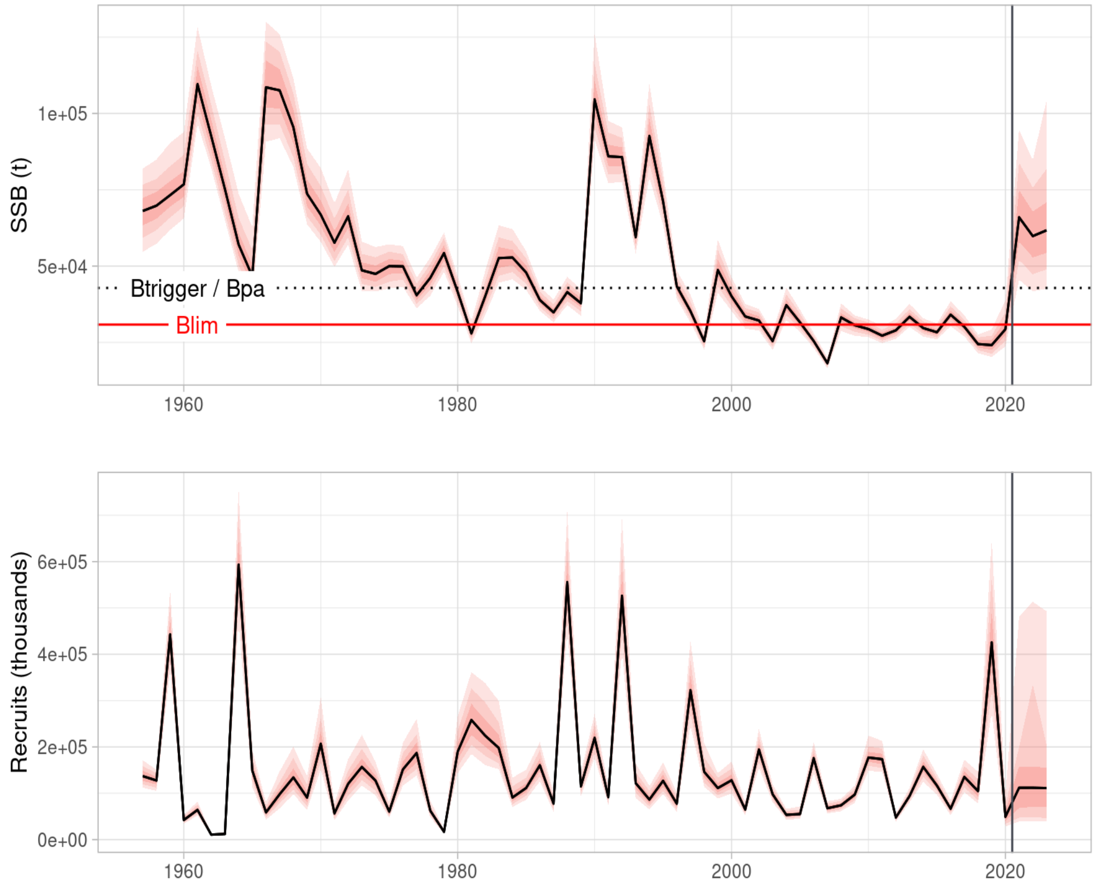


Figure 33. Sole in Subarea 4: Stochastic forecast of spawning stock biomass (SSB) against the corresponding reference points, and recruitment variability applied in it. The black line shows the median value, which is not exactly equal to the predicted values used in the advice. Darker and lighter red ribbons present the 95% and 50% quantiles, respectively.

18 Sole (*Solea solea*) in Division 27.7.d (Eastern English Channel)

Please note: This section was added to the report in September 2022.

This section of the report provides a comprehensive description of the methods and data used for the 2022 assessment of sole in Division 27.7.d. Additional background information can be found in the Stock Annex which was updated after the inter-benchmark in June 2022.

18.1 General

18.1.1 Stock definition

During the WKNSEA 2017 benchmark, the available information on stock identity was investigated, including genetic, tagging and otolith information. Sole in the eastern English Channel (7.d) is still considered to be a stock separated from the larger North Sea stock (27.4) to the east and the smaller geographically-separated stock to the west in 27.7.e (western English Channel). Considering the sub-stock structure, three regions with low connectivity were identified within Division 7.d for larvae, juveniles and adults (Archambault *et al.,* 2016; Lecomte *et al.,* 2020; Randon *et al.,* 2018; 2020). More information is provided in the Stock Annex, the report of the benchmark and the associated working document (ICES, 2021).

18.1.2 Ecosystem aspects

A general description of the available information on ecological aspects can be found in the Stock Annex.

18.1.3 Fisheries

A general description of the fishery is presented in the Stock Annex.

18.1.3.1 Management regulations

Management of sole in 7.d is by TAC and technical measures.

The minimum landing size for sole is 24 cm (EU legislation). Sole in the eastern English Channel is fully under the landing obligation since 2018 (partially since 2016) (EU, 2018/2034). There are two exemptions in place which allow for discarding of undersized sole in Division 7.d:

1) a survival exemption for small coastal otter trawlers (<10 m and <221 kW) fishing less than 90 minutes in areas with a depth less than 30 m (outside nursery areas) and with cod-end mesh size of 80–99 mm.

2) a *de minimis* exemption for vessels using trammel and gill nets (max. 3% of annual catches) and using TBB gear with a mesh size of 80–119 mm equipped with the Flemish panel (max. 3% of annual catches).

A historical overview of the TAC for sole 7.d since 2000 is presented in the table below (short version) and in Table 18.1.

Historical overview of the TACs for sole in Division 27.7.d (2011–2022); Note: TAC represents catch from 2016 onwards (landing obligation)

Year	2011	2012	2013	2014	2015	2016
TAC	4852	5580	5900	4838	3483	3258
Year	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
TAC	2724	3405	2515	2797	3248	2380

Except for 2009 and 2010, the TAC has not been restrictive since 2003. In 2014, it became restrictive for Belgium, and in 2015 this was the case for Belgium and France (see 18.2.1.1 TAC uptake). Note that initial quota are compared regardless of quota exchanges among countries.

In response to the drop in SSB and the poorer recruitment from 2012 onwards, the main countries participating in the fishery implemented additional conservation measures. For Belgian beam trawlers in 27.7.d (and 27.7.fg, 27.7.a), it is mandatory since 1 April 2015 to incorporate a 3 m long section (tunnel) with a 120 mm mesh size before the cod-end (Flemish panel), in order to reduce the catches of small sole (reduction of undersized sole with 40% and marketable sole with 16%). France engaged in 2016 to i) strengthen the protection of the nursery areas, ii) increase the area closed to fishing within the nursery areas, and iii) increase the minimum conservation reference size to 25 cm for French vessels in accordance with EU legislation, where appropriate. From 11 March until 31 December 2017, the minimum conservation reference size for Belgian vessels also increased to 25 cm. This MCRS is still used up until now (dd. May 2021). Finally, UK beam trawlers usually fish using mesh sizes greater than statutory in order to avoid discarding and to avoid wasting quota.

18.1.3.2 Additional information provided by the fishing industry

In 2019, the French fishing industry provided input on their perceived status of the stock.

The French gillnet fishers state that they have trouble catching sole in the eastern part of the eastern English Channel. The French otter trawl fishers operating mainly in the south-western part of the eastern English Channel have reported a decline in catches in 2016 and 2017, followed by an increase in catches since 2018 to the ten-year average level.

18.1.4 ICES advice

18.1.4.1 ICES advice for 2021

The ICES advice for 2021 was:

ICES advises that when the MSY approach is applied, catches in 2021 should be no more than 3248 tonnes. Note that advice was given as for Category 3 stocks for which no estimation of the SSB in 2020 is provided.

In 2020, the stock status was presented as follows:

		Fishing pressure					Stock size				
		2017	2018	2019			2017	2018	2019	
Maximum sustainable yield	F_{MSY} proxy	✓	✓	✓	Below proxy	MSY $B_{trigger}$ proxy	✓	✓	✓	Above proxy
Precautionary approach	F_{pa}, F_{lim}	✓	✓	✓	Harvested sustainably	B_{pa}, B_{lim}	✓	✓	✓	Full reproductive capacity
Management plan	F_{MGT}	✓	✓	✓	Below proxy	B_{MGT}	✓	✓	✓	Above proxy

18.1.4.2 ICES advice for 2022

The ICES advice for 2022 was:

ICES advises that when the MSY approach is applied, catches in 2022 should be no more than 2380 tonnes.

In 2021, the stock status was presented as follows:

		Fishing pressure					Stock size			
		2018	2019	2020			2019	2020	2021	
Maximum sustainable yield	F_{MSY}	✗	✗	✗	Above	MSY $B_{trigger}$	✗	✗	✗	Below trigger
Precautionary approach	F_{pa}, F_{lim}	✓	✓	✓	Harvested sustainably	B_{pa}, B_{lim}	O	O	O	Increased risk
Management plan	F_{MGT}	✗	✗	✗	Above	B_{MGT}	✗	✗	✗	Below

18.2 Data

As a result of the data call for the 2021 WKNSEA benchmark (ICES, 2021), new landings and discard time series were uploaded by France and Belgium. Data were processed in InterCatch from 2004 onwards.

18.2.1 Catches

18.2.1.1 TAC uptake

Table 18.1 and Figure 18.1 summarise the official sole landings by country for Division 7.d. The landings have steadily increased over the 1970s and 1990s, fluctuated around an average of 4838 t in 2000–2014 (range: 3832 t–6247 t), and dropped to 3411 tonnes in 2015 and even further to 2224 tonnes in 2017. In 2018, a small increase up to 2312 tonnes was observed. However, in 2019, 2020 and 2021, landings decreased further to 1773, 1706 and 1664 tonnes respectively. Over the last *ca.* 20 years, the contribution to the landings of the three main countries involved in this fishery has remained rather stable over time (~30% Belgium, ~15% UK, and ~55% France) (Figure 18.2).

Since 2010, full uptake of the sole 27.7.d TAC has not been realized. However, in 2014, the Belgian quota was overshot by 15%. In 2015, Belgium overshot its national quota again by 12% and France faced a 1% overshoot. The total uptake in 2015 was 98% (official landings). Since then, the total uptake has decreased to only 51% in 2021. Note that the initial quota is compared with uptake not taking into account quota exchange among countries during the year.

When comparing ICES catch estimates (InterCatch) with the TAC (catch), a total uptake of 82% was realized in 2017, 78% in 2018, 82% in 2019, 70% in 2020 and only 59% in 2021 (Figure 18.3). Figure 18.4 presents a historic overview of TAC levels compared to official landings and ICES estimates (both landings and discards).

18.2.1.2 ICES catch estimates (InterCatch)

New ICES estimates were uploaded and processed in InterCatch from 2004 onwards as a result of the WKNSEA 2021 benchmark. The new upload involved a thorough revision of the French and Belgian time series (more information in the WKNSEA 2021 benchmark report: ICES, 2021). The proportion of landings with discards has gradually increased over the years 2004–2012 (Figure 18.5). From 2012 onwards, this increasing trend levelled off, fluctuating between 70 and 80%. A decrease was noted in 2020 to 54%, most likely due to the Covid-19 pandemic. In 2021, the proportion of landings with discards amounted back to 82%. The age coverage for landings increased from 2004–2011 and remained stable around 80% (Figure 18.5). The age coverage for 2021 is 88% and shown by country and by fleet in Figure 18.6 and 18.7 respectively. The age coverage for discards fluctuates around 60% over the whole time series and is at 75% in 2021 (Figure 18.5).

A detailed overview of imported or raised data and sampled or estimated distributions for 2021 is given in Table 18.2.

Discards are included in the assessment from working year 2017 onwards. If discards are unavailable for a particular year-quarter-country-métier combination, they are assumed to be unknown (non-zero) and therefore raised (InterCatch). The weighting factor for raising the discards was '*Landings CATON*' (landings catch).

Discard raising was performed on a **gear level** regardless of season or country. The following groups were distinguished based on gear:

- *TBB*
- *OTB including OTB, OTT, SSC, SDN*
- *GTR including GTR and GNS*

The remaining gears were combined in a REST group (including MIS, FPO, DRB, LHM, LLS).

The GNS/GTR, TBB and OTB/OTT/SSC/SDN contribute respectively 32%, 35% and 31% to the landings of sole in 27.7.d (Table 18.3).

Raising within a gear group was performed when the proportion of landings for which discard weights are available was **equal or larger than 50%** compared to the total landings of that group. For the 2021 data, this was the case for the TBB, GTR and OTB gear group. The remaining gears were grouped in the REST group, which was raised using all available information except for 2 strata with a discard rate larger than 50% (FRA OTB_DEF_70-99 Q2 and Q4).

To **allocate age** compositions, landings and discards were handled separately; samples from landings were used only for landings and *vice versa*. When age distributions (both landings and discards) had to be borrowed from other strata, allocations were performed on a **gear level**. The same gear groups (TBB, OTB, GTR and REST) as used for discard raising were applied. When the **threshold of 50%** was reached for the proportion of landings or discards covered by age, allocation of age occurred with all available information within that gear group. For the 2021 landings data, this threshold was reached for all gear groups. For the 2021 discards, this was only the case for the TBB and GTR group. When the threshold was not reached, unsampled data were pooled in the REST group and ages were allocated using all sampled data. The weighting factor was '*Mean Weight weighted by numbers at age*'.

From 2018 onwards, **BMS landings** and **logbook registered discards** were available in InterCatch. However, all were zero up to 2020. In 2020, 247 kg of BMS was reported from the English GNS_DEF_all Q4 and OTB_DEF_70-99 Q4 strata. In 2021, 205 kg of BMS was reported from the English GNS_DEF_all Q1, OTB_DEF_70-99 Q1 and GTR_DEF_all Q3 strata. Logbook registered discards were not considered for the age allocations. Age allocation of BMS landings was done together with discards.

The official catch statistics have reported BMS landings in 2017 (144 kg), 2019 (2.8 kg), 2020 (249 kg) and 2021 (3757 kg). No BMS landings were reported in 2018.

18.2.1.3 Reconstruction of discards

Due to the lack of discard information prior to 2004, discards were reconstructed for the period 1982–2003 (ICES, 2021). Similarly, as during the WKNSEA 2017 benchmark, an average discard proportion at age was calculated for the period 2004–2008. This decision was motivated by the fact that discard behaviour at age changed after 2008 and a general increase in discarding was found in the most recent years (Figure 18.8).

First, the InterCatch information from the most recent years (2004–2019) on discards and landings numbers-at-age, weights-at-age and overall tonnage was SOP corrected as follows. Numbers were multiplied with weights and summed per year. Then the ratio between the overall tonnage from InterCatch and this sum was calculated. This gave a SOP factor by year which was then multiplied by the numbers-at-age per year.

Subsequently, only the numbers-at-age were retained for the period 2004–2008 and the mean numbers-at-age were calculated. The ratio of the discards mean numbers-at-age and the landings mean numbers-at-age for 2004–2008 was then multiplied by the old landings numbers-at-age, which were also SOP corrected. This finally resulted in discards numbers-at-age for the period 1982–2003.

Discards weights-at-age were calculated in the same way. A ratio between discards and landings weight-at-age for the period 2004–2008 was calculated and multiplied by the landings weight-at-age for the period 1982–2003. This resulted in discards weight-at-age for the period 1982–2003.

18.2.1.4 Discard rate

The discard rate, calculated as the ratio between ICES discard estimates (tonnes) and ICES catch estimates (tonnes), fluctuates between 3 and 10% over the time series (1982–2018) (Figure 18.9). However, in the last three years this rate increased up to 20%. For a target species such as sole, this recent rate is very high.

In 2020, as a result of the Covid-19 pandemic, hampered sampling could have been affecting the discard rate (see §18.2.1.2). Usually most of the imported discards originate from France (62% in 2018) followed by Belgium (34% in 2018) and England (4% in 2018). However, in 2020, 66% of the imported discards originated from Belgium and only 34% from France. This was the result of the reduced sampling by France due to the pandemic. Belgium only submits discard data from the TBB group, while France usually provides a mix of GTR, OTB and TBB strata. Following the discard raising procedures (§18.2.1.2), the threshold of raising the OTB and GTR group using only OTB and GTR strata respectively was not met for the 2020 data (in contrast to the three preceding years). Consequently, these strata were raised in a REST group including BEL TBB_DEF_70-99 (DR = 0.22), FRA GTR_DEF_100-119 Q1 (DR = 0.023), Q3 (DR = 0.018), Q4 (DR = 0.010), FRA GTR_DEF_90-99 Q1 (DR = 0.044), FRA OTB_DEF_70-99 Q3 (DR = 0.326) and ENG OTB_DEF_70-99 Q1 (DR = 0). The French OTB_DEF_70-99 Q1 stratum was not included because the discard rate exceeded 50% (DR = 0.514). Consequently, the Belgian discard samples had a higher impact for the 2020 data compared to previous years. In 2020, Belgian discard rates were unusually high (22% versus 12% in 2018 and 14% in 2019). However, the Belgian observer programme was not hampered by the Covid-19 pandemic. In 2021, the Belgian discard rate was 15%.

Other explanations could be good recruitment entering the fishable population or decreasing size at age. In the current assessment, recruitment estimates have been downscaled substantially compared to last year's assessment, which showed a large 2018 year class. The decreasing size at age is also explained in §18.2.1.6. However, this is a rather gradual process and is not expected to affect the discard rate so abruptly. Further investigation is needed to fully understand this process.

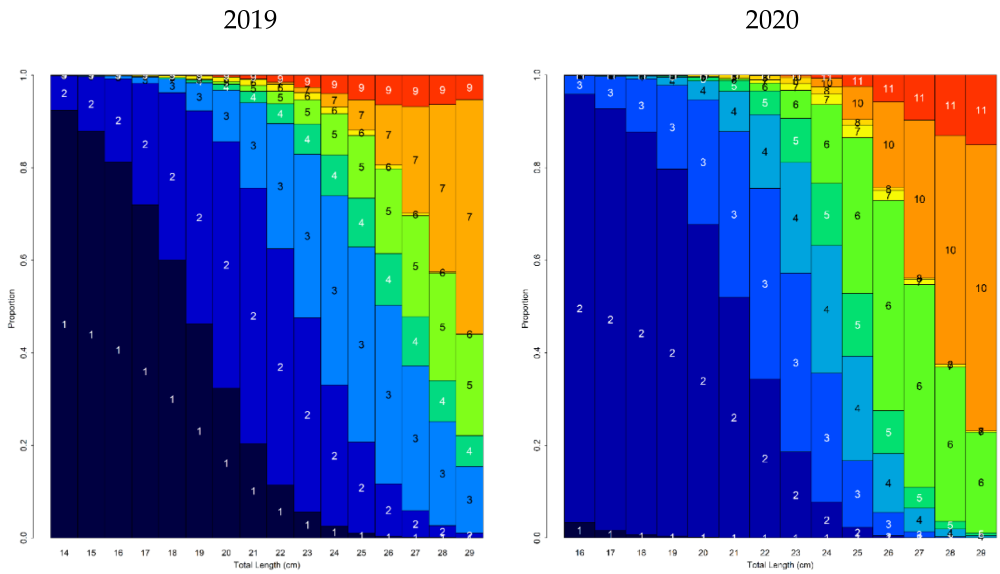
18.2.1.5 Numbers-at-age

Catch, landings and discards numbers-at-age are shown in Figure 18.10, 18.11, 18.12, 18.13 and Table 18.4.

Catch numbers have decreased over the time series and lower numbers are caught since 2015 (Figure 18.10). In 2008–2009, a stronger year class entered the stock and was found in the landings from age 2 onwards. The 2018-year class is the first since 2008-2009 that seems large enough to be observed in the landings. However, very few 2-year olds have been observed in the landings.

Almost half of the 2- and 3-year-old fish were discarded in 2020. In contrast to another period with a strong year class (e.g. 2001-year class), it is apparent that proportionally more 2-year olds end up in the discard fraction (Figure 18.10).

Additionally, Figure 18.13 shows a considerable amount of older discards, especially in 2019 and 2020. Considering the larger impact of the Belgian samples in 2020, Belgian age-length keys (modelled) were investigated (see graphs below showing the proportion per age per length class). Discards up to 29 cm were aged and while in 2019 over 40% were younger than age 6, in 2020 this was less than 5%. This confirms the pattern of decreasing length-at-age also found in the UK BTS survey data (ICES, 2021).



18.2.1.6 Weight-at-age

Weights-at-age for discards and landings are shown in Figure 18.14 and 18.15 respectively and weights-at-age in the catch are given in Figure 18.16 and Table 18.5. Catch weights-at-age have gradually declined over the past 10 years, especially in the younger ages (age 1–5). Furthermore, although discards of older ages are being caught (up to age 8 and older), their mean weight-at-age varied around 100 grams. This points to a trend of decreasing weight-at-age and thus smaller (§18.2.1.5) and thinner fish.

18.2.2 Stock weight-at-age

Stock weights-at-age were revised during the WKNSEA 2021 benchmark (ICES, 2021). Quarter 1 catch weight-at-age was extracted from InterCatch for the period 2004–2021 and used as stock weight-at-age for this period. Note that Belgian catch information (numbers and mean weight-at-age) was added manually because Belgian data were uploaded per year (not quarter, with the exception of 2018). Subsequently, the mean proportion at age was calculated between the catch weight-at-age in quarter 1 and the overall catch weight-at-age for the period 2004–2019. This ratio was then multiplied by the catch weight-at-age for the period 1982–2003 to get the quarter 1 catch weight-at-age for 1982–2003 (Figure 18.17; Table 18.6).

18.2.3 Maturity and natural mortality

During the WKNSEA 2017 benchmark (ICES, 2017), the knife-edged maturity ogive with full maturation from age 3 onwards was revised. Using data from the French IBTS survey and commercial data from Belgium, France and the UK (15 191 records), a new maturity ogive was constructed (see table below). More information on how this was achieved is provided in the WKNSEA 2017 report and the associated working document (ICES, 2017).

Age	0	1	2	3	4	5	6	7	8	9	10	11(+)
Maturity	0.00	0.00	0.53	0.92	0.96	0.97	1.00	1.00	1.00	1.00	1.00	1.00

Natural mortality is assumed constant over ages and years at 0.1. English and French tagging data were investigated (prior to the WKNSEA 2021 benchmark), but two problems were encountered. First, most of the tagging data dated back to before the beginning of the sole 7.d time series. Second, in the most recent years, there were too little recaptures which inhibited the calculation of a new estimate for natural mortality (Lecomte *et al.*, 2020).

18.2.4 Tuning series

The assessment of sole in the eastern English Channel is tuned with three survey (UK(E&W)-BTS-Q3, UK-YFS and FRA-YFS) and three commercial tuning series (FRA-COTB, UK(E&W)-CBT and BE-CBT).

During the WKNSEA 2021 benchmark, the Belgian commercial beam trawl index and the French commercial otter trawl index were revised (ICES, 2021). The UK commercial beam trawl index was revised during the 2019 inter-benchmark (ICES, 2019). A minor change was made to the Belgian commercial beam trawl series during the inter-benchmark in June 2022 (ICES, 2022). This change included the removal of the rectangle threshold on the data. All three commercial tuning fleets are included in the assessment as fishable biomass indices (aggregated over all age) (Figure 18.18). The Belgian and French index follow the same trend with the exception of the year 2020 where the Belgian index gives an increase and the French index a further decrease. The UK commercial index gives information back up to 1986 and shows an opposite trend around 2005 and in 2008–2014 compared to the Belgian and French index. The opposite trends could be explained by the specific area where the UK beam trawl fleet is fishing (along the southern English coasts). In recent years, trends are similar.

The survey tuning fleets are included as age-disaggregated indices. For the UK beam trawl survey (BTS) information from ages 1–6 is available and the UK and French Young fish surveys provide information on age 1 (Figure 18.19).

18.2.4.1 Belgian commercial beam trawl LPUE index

For the Belgian index (2004–present), both the data and method to derive a tuning series were revised during the WKNSEA 2021 benchmark. In consistence with the correction of the Belgian catch data, the index was calculated using data from fishing trips in which fishing activity, as registered in the electronic logbooks, was restricted to the eastern English Channel (division 27.7d). To reduce the noise generated by the unbalanced sampling design of the logbook data, only observations from fishing vessels that fished at least 5 years in the eastern English Channel were included in the analysis. The threshold present on the ICES statistical rectangles was removed during the 2022 IBP to allow for a more robust index which buffers change to historical data when new data becomes available.

The statistical model used to standardize the landings and effort data was modified during the WKNSEA 2021 benchmark. A logistic regression was applied to model the presence/absence of sole in the landings, whereas a lognormal model was used to standardize the positive catch rate. Both models included an intercept, a seasonal trend, and annual trend. The seasonal trend was introduced by means of a penalized smoothing spline and constrained to be cyclic. To reduce the number of parameters, the same seasonal model was used for both the presence/absence and positive catch rate model. The annual trend in both models was assumed to be a first order autoregressive process such that the year effects in both models were estimated as random effects. The model for the positive catch also included random effects (IID) on the ICES statistical rectangles and vessel reference number to account for respectively, spatial variation, and variation caused by skipper effects or technical characteristics of the vessel. Finally, an index was derived by multiplying the probability of having a positive catch, and the expected positive catch rate for each year (Table 18.7).

18.2.4.2 French commercial otter trawl LPUE index

Prior to the WKNSEA 2017 benchmark, no French commercial tuning series were included in the assessment. During the WKNSEA 2017 benchmark, a raw LPUE index was calculated based on the OTB_DEF_70-99 fleet, which targets sole seasonally and mainly along the French coast. During the WKNSEA 2021 benchmark, this index was also recalculated according to the revision of the French catch data and a model was applied (ICES, 2021). To account for dependencies in the landings and effort data, the new FRA commercial otter trawl index was developed (2005-present) based on a selected number of vessels practicing the OTB_DEF_70_99 métier. Only vessels accounting for the top 95% sole landings of OTB_DEF_70-99 were kept in the analysis and they had to be active in the fishery at least two thirds of the time series (*i.e.* 10 years as of 2019).

To standardize the LPUE, a hurdle lognormal mixed model (occurrence and lognormal model) is used to correct for vessels, seasonality and spatial effects. The best hurdle model formulation used a first order random walk to fit temporal trends in the main year effect and the spatio-temporal interaction, and the spatial correlation is constrained by a neighbourhood structure using a Besag model. The biomass index is shown in Table 18.8.

18.2.4.3 UK commercial beam trawl LPUE index

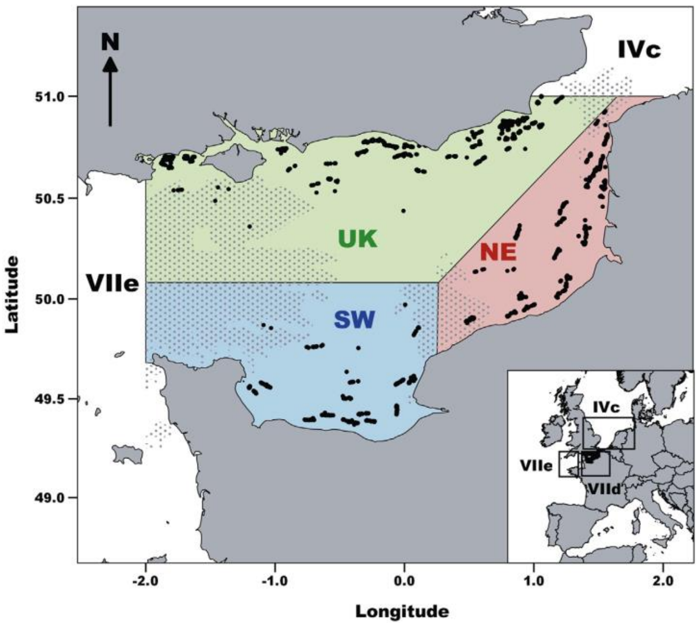
Due to database issues, it was no longer possible to provide an LPUE index based on kW. fishing hours for the UK CBT. The new index is a modelled landings per activity days index from 1986–present (ICES, 2019; Table 18.9).

18.2.4.4 Survey tuning indices

During the 2022 IBP, the UK BTS survey was investigated (Table 18.10). It became clear that the survey was able to track the cohorts better in the beginning of the time series compared to the end of the time series. From 2010 onwards, poor tracking was present as shown in Figure 18.20. The internal consistency plots confirmed this pattern (Figure 18.21). Figure 18.21 shows that especially the correlation between ages 1-2, 2-3 and 3-4 changed considerably, while this correlation was more stable for ages 4-5 and 5-6. The age information from ages 1-3 from 2010 onwards was therefore removed. This was most likely related to the changing size at age. However, uncertainty around age readings was also brought up to explain the observed change. This will be investigated further.

The French YFS (Table 18.12), which is confined to the Somme estuary (see stock annex), shows a rather constant and low index in the period 2014–2018 (Figure 18.19). In 2019 and 2020 an increase in recruitment is measured. The UK YFS (Table 18.11) stopped in 2006 and was situated along the southern English coast.

During the WKNSEA 2021 benchmark, evidence for the presence of three subpopulations was investigated (Lecomte *et al.,* 2020; Randon *et al.,* 2018, 2020; indicated on map below). The UK BTS data was further analysed and higher abundances of sole were found in the south-western population (Seine Bay), followed by the northern UK subpopulation (especially age 1–3). Lowest abundances were found in the French NE subpopulation, where the FRA YFS takes place. Nevertheless, trends over all subpopulations were similar with only minor differences in most recent years. Considering the UK BTS is concentrated in the coastal zones and in quarter 3, further investigation is necessary considering the dynamics of these subpopulations and their impact on the overall stock (ICES, 2021).



18.3 Analyses of stock trends/Assessment

18.3.1 Review of last year's assessment

During WGNSSK working groups, several issues had been encountered with this stock resulting in an inter-benchmark in 2019, a benchmark in 2020 and another benchmark in 2021. During WGNSSK 2020, the XSA assessment was not considered reliable in absolute terms, but it was perceived indicative of trends. Therefore, category 3 advice was provided using the 2 over 3 rule applied to the SSB estimates. The WGNSSK 2021 assessment was the first one using the SAM model. However, the WGNSSK 2022 observed 1) a trend in the survey catchability of the UK beam trawl survey (UK BTS) likely related to the smaller size of sole in the more recent years, and 2) a poor fit of the state-space assessment model (SAM) to the observed catches. This led to an inter-benchmark in June 2022.

The audit of last year's assessment was completed and no significant issues were found.

18.3.2 Final assessment

During the 2022 IBP, the SAM model input and configuration were revised as shown in the table below and Figure 18.22 and Table 18.13.

Settings	
Model	SAM
First data year	1982
Last data year	2021
Ages	1–11+
Plus group	Yes
Stock weights-at-age	Q1 catch weight-at-age; reconstructed for 1982-2003
Discards Numbers- and weight-at-age	Reconstructed for 1982-2003
Abundance indices	Commercial: BEL CBT LPUE (2004-present); FRA COTB LPUE (2005-present); UK CBT LPUE (1986-present)
	Survey: UK (E&W) BTS (1989-present) from 2010-present including only ages 4-6; UK YFS (1987-2006); FRA YFS (1987-present)
Natural mortality	0.1
Maturity ogive	Age1 = 0.00; Age2 = 0.53; Age3 = 0.92; Age4 = 0.96; Age5 = 0.97; Age6-11+ = 1.00
Number of parameters describing F-at-age in catch (keyLog-Fsta) (columns represent ages)	0 1 2 3 4 5 5 6 6 7 7 (catch)
Correlation of F across ages (corFlag)	0 (independent)
Number of parameters describing F-at-age in surveys (keyLogFpar) (columns represent ages)	0 (BEL CBT LPUE; FSB) 1 (UK CBT LPUE; FSB) 2 (FRA COTB LPUE; FSB) 3 4 5 6 7 7 (UK BTS; age 1 -6) 8 (UK YFS; age 1) 9 (FRA YFS; age 1)
Density dependent catchability power parameters (keyQpow)	None
Coupling of process variance parameters for F (keyVarF)	0 0 0 0 0 0 0 0 0 0 0
Coupling of process variance parameters for log(N) (keyVar-LogN)	0 1 1 1 1 1 1 1 1 1 1
Coupling of variance parameters on the observations (keyVarObs) (columns represent ages)	0 1 2 2 2 2 2 2 2 2 2 (catch; age 1 – 11+) 3 (BEL CBT LPUE; FSB) 4 (UK CBT LPUE; FSB) 5 (FRA COTB LPUE; FSB) 6 7 8 8 8 8 (UK BTS; age 1 - 6) 9 (UK YFS; age 1) 10 (FRA YFS; age 1)
Covariance structure per fleet (obsCorStruct)	ID ID ID ID AR ID ID

Settings	
(columns represent fleets: catch, BEL CBT LPUE, UK CBT LPUE, FRA COTB LPUE, UK BTS, UK YFS, FRA YFS) ID = independent AR = autocorrelated	
Coupling of correlation parameters (keyCorObs) (columns represent ages)	0 1 1 1 1 (UK BTS; age 1/2 - age 5/6)
Stock recruitment code (stockRecruitmentModelCode)	0 (random walk)
Number of years where catch scaling is applied (noScale-dYears)	None
Vector of years where catch scaling is applied (keyScale-dYears)	None
Matrix specifying coupling of scale parameters (key-ParScaledYA)	None
Fbar ranges	3-7
Type of biomass index (keyBiomassTreat)	2 (fishable stock biomass, FSB)
Option for observational likelihood (obsLikelihoodFlag)	LN LN LN LN LN LN LN
Treatment for weight attribute (fixVarToWeight)	/
Fraction of t(3) distribution used in log(F) increment distri-bution	/
Fraction of t(3) distribution used in log(N) increment distri-bution	/
Vector describing fraction for fleets (fracMixObs)	/
Vector describing break year between recruitment (con-stRecBreaks)	/
Coupling of parameters used in prediction-variance link for observations (predVarObsLink)	None

The SAM model fitting diagnostics and survey catchabilities are shown in Table 18.14 and Table 18.15 respectively. The assessment summary is given in Table 18.16 and Figure 18.23.

The *catches* predicted by SAM now corroborate the observed catches better compared to last year's assessment. Catches are approximately 1500 tonnes lower compared to the beginning of the time series.

The model estimates that the *SSB* ranged between 11 000 and 19 000 tonnes during the period 1982–2021. In 2020, the SSB was estimated at the lowest level of the time series. SSB at age is highest for age 5 in 2021 (Table 18.19).

The *fishing mortality* (F_{bar}) fluctuated over time with periods of high F in the late 1980s, 1990s and 2000s. Since 2010, F_{bar} has gradually declined, from ~0.40, to ~0.22 in 2021, the lowest level of the time series. The *fishing mortality-at-age* shows that the age 1 group is hardly caught by the fishery (Figure 18.24; Table 18.18), which is in contrast with all other age groups. The F-at-age shows that the selectivity of the fishery changed remarkably over time. Before 2005, fishing mortality was always highest for age groups 3, 4 and 5, while in the most recent years, fishing mortality for these ages declined strongly. Furthermore, the fishing mortality for age groups 6-11+ also declined with F on ages 10 and 11+ decreasing below F on age 2.

The *recruitment* (age 1) is estimated to range between 11 000 and 51 000 thousands individuals, and shows some periods of high recruitment e.g. in the early 1990s and in the period 2000-2010. Since the large recruitment in 2010, recruitment has been stable at lower levels (Table 18.17).

The process residuals do not indicate any large problems with respect to the model configuration (Figure 18.25).

The one step ahead residuals for the catch data do not indicate strong patterns across ages and years, except for some of the older ages (age 7, 9 and 11+) in the most recent years (Figure 18.26). The same is true for the UK BTS: no clear pattern except for the last years in the older ages. The UK CBT index shows some clear patterns over the years, which could be explained by the different trend this index shows compared to the other commercial tuning fleets.

The retrospective analysis does not indicate large problems with the model with respect to the SSB, Fbar and recruitment estimates (Figure 18.27). Almost all peels fall within the confidence bounds and Mohn's Rho values are within limits as defined at WKFORBIAS (Mohn's Rho SSB = 0.037; Fbar = -0.023 and recruitment = 0.056; ICES, 2020).

The leave-one-out runs indicate no strong dependency for one of the tuning fleets (Figure 18.28). However, removing the UK BTS gives a slightly lower SSB and higher F_{bar}, but all within the levels of confidence.

Figure 18.29 gives the model summary compared to the 2021 assessment. SSB is estimated slightly lower in the most recent year and catches and F_{bar} are estimated much lower compared to last year's assessment.

18.3.3 Historical stock trends

Trends in catch, SSB, F_{bar} and recruitment are presented in Table 18.16 and Figure 18.30.

Catches have been fluctuating around 4000 tonnes up to the year 2000. Catches fluctuating around 5000 tonnes were registered for the period 2000–2014. From 2015 onwards catches dropped below 4000 tonnes and dropped further below 3000 tonnes in 2016 and below 2000 tonnes in 2020 (1971 tonnes). In 2021, the lowest catches of the time series have been realised.

The *spawning-stock biomass* (SSB) has been fluctuating without trend since the 1980s between MSY $B_{trigger}$ and B_{lim}. In the period 2000–2015, SSB has been fluctuating around MSY $B_{trigger}$. However, in the most recent part of the time series, SSB has been fluctuating around B_{lim} and reaching B_{lim} in 2020.

Fishing mortality (F) has been exceeding F_{lim} (0.352) for the major part of the time series. From 2013 onwards, F decreased to below F_{pa} (0.318), decreasing further to drop below F_{MSY} (0.230) in 2020. In 2021, the lowest fishing mortality of the time series is reached (0.22).

Recruitment has been fluctuating without trend with occasional strong year classes. The last 10 years, recruitment has been lower compared to the earlier part of the time series.

18.4 Short-term forecast

Since the last benchmark (WKNSEA 2021), the short term forecast of sole in Division 27.7d is performed using the *stockassessment* package. Stock weights-at-age for the next three years are assumed to be the mean stock weight-at-age of the last five years. Selectivity of the fishery for the next three years is assumed to be the mean selectivity of the last five years.

Recruitment in the future years is the median of resampling from 2012 until the assessment year minus 1 (2012–2020). A stochastic forecast is conducted with 1000 simulations. The process noise F is set to false. The forecast results are split into landings and discards with the proportion of landings calculated as the mean of the last 5 years. An overview of the forecast settings is provided in the stock annex.

For the fishing mortality in the intermediate year, there are two possible scenarios: 1) status quo fishing mortality (Fsq) or 2) TAC constraint. For the status quo fishing mortality, there are again two options: 1a) if the Fbar shows no trend over the last three years, the mean Fbar of the last three years is taken as intermediate year assumption, 1b) if the Fbar shows a decreasing or increasing trend over the last three years, we scale to the last data year, which means that the Fbar in the intermediate years is the same as the last data year. For the TAC constraint option, the Fbar is calculated in the intermediate year as if the TAC would be fully fished in that year.

For this year's assessment, the Fsq option scaled to the last data year (2021) was considered (decreasing trend in Fbar: F_{2019} = 0.2345, F_{2020} = 0.2282, F_{2021} = 0.2196). Consequently, F in the intermediate year (2022) is set to F_{2021}.

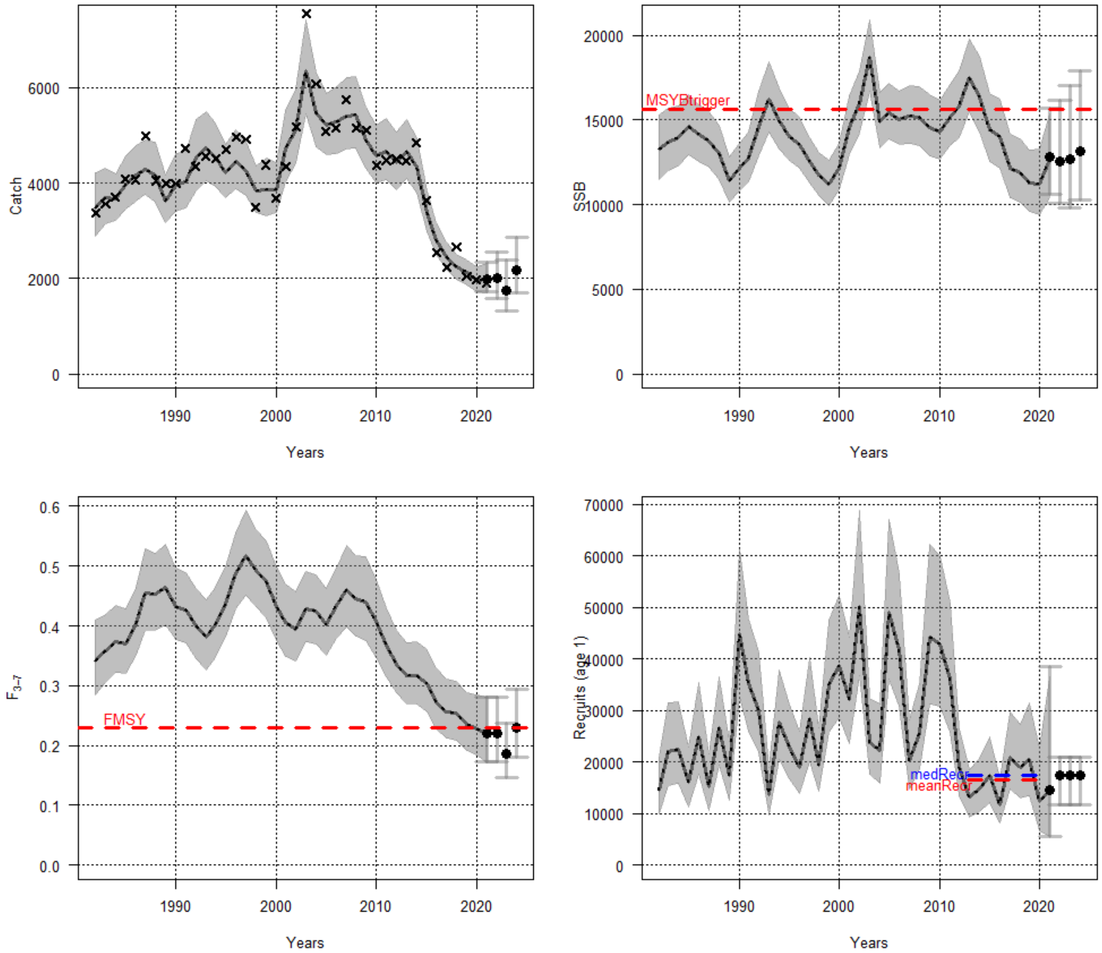
SSB 2023	F_{bar} (age 3–7)	F_{dis}	F_{lan}	recruits (age 1; thousands)
12682 t	0.2196	0.036	0.184	17337
landings	**discards**	**catch**	**TAC 2022**	**Catch advice for 2022**
1763 t	242 t	2005 t	2380 t	2380 t

Following the ICES advice rules, the target F in the advice year is set at F_{MSY} in case the SSB in the advice year (2023) is above MSY $B_{trigger}$, else, the target F is set as F_{MSY} x ($SSB_{advice\_year}/B_{trigger}$). In case the SSB is insufficient to bring the stock above B_{lim} in the advice year + 1, a zero TAC can be advised.

The SSB in 2023 (12 682 tonnes) was below MSY $B_{trigger}$ (15 654 tonnes), which means that F_{MSY} should be rescaled to in this case 0.186 (MSY approach). This resulted in a catch advice for 2023 of 1747 tonnes, which is a 27% decrease compared to the catch advice for 2022 (2380 tonnes). This decrease in advice is the result of a revision of the assessment during the 2022 inter-benchmark and a re-calculation of the reference points. In addition, the 2023 SSB is below MSY $B_{trigger}$ leading to a reduced F_{MSY}.

The output of the forecast, for the F_{sq} option (scaled to the last data year), is shown in the table and figure below.

basis	catch	landings	discards	$F_{3–7}$	F_lan	F_dis	SSB 2023	SSB 2024	SSB change	Advice change
F_{target}	1747	1529	218	0.186	0.156	0.030	12682	13162	3.8%	-27%
F_{MSY}	2116	1851	265	0.230	0.193	0.037	12682	12737	0.43%	-11.1%
F_{lower}	1487	1300	187	0.156	0.131	0.025	12682	13484	6.3%	-38%
$F_{lower\_rescaled}$	1221	1067	154	0.126	0.106	0.021	12682	13789	8.7%	-49%
F_{upper}	2577	2255	322	0.287	0.24	0.047	12682	12207	-3.8%	8.3%
F = 0	0	0	0	0	0	0	12682	15237	20%	-100%
F_{pa}	2821	2468	353	0.318	0.27	0.052	12682	11933	-5.9%	18.5%
F_{lim}	3070	2689	381	0.352	0.29	0.057	12682	11641	-8.2%	29%
SSB = B_{pa}	-	-	-	-	-	-	-	15654	-	-
SSB = $MSYB_{trigger}$	-	-	-	-	-	-	-	15654	-	-
SSB = B_{lim}	3463	3032	431	0.41	0.34	0.066	12682	11181	-11.8%	46%
F = F_{2022}	2032	1777	255	0.22	0.184	0.036	12682	12836	1.21%	-14.6%



Catch
Years
SSB
MSYBtrigger
F3-7
FMSY
Recruits (age 1)
medRecr
meanRecr

18.5 Biological reference points

The table below summarizes all known reference points for sole in Division 27.7.d and their technical basis. Reference points have been redefined as a result of the 2022 IBP (ICES, 2022).

Framework	Reference point	Value	Technical basis	Source
MSY approach	MSY $B_{trigger}$	15654	B_{pa}; in tonnes.	ICES (2022)
	F_{MSY}	0.230	Stochastic simulations (EqSim) with segmented regression fixed at B_{lim} based on recruitment period 1982–2020.	ICES (2022)
Precautionary approach	B_{lim}	11181	B_{loss}, lowest observed SSB (2020) with 2021 as the last year of catch data; in tonnes.	ICES (2022)
	B_{pa}	15654	B_{lim} × 1.4; in tonnes.	ICES (2022)
	F_{lim}	0.352	The F that on average leads to B_{lim} from EqSim.	ICES (2022)
	F_{pa}	0.318	The F that provides a 95% probability for SSB to be above B_{lim} ($F_{P.05}$ with AR)	ICES (2022)
F_{MSY} ranges	F_{lower}	0.156–0.230	Consistent with ranges resulting in no more than 5% reduction in long-term yield compared with F_{MSY}	ICES (2016, 2022)
	F_{upper}	0.230–0.287	Consistent with ranges resulting in no more than 5% reduction in long-term yield compared with F_{MSY}	ICES (2016, 2022)

18.6 Quality of the assessment

The sole in Division 27.7d stock was thoroughly reviewed during the 2022 IBP (ICES, 2022) where issues with the trend in survey catchability and the poor fit of the SAM model to the observed catches was investigated and improved.

18.7 Benchmark issue list

18.7.1 Data issues

During the benchmark, it was noted that sole in Division 27.7d exhibited a declining trend in the in the weights and lengths-at-age in recent years and more apparent in the older ages. It is not clear what mechanism is driving such decline. Future work should look into the potential causes for this declining trend.

Maturity estimates were not investigated during the last benchmark (WKNSEA 2021; ICES, 2021). Therefore, maturity estimates as calculated during the WKNSEA 2017 benchmark are used. These are derived from both commercial landings and survey data. Using commercial data could potentially introduce bias. When maturity estimates are revised, only fishery independent data should be considered (if available) to ensure that they align with contemporary stock dynamics. Future work should also revisit growth and natural mortality. However, for the latter data are currently inadequate (Lecomte *et al.,* 2020).

The subpopulation structure in this stock should be investigated further.

To improve estimation of discards in the assessment, discard mortality by gear type could be considered.

The poorer tracking of cohorts and internal consistency in the most recent part of the UK BTS time series should be investigated further.

18.7.2 Assessment issues

Biological and environmental processes should be explored for potential use in a model.

18.7.3 Short-term forecast issues

Currently no issues.

18.8 Management considerations

The sole stock in Division 27.7.d is harvested in a mixed fishery with plaice in 27.7.d. Due to the minimum mesh size in the mixed beam and otter trawl fisheries (80 mm), a large number of undersized plaice are discarded. The 80 mm mesh size is not matched to the minimum landing size of plaice (27 cm). Measures taken specifically to control sole fisheries will impact the plaice fisheries.

18.9 References

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Table 18.1: Sole 27.7.d - Official landings (tonnes) by country over the period 1974–2021; ICES estimates (as reported in InterCatch) for both landings and discards (tonnes) used by the working group. TAC (tonnes) represents landings until 2015. From 2016 onwards, TAC represents catch. * including BMS

Year	Official Landings					ICES estimates		TAC
	Belgium	France	UK (E&W)	Other	Total	Landings	Discards	
1974	159	383	309	3	854	884		
1975	132	464	244	1	841	882		
1976	203	599	404		1206	1305		
1977	225	737	315		1277	1335		
1978	241	782	366		1389	1589		
1979	311	1129	402		1842	2215		
1980	302	1075	159		1536	1923		
1981	464	1513	160		2137	2477		
1982	525	1828	317	4	2674	3190	196	
1983	502	1120	419		2041	3458	101	
1984	592	1309	505		2406	3575	141	
1985	568	2545	520		3633	3837	242	
1986	858	1528	551		2937	3932	145	
1987	1100	2086	655		3841	4791	197	3850
1988	667	2057	578		3302	3853	198	3850
1989	646	1610	689		2945	3805	192	3850
1990	996	1255	785		3036	3647	342	3850
1991	904	2054	826		3784	4351	368	3850
1992	891	2187	706	10	3794	4072	275	3500
1993	917	2322	610	13	3862	4299	273	3200
1994	940	2382	701	15	4038	4383	122	3800
1995	817	2248	669	9	3743	4420	282	3800
1996	899	2322	877		4098	4797	174	3500
1997	1306	1702	933		3941	4764	147	5230
1998	541	1703	803		3047	3363	127	5230
1999	880	2251	769		3900	4135	247	4700
2000	1021	2190	621		3832	3476	201	4100
2001	1313	2482	822		4617	4025	317	4600
2002	1643	2780	976		5399	4733	444	5200
2003	1657	3475	1114	1	6247	6977	584	5400
2004	1485	3070	1112		5667	5819	258	5900
2005	1221	2832	567		4620	4748	344	5700
2006	1547	2627	658	0.000	4832	4830	315	5720
2007	1530	2981	801	1.000	5313	5421	332	6220
2008	1368	2880	724	0.000	4972	4963	183	6593
2009	1475	3047	760	0.000	5282	4828	287	5274
2010	1294	2476	679	0.000	4449	4108	273	4219

Year	Official Landings					ICES estimates		TAC
	Belgium	France	UK (E&W)	Other	Total	Landings	Discards	
2011	1222	2281	700	0.000	4203	4136	342	4852
2012	941	2475	627	0.250	4043	4058	445	5580
2013	952	2884	605	0.000	4441	4295	180	5900
2014	1496	2507	648	0.100	4651	4626	216	4838
2015	1048	1895	468	0.000	3411	3385	263	3483
2016	799	1337	392	0.044	2528	2433	106	3258
2017	697	1178	349	0.154	2224	2090	156	2724
2018	653	1265	394	0.180	2312	2395	263	3405
2019	603*	925	245*	0.056	1773	1648	404	2515
2020	686*	827	193*	0.058	1706	1562	409*	2797
2021	624*	806	233*	0.958	1664	1561	348*	3248
2022								2380

Table 18.2: Sole 27.7.d - Summary of the InterCatch data in 2021 (imported vs. raised data; sampled vs. estimated data)

CatchCategory	RaisedOrImported	SampledOrEstimated	CATON	perc
Landings	Imported_Data	Sampled_Distribution	1374	88
Landings	Imported_Data	Estimated_Distribution	187.6	12
Discards	Imported_Data	Sampled_Distribution	248.3	71
Discards	Imported_Data	Estimated_Distribution	57.3	16
Discards	Raised_Discards	Estimated_Distribution	42.13	12
BMS landing	Imported_Data	Estimated_Distribution	0.205	100

Table 18.3: Sole 27.7.d - Landings percentages by gear type for 2015–2021 (GNS/GTR = gill and trammel nets; TBB = beam trawls; OTB/OTT/SSC/SDN = otter trawls and seines; other gears include MIS/FPO/DRB/LHM/LLS)

Landings by gear	2015	2016	2017	2018	2019	2020	2021
GNS/GTR	47%	46%	46%	44%	33%	28%	32%
TBB	35%	34%	31%	28%	33%	36%	35%
OTB/OTT/SSC/SDN	15.1%	15.9%	17.6%	24%	30%	33%	31%
Other	3.8%	4.5%	4.7%	4.5%	3.7%	2.8%	2.7%

Table 18.4: Sole 27.7.d - Catch numbers at age (in thousands)

age	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
1	375	0	59	122	122	22	236	405	3092	952	261	211	77
2	3432	1136	2630	4961	1685	4197	2910	4686	3836	9646	5446	6769	934
3	5688	3812	3476	5795	5904	4158	7995	3586	6214	4575	9794	7179	6912
4	1710	3971	2630	1675	3259	3336	1633	4482	1172	4242	1925	5551	6017
5	558	895	1890	1032	911	2068	1167	1443	1505	608	2006	1015	3427
6	636	731	736	1863	771	1046	859	842	302	1000	289	565	586
7	535	624	454	145	1062	1095	390	574	392	258	370	163	570
8	233	330	313	158	155	785	255	201	260	247	135	188	109
9	118	107	134	156	190	111	256	166	129	258	171	116	147
10	81	88	98	69	212	163	83	224	126	92	95	62	93
11+	196	191	235	128	372	459	275	282	489	382	231	129	258

age	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
1	2082	22	60	82	417	343	418	1756	57	121	771	412	168
2	4006	2456	2004	1855	4395	4831	8136	9431	15482	4164	6957	6942	7620
3	4874	8650	6761	6259	9470	5412	6905	8367	10669	11013	5185	4285	8307
4	4857	3094	5106	2761	3369	4485	1627	3839	4069	3682	4777	3097	3169
5	2987	3227	2096	1649	1319	1084	2509	1422	2168	4595	1256	3316	1794
6	1986	1830	1676	612	871	507	731	657	656	1670	920	1207	2769
7	377	1289	920	562	352	320	291	299	2068	379	636	1128	1010
8	278	271	776	443	672	148	128	129	229	394	392	579	753
9	88	319	239	354	351	328	56	97	73	291	211	239	450
10	106	112	169	239	192	150	81	57	134	254	104	233	194
11+	241	344	267	301	359	248	265	197	285	443	266	383	473

age	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
1	826	1270	585	353	739	40	372	300	144	565	1643	664	7	1038
2	2872	4446	5827	6148	3759	1150	1244	2131	1145	1060	3378	2341	2736	1158
3	8562	4494	4255	6938	8544	5951	3502	2101	2185	2467	1846	3086	2683	3306
4	5679	6164	2953	2854	5253	6595	6639	2303	1253	1447	2626	1086	2223	1726
5	1452	2500	3034	1562	1433	2539	4259	3496	1308	826	1022	1476	812	1206
6	1086	808	1621	1469	930	762	1853	2555	1553	876	736	481	915	512
7	758	719	320	562	563	545	687	1194	1059	850	619	312	427	424
8	410	664	277	178	414	535	417	463	598	698	821	227	166	251
9	157	277	288	147	98	205	374	142	188	287	451	392	131	127
10	168	239	102	132	46	59	145	238	211	139	286	282	182	67
11+	276	425	376	179	259	129	255	272	322	194	292	230	331	204

Table 18.5: Sole 27.7.d - Catch weights at age (kg)

age	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
1	0.078	0.000	0.076	0.068	0.103	0.073	0.078	0.081	0.091	0.087	0.078	0.065	0.076
2	0.155	0.157	0.162	0.166	0.164	0.159	0.138	0.140	0.162	0.146	0.139	0.134	0.136
3	0.215	0.220	0.224	0.220	0.203	0.226	0.216	0.184	0.228	0.199	0.194	0.189	0.178
4	0.309	0.299	0.311	0.279	0.303	0.292	0.276	0.269	0.287	0.264	0.265	0.245	0.233
5	0.385	0.403	0.379	0.367	0.362	0.352	0.359	0.292	0.348	0.353	0.289	0.334	0.287
6	0.427	0.435	0.435	0.393	0.386	0.406	0.408	0.357	0.339	0.393	0.402	0.383	0.354
7	0.439	0.434	0.416	0.515	0.436	0.410	0.458	0.387	0.469	0.421	0.390	0.536	0.380
8	0.509	0.524	0.538	0.543	0.520	0.482	0.514	0.472	0.465	0.430	0.462	0.553	0.505
9	0.502	0.537	0.529	0.594	0.502	0.465	0.553	0.515	0.487	0.434	0.459	0.515	0.484
10	0.463	0.583	0.565	0.595	0.523	0.538	0.563	0.547	0.518	0.478	0.463	0.766	0.496
11+	0.672	0.628	0.714	0.800	0.602	0.618	0.665	0.701	0.562	0.566	0.566	0.667	0.616

age	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
1	0.099	0.109	0.106	0.101	0.099	0.110	0.082	0.091	0.101	0.097	0.123	0.133	0.095
2	0.160	0.150	0.139	0.145	0.137	0.129	0.138	0.147	0.148	0.147	0.158	0.150	0.158
3	0.171	0.170	0.180	0.165	0.181	0.169	0.202	0.195	0.218	0.181	0.191	0.192	0.175
4	0.228	0.227	0.231	0.233	0.213	0.221	0.281	0.251	0.286	0.238	0.262	0.233	0.201
5	0.254	0.268	0.291	0.285	0.259	0.331	0.287	0.315	0.365	0.269	0.353	0.286	0.267
6	0.332	0.323	0.342	0.343	0.280	0.376	0.333	0.375	0.407	0.293	0.434	0.338	0.280
7	0.356	0.360	0.389	0.382	0.290	0.424	0.367	0.376	0.165	0.410	0.455	0.394	0.339
8	0.385	0.405	0.404	0.417	0.341	0.427	0.374	0.393	0.474	0.449	0.490	0.425	0.387
9	0.490	0.435	0.503	0.484	0.358	0.384	0.493	0.469	0.424	0.390	0.566	0.562	0.452
10	0.494	0.465	0.474	0.435	0.374	0.459	0.511	0.420	0.504	0.487	0.648	0.497	0.424
11+	0.654	0.585	0.651	0.616	0.535	0.680	0.544	0.531	0.565	0.664	0.550	0.552	0.570

age	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
1	0.121	0.113	0.101	0.089	0.058	0.095	0.098	0.077	0.093	0.094	0.081	0.058	0.091	0.083
2	0.156	0.155	0.152	0.148	0.121	0.141	0.134	0.127	0.136	0.143	0.121	0.118	0.114	0.125
3	0.207	0.201	0.192	0.201	0.181	0.189	0.176	0.168	0.199	0.184	0.171	0.175	0.152	0.160
4	0.243	0.252	0.241	0.245	0.233	0.241	0.231	0.223	0.242	0.229	0.214	0.230	0.197	0.197
5	0.258	0.268	0.276	0.301	0.270	0.297	0.267	0.266	0.266	0.252	0.268	0.244	0.224	0.240
6	0.311	0.322	0.322	0.330	0.312	0.301	0.325	0.282	0.285	0.291	0.289	0.274	0.243	0.282
7	0.370	0.316	0.334	0.357	0.375	0.384	0.328	0.330	0.320	0.293	0.289	0.290	0.271	0.286
8	0.397	0.383	0.337	0.424	0.354	0.402	0.389	0.329	0.371	0.362	0.250	0.318	0.312	0.324
9	0.433	0.383	0.367	0.389	0.424	0.415	0.413	0.408	0.361	0.432	0.327	0.272	0.382	0.376
10	0.511	0.430	0.520	0.425	0.544	0.463	0.494	0.372	0.358	0.479	0.362	0.338	0.285	0.394
11+	0.509	0.484	0.502	0.534	0.521	0.572	0.527	0.480	0.436	0.525	0.409	0.394	0.417	0.482

Table 18.6: Sole 27.7.d - Stock weights at age (kg)

age	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
1	0.077	0.078	0.075	0.067	0.102	0.072	0.077	0.080	0.090	0.086	0.077	0.064	0.075	0.098	0.108
2	0.167	0.169	0.175	0.179	0.177	0.172	0.149	0.151	0.175	0.157	0.150	0.145	0.147	0.173	0.162
3	0.243	0.248	0.253	0.248	0.229	0.255	0.244	0.208	0.257	0.225	0.219	0.213	0.201	0.193	0.192
4	0.352	0.340	0.354	0.318	0.345	0.332	0.314	0.306	0.327	0.301	0.302	0.279	0.265	0.260	0.258
5	0.424	0.444	0.417	0.404	0.399	0.388	0.395	0.322	0.383	0.389	0.318	0.368	0.316	0.280	0.295
6	0.472	0.481	0.481	0.435	0.427	0.449	0.451	0.395	0.375	0.435	0.445	0.424	0.392	0.367	0.357
7	0.488	0.482	0.462	0.572	0.485	0.456	0.509	0.430	0.521	0.468	0.434	0.596	0.422	0.396	0.400
8	0.441	0.454	0.466	0.471	0.451	0.418	0.445	0.409	0.403	0.373	0.400	0.479	0.438	0.334	0.351
9	0.486	0.520	0.512	0.575	0.486	0.450	0.536	0.499	0.472	0.420	0.445	0.499	0.469	0.475	0.421
10	0.481	0.606	0.587	0.618	0.543	0.559	0.585	0.568	0.538	0.497	0.481	0.796	0.515	0.513	0.483
11+	0.720	0.676	0.766	0.861	0.646	0.662	0.713	0.754	0.604	0.607	0.606	0.718	0.662	0.701	0.629

age	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
1	0.105	0.100	0.098	0.109	0.081	0.090	0.100	0.097	0.123	0.136	0.087	0.115	0.113	0.101	0.089
2	0.150	0.156	0.148	0.139	0.149	0.159	0.160	0.142	0.154	0.142	0.140	0.141	0.148	0.129	0.119
3	0.203	0.186	0.204	0.191	0.228	0.220	0.246	0.179	0.189	0.182	0.168	0.190	0.196	0.193	0.188
4	0.263	0.265	0.242	0.252	0.320	0.286	0.326	0.225	0.262	0.241	0.220	0.246	0.264	0.260	0.250
5	0.320	0.314	0.285	0.365	0.316	0.347	0.402	0.265	0.361	0.316	0.282	0.249	0.288	0.292	0.313
6	0.378	0.379	0.310	0.416	0.368	0.415	0.450	0.285	0.443	0.352	0.315	0.338	0.344	0.363	0.338
7	0.432	0.425	0.322	0.471	0.408	0.418	0.183	0.409	0.466	0.398	0.346	0.333	0.304	0.363	0.371
8	0.350	0.361	0.295	0.370	0.324	0.341	0.411	0.510	0.514	0.465	0.443	0.435	0.438	0.371	0.481
9	0.487	0.469	0.347	0.372	0.477	0.454	0.411	0.391	0.598	0.574	0.496	0.373	0.352	0.421	0.409
10	0.493	0.452	0.389	0.477	0.531	0.436	0.524	0.514	0.704	0.496	0.397	0.713	0.437	0.542	0.458
11+	0.700	0.661	0.577	0.727	0.585	0.569	0.608	0.692	0.588	0.632	0.613	0.472	0.606	0.537	0.561

age	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
1	0.057	0.092	0.097	0.075	0.090	0.094	0.081	0.060	0.093	0.082
2	0.104	0.104	0.093	0.102	0.101	0.135	0.111	0.104	0.097	0.125
3	0.177	0.163	0.144	0.177	0.211	0.176	0.177	0.177	0.142	0.175
4	0.228	0.244	0.235	0.244	0.273	0.229	0.247	0.232	0.203	0.220
5	0.275	0.339	0.283	0.296	0.294	0.267	0.296	0.272	0.263	0.276
6	0.331	0.340	0.346	0.308	0.331	0.305	0.324	0.305	0.273	0.318
7	0.387	0.439	0.396	0.373	0.367	0.323	0.343	0.307	0.317	0.329
8	0.384	0.416	0.429	0.336	0.448	0.384	0.332	0.352	0.369	0.376
9	0.467	0.431	0.442	0.398	0.537	0.478	0.371	0.286	0.459	0.393
10	0.548	0.416	0.592	0.380	0.456	0.508	0.407	0.361	0.346	0.419
11+	0.573	0.683	0.541	0.519	0.580	0.575	0.463	0.457	0.495	0.581

Table 18.7: Sole 27.7.d - Tuning series 1: revised Belgian commercial beam trawl LPUE (2004–2021)

	Effort	Biomass index
2004	1	16.07102
2005	1	16.20541
2006	1	17.09236
2007	1	17.79022
2008	1	16.36477
2009	1	20.32394
2010	1	20.63855
2011	1	18.40721
2012	1	19.5939
2013	1	19.57105
2014	1	26.37338
2015	1	19.24699
2016	1	15.34256
2017	1	12.77736
2018	1	13.60644
2019	1	12.38352
2020	1	14.09632
2021	1	13.00367

Table 18.8: Sole 27.7.d - Tuning series 2: revised French commercial otter trawl LPUE (2005–2021)

	Effort	Biomass index
2005	1	12.38602
2006	1	20.22522
2007	1	16.0661
2008	1	19.21138
2009	1	17.38505
2010	1	21.70135
2011	1	20.80243
2012	1	15.74394
2013	1	19.09761
2014	1	23.43202
2015	1	16.43014
2016	1	16.54022
2017	1	13.09417
2018	1	19.08316
2019	1	15.27678
2020	1	14.34685
2021	1	13.64243

Table 18.9: Sole 27.7.d - Tuning series 3: UK (E&W) commercial beam trawl LPUE (1986–2021)

	Effort	Biomass index
1986	1	136.8362
1987	1	141.6753
1988	1	132.335
1989	1	108.4702
1990	1	110.4072
1991	1	71.76351
1992	1	65.85249
1993	1	54.27752
1994	1	56.35275
1995	1	66.55716
1996	1	92.21047
1997	1	89.13409
1998	1	102.132
1999	1	95.19193
2000	1	94.18399
2001	1	98.68089
2002	1	129.2171
2003	1	119.2152
2004	1	127.0566
2005	1	142.3952
2006	1	126.3615
2007	1	122.0006
2008	1	109.1686
2009	1	85.90204
2010	1	87.42909
2011	1	83.74945
2012	1	78.12183
2013	1	82.61268
2014	1	87.54479
2015	1	92.96908
2016	1	97.52973
2017	1	76.4706
2018	1	77.20523
2019	1	74.07598
2020	1	87.76585
2021	1	93.84516

Table 18.10: Sole 27.7.d - Tuning series 4: UK (E&W) beam trawl survey (Q3) (1989–2021); grey values are currently not included in the assessment.

	Effort	Age1	Age2	Age3	Age4	Age5	Age6
1989	1	3.01	22.09	4.62	2.45	0.56	0.35
1990	1	17.96	5.55	5.55	1.24	1.01	0.33
1991	1	12.14	31.17	3.19	2.82	0.48	0.67
1992	1	1.33	15.29	13.47	1.07	1.61	0.34
1993	1	0.82	22.96	11.42	9.97	1.14	1.52
1994	1	8.33	4.26	11.07	4.65	4.3	0.28
1995	1	5.89	16.09	2.22	3.51	1.67	2.12
1996	1	5.3	10.79	5.97	1.07	1.86	1.15
1997	1	24.75	10.85	4.42	1.94	0.26	0.82
1998	1	3.27	24.11	3.67	1.47	0.83	0.19
1999	1	35.99	8.22	11.33	1.59	0.73	1.02
2000	1	14.98	27.45	5.52	4.85	1.48	0.68
2001	1	10.19	27.88	11.55	1.67	2.33	0.75
2002	1	53.56	16.11	8.6	5.11	0.45	1.04
2003	1	11.03	45.65	5.87	3.2	2.05	0.42
2004	1	12.67	11.81	10.97	2.08	2.02	1.34
2005	1	43.27	6.91	3.5	5.18	1.9	1.15
2006	1	10.84	42.62	4.51	2.68	2.59	0.55
2007	1	2.57	28.97	15.45	1.47	1.04	1.56
2008	1	3.77	7.35	9.14	5.82	0.4	0.68
2009	1	51.25	19.16	7.1	5.81	5.02	0.44
2010	1	16.59	30.76	5.14	1.66	2.7	2.73
2011	1	13.66	28.6	14.7	1.66	0.54	2.62
2012	1	1.75	9.72	7.51	3.53	0.92	0.39
2013	1	0.72	8.91	15.09	9.72	3.23	1.12
2014	1	25.39	16.35	12.38	11.92	5.09	2.73
2015	1	25.24	21.36	6.04	2.29	4.51	2.08
2016	1	10.17	33.14	11.17	3.16	3.17	3.02
2017	1	27.85	15.18	16.26	2.67	2.13	1.52
2018	1	14.86	36.49	6.66	10.32	1.74	2.13
2019	1	56.54	31.08	19.53	1.18	4.01	2.53
2020	1	1.87	42.73	8.01	4.62	1.15	1.84
2021	1	32.95	16.06	22.82	5.31	4.65	1.10

Table 18.11: Sole 27.7.d - Tuning series 5: UK (E&W) young fish survey (1987–2006)

	Effort	Age1
1987	1	1.38
1988	1	1.87
1989	1	0.62
1990	1	1.9
1991	1	3.69
1992	1	1.5
1993	1	1.33
1994	1	2.68
1995	1	2.91
1996	1	0.57
1997	1	1.12
1998	1	1.12
1999	1	1.47
2000	1	2.47
2001	1	0.38
2002	1	4.15
2003	1	1.44
2004	1	2.72
2005	1	4.07
2006	1	2.21

Table 18.12: Sole 27.7.d - Tuning series 6: French young fish survey (1987–2021) funded by EDF (noursom)

	Effort	Age1
1987	1	0.07
1988	1	0.17
1989	1	0.14
1990	1	0.54
1991	1	0.38
1992	1	0.22
1993	1	0.03
1994	1	0.7
1995	1	0.28
1996	1	0.15
1997	1	0.03
1998	1	0.1
1999	1	0.35
2000	1	0.31
2001	1	1.21
2002	1	0.11
2003	1	0.32
2004	1	0.15
2005	1	0.82
2006	1	0.83
2007	1	0.08
2008	1	0.06
2009	1	2.78
2010	1	0.1
2011	1	0.32
2012	1	0.35
2013	1	0.052
2014	1	0.04
2015	1	0.09
2016	1	0.04
2017	1	0.05
2018	1	0.03
2019	1	0.45
2020	1	0.38
2021	1	0.07

Table 18.13: Sole 27.7.d – SAM model configuration of the 2022 assessment

```
# Where a matrix is specified rows corresponds to fleets and columns to ages.
# Same number indicates same parameter used
# Numbers (integers) starts from zero and must be consecutive

$minAge
# The minimum age class in the assessment
 1
$maxAge
# The maximum age class in the assessment
 11
$maxAgePlusGroup
# Is last age group considered a plus group (1 yes, or 0 no).
 1 0 0 0 0 0 0

$keyLogFsta
# Coupling of the fishing mortality states (normally only first row is used).
     [,1] [,2] [,3] [,4] [,5] [,6] [,7] [,8] [,9] [,10] [,11]
[1,]    0    1    2    3    4    5    5    6    6     7     7
[2,]   -1   -1   -1   -1   -1   -1   -1   -1   -1    -1    -1
[3,]   -1   -1   -1   -1   -1   -1   -1   -1   -1    -1    -1
[4,]   -1   -1   -1   -1   -1   -1   -1   -1   -1    -1    -1
[5,]   -1   -1   -1   -1   -1   -1   -1   -1   -1    -1    -1
[6,]   -1   -1   -1   -1   -1   -1   -1   -1   -1    -1    -1
[7,]   -1   -1   -1   -1   -1   -1   -1   -1   -1    -1    -1
$corFlag
# Correlation of fishing mortality across ages (0 independent, 1 compound symmetry, or 2 AR(1))
 0
$keyLogFpar
# Coupling of the survey catchability parameters (normally first row is not used, as that is covered
by fishing mortality).
     [,1] [,2] [,3] [,4] [,5] [,6] [,7] [,8] [,9] [,10] [,11]
[1,]   -1   -1   -1   -1   -1   -1   -1   -1   -1    -1    -1
[2,]    0   -1   -1   -1   -1   -1   -1   -1   -1    -1    -1
[3,]    1   -1   -1   -1   -1   -1   -1   -1   -1    -1    -1
[4,]    2   -1   -1   -1   -1   -1   -1   -1   -1    -1    -1
[5,]    3    4    5    6    7    7   -1   -1   -1    -1    -1
[6,]    8   -1   -1   -1   -1   -1   -1   -1   -1    -1    -1
[7,]    9   -1   -1   -1   -1   -1   -1   -1   -1    -1    -1
$keyQpow
# Density dependent catchability power parameters (if any).
     [,1] [,2] [,3] [,4] [,5] [,6] [,7] [,8] [,9] [,10] [,11]
[1,]   -1   -1   -1   -1   -1   -1   -1   -1   -1    -1    -1
[2,]   -1   -1   -1   -1   -1   -1   -1   -1   -1    -1    -1
[3,]   -1   -1   -1   -1   -1   -1   -1   -1   -1    -1    -1
[4,]   -1   -1   -1   -1   -1   -1   -1   -1   -1    -1    -1
[5,]   -1   -1   -1   -1   -1   -1   -1   -1   -1    -1    -1
[6,]   -1   -1   -1   -1   -1   -1   -1   -1   -1    -1    -1
[7,]   -1   -1   -1   -1   -1   -1   -1   -1   -1    -1    -1
$keyVarF
# Coupling of process variance parameters for log(F)-process (normally only first row is used)
     [,1] [,2] [,3] [,4] [,5] [,6] [,7] [,8] [,9] [,10] [,11]
[1,]    0    0    0    0    0    0    0    0    0     0     0
[2,]   -1   -1   -1   -1   -1   -1   -1   -1   -1    -1    -1
[3,]   -1   -1   -1   -1   -1   -1   -1   -1   -1    -1    -1
[4,]   -1   -1   -1   -1   -1   -1   -1   -1   -1    -1    -1
[5,]   -1   -1   -1   -1   -1   -1   -1   -1   -1    -1    -1
[6,]   -1   -1   -1   -1   -1   -1   -1   -1   -1    -1    -1
[7,]   -1   -1   -1   -1   -1   -1   -1   -1   -1    -1    -1
$keyVarLogN
# Coupling of process variance parameters for log(N)-process
```

```
 0 1 1 1 1 1 1 1 1 1 1
$keyVarObs
# Coupling of the variance parameters for the observations.
    [,1] [,2] [,3] [,4] [,5] [,6] [,7] [,8] [,9] [,10] [,11]
[1,]    0    1    2    2    2    2    2    2    2     2     2
[2,]    3   -1   -1   -1   -1   -1   -1   -1   -1    -1    -1
[3,]    4   -1   -1   -1   -1   -1   -1   -1   -1    -1    -1
[4,]    5   -1   -1   -1   -1   -1   -1   -1   -1    -1    -1
[5,]    6    7    8    8    8    8   -1   -1   -1    -1    -1
[6,]    9   -1   -1   -1   -1   -1   -1   -1   -1    -1    -1
[7,]   10   -1   -1   -1   -1   -1   -1   -1   -1    -1    -1
$obsCorStruct
# Covariance structure for each fleet ("ID" independent, "AR" AR(1), or "US" for unstructured). |
Possible values are: "ID" "AR" "US"
 ID ID ID ID AR ID ID
$keyCorObs
# Coupling of correlation parameters can only be specified if the AR(1) structure is chosen above.
# NA's indicate where correlation parameters can be specified (-1 where they cannot).
    1-2 2-3 3-4 4-5 5-6 6-7 7-8 8-9 9-10 10-11
[1,]  NA  NA  NA  NA  NA  NA  NA  NA   NA    NA
[2,]  -1  -1  -1  -1  -1  -1  -1  -1   -1    -1
[3,]  -1  -1  -1  -1  -1  -1  -1  -1   -1    -1
[4,]  -1  -1  -1  -1  -1  -1  -1  -1   -1    -1
[5,]   0   1   1   1   1  -1  -1  -1   -1    -1
[6,]  -1  -1  -1  -1  -1  -1  -1  -1   -1    -1
[7,]  -1  -1  -1  -1  -1  -1  -1  -1   -1    -1
$stockRecruitmentModelCode
# Stock recruitment code (0 for plain random walk, 1 for Ricker, and 2 for Beverton-Holt).
 0
$noScaledYears
# Number of years where catch scaling is applied.
 0
$keyScaledYears
# A vector of the years where catch scaling is applied.
 Numeric(0)
$keyParScaledYA
# A matrix specifying the couplings of scale parameters (nrow = no scaled years, ncols = no ages).
<0 x 0 matrix>
$fbarRange
# lowest and highest age included in Fbar
 3 7
$keyBiomassTreat
# To be defined only if a biomass survey is used (0 = SSB index; 1 = catch index; 2 = FSB index; 3 =
total catch; 4 = total landings; 5 = TSB index).
 -1  2  2  2 -1 -1 -1
$obsLikelihoodFlag
# Option for observational likelihood | Possible values are: "LN" "ALN"
 LN LN LN LN LN LN LN
$fixVarToWeight
# If weight attribute is supplied for observations this option sets the treatment (0 relative weight,
1 fix variance to weight).
 0
$fracMixF
# The fraction of t(3) distribution used in logF increment distribution
 0
$fracMixN
# The fraction of t(3) distribution used in logN increment distribution
 0 0 0 0 0 0 0 0 0 0 0
$fracMixObs
# A vector with same length as number of fleets, where each element is the fraction of t(3) distribution
used in the distribution of that fleet
0 0 0 0 0 0 0
```

```
$constRecBreaks
# Vector of break years between which recruitment is at constant level. The break year is included in
the left interval. (This option is only used in combination with stock recruitment code =3)
numeric(0)
$predVarObsLink
# Coupling of parameters used in a prediction-variance link for observations
     [,1] [,2] [,3] [,4] [,5] [,6] [,7] [,8] [,9] [,10] [,11]
[1,]   -1   -1   -1   -1   -1   -1   -1   -1   -1    -1    -1
[2,]   NA   NA   NA   NA   NA   NA   NA   NA   NA    NA    NA
[3,]   NA   NA   NA   NA   NA   NA   NA   NA   NA    NA    NA
[4,]   NA   NA   NA   NA   NA   NA   NA   NA   NA    NA    NA
[5,]   -1   -1   -1   -1   -1   -1   NA   NA   NA    NA    NA
[6,]   NA   NA   NA   NA   NA   NA   NA   NA   NA    NA    NA
[7,]   NA   NA   NA   NA   NA   NA   NA   NA   NA    NA    NA
$hockeyStickCurve
20
$stockWeightModel
0
$keyStockWeightMean
NA NA NA NA NA NA NA NA NA NA NA
$keyStockWeightObsVar
NA NA NA NA NA NA NA NA NA NA NA
$catchWeightModel
0
$keyCatchWeightMean
NA NA NA NA NA NA NA NA NA NA NA
$keyCatchWeightObsVar
NA NA NA NA NA NA NA NA NA NA NA
$matureModel
0
$keyMatureMean
NA NA NA NA NA NA NA NA NA NA NA
$mortalityModel
0
$keyMortalityMean
NA NA NA NA NA NA NA NA NA NA NA
$keyMortalityObsVar
NA NA NA NA NA NA NA NA NA NA NA
$keyXtraSd
[,1] [,2] [,3] [,4]
```

Table 18.14: Sole 27.7.d – SAM model fitting diagnostics of the 2022 assessment

Model fitting		
log(Lik)	#par	AIC
-449.6476	26	951.2953

Table 18.15: Sole 27.7.d – SAM model survey catchability of the 2022 assessment

estimate	1	2	3	4	5	6	7	8	9	10	11
BE-CBT-LPUE	-4.3433	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
UK(E&W)-CBT	-2.5937	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
FR-COTB-model	-4.3240	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
UK(E&W)-BTS-Q3	-7.9899	-7.1639	-7.4998	-7.7646	-7.8973	-7.8973	NA	NA	NA	NA	NA
UK(E&W)-YFS	-9.6603	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
FR-YFS	-11.7887	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

sd	1	2	3	4	5	6	7	8	9	10	11
BE-CBT-LPUE	0.0739	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
UK(E&W)-CBT	0.0678	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
FR-COTB-model	0.0808	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
UK(E&W)-BTS-Q3	0.1988	0.0875	0.0942	0.0781	0.0715	0.0715	NA	NA	NA	NA	NA
UK(E&W)-YFS	0.1354	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
FR-YFS	0.1685	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table 18.16: Sole 27.7.d – Assessment summary

Year	Recruitment			Spawning stock biomass			Landings	Discards*	Fishing mortality		
	Age 1	High	Low	SSB	High	Low			F_{3-7}	High	Low
	thousands			tonnes			tonnes	tonnes			
1982	14483	20990	9993	13269	15314	11497	3190	196	0.34	0.41	0.28
1983	22072	31478	15477	13706	15669	11988	3458	101	0.36	0.42	0.31
1984	22416	31739	15831	13943	15809	12297	3575	141	0.37	0.43	0.32
1985	16039	22855	11255	14629	16508	12963	3837	242	0.37	0.43	0.32
1986	24937	35428	17553	14127	15917	12537	3932	145	0.40	0.46	0.35
1987	15187	21600	10678	13751	15472	12222	4791	197	0.46	0.53	0.39
1988	26733	36668	19489	12984	14669	11493	3853	198	0.45	0.52	0.39
1989	17459	24056	12671	11402	12784	10169	3805	192	0.46	0.54	0.40
1990	44835	61464	32705	12143	13632	10816	3647	342	0.43	0.50	0.38
1991	35274	47767	26049	12740	14286	11361	4351	368	0.43	0.49	0.37
1992	30010	41449	21728	14653	16686	12868	4072	275	0.40	0.46	0.35
1993	13662	19036	9805	16233	18438	14292	4299	273	0.38	0.44	0.33
1994	27762	37784	20398	14954	16861	13262	4383	122	0.40	0.46	0.35
1995	22904	31381	16716	14045	15657	12599	4420	282	0.44	0.50	0.38
1996	19035	26009	13932	13581	15141	12181	4797	174	0.49	0.56	0.43
1997	28490	40269	20157	12576	13980	11312	4764	147	0.52	0.59	0.45
1998	19472	26627	14240	11749	13079	10554	3363	127	0.49	0.56	0.43
1999	35029	47624	25766	11212	12628	9955	4135	247	0.47	0.54	0.41
2000	38689	52362	28587	12165	13598	10882	3476	201	0.43	0.50	0.38
2001	32247	44218	23516	14571	16431	12922	4025	317	0.41	0.47	0.35
2002	50278	68808	36738	15939	17898	14195	4733	444	0.39	0.46	0.34
2003	23873	32336	17625	18685	20912	16696	6977	584	0.43	0.49	0.37
2004	22334	31182	15997	14889	16599	13354	5819	258	0.42	0.49	0.37
2005	49199	67037	36108	15428	17154	13876	4748	344	0.40	0.46	0.35
2006	41896	56716	30949	15042	16725	13529	4830	315	0.43	0.50	0.38
2007	20393	28167	14764	15213	17022	13596	5421	332	0.46	0.53	0.40
2008	25481	35232	18429	15130	16978	13484	4963	183	0.45	0.52	0.38
2009	44239	62394	31367	14578	16483	12894	4828	287	0.44	0.52	0.38
2010	43045	60012	30876	14315	16189	12658	4108	273	0.41	0.48	0.35
2011	36225	51071	25694	15184	17086	13493	4136	342	0.37	0.43	0.32
2012	18977	26718	13478	15823	17903	13985	4058	445	0.34	0.39	0.29
2013	13213	18630	9371	17510	19791	15491	4295	180	0.32	0.37	0.27
2014	14721	20741	10449	16391	18798	14293	4626	216	0.32	0.37	0.27
2015	17337	24854	12093	14414	16566	12542	3385	263	0.30	0.36	0.26
2016	11805	16802	8294	14028	16194	12151	2433	106	0.27	0.33	0.23
2017	20880	29652	14704	12142	14175	10401	2090	156	0.26	0.31	0.21
2018	18904	27271	13105	11883	13886	10170	2395	263	0.25	0.31	0.21

Year	Recruitment			Spawning stock biomass			Landings	Discards*	Fishing mortality		
	Age 1	High	Low	SSB	High	Low			F_{3-7}	High	Low
	thousands			tonnes			tonnes	tonnes			
2019	20508	31461	13369	11252	13185	9603	1648	404	0.23	0.29	0.191
2020	12387	22724	6752	11181	13295	9404	1562	409	0.23	0.28	0.184
2021	14305	36517	5604	12650	15367	10413	1561	348	0.22	0.28	0.172
2022	17337**	20880	11805	12582	16154	10044					

*** Discard estimates prior to 2004 assume the average discard proportion by age for 2004–2008 (WKNSEA; ICES, 2021).**

**** Median recruitment resampled from the years 2012–2020.**

Table 18.17: Sole 27.7.d – Stock numbers for the 2022 SAM assessment (in thousands).

age	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
1	14483	22072	22416	16039	24937	15187	26733	17459	44835	35274	30010	13662	27762	22904	19035
2	17784	12618	20167	20627	13875	23472	13003	24997	14932	41877	30403	28702	11609	25381	19539
3	21023	13218	9814	15840	15300	10234	17945	8828	18287	10449	30721	22445	22250	9573	19631
4	4986	13246	7961	5786	9240	8091	5219	9246	4118	10065	5548	18070	13642	13381	5545
5	3257	2945	8248	4722	3544	5389	4218	2869	4723	2116	5563	3227	10767	7830	7682
6	3100	2375	1888	5817	3209	2375	3178	2421	1519	2656	1205	3160	2001	6367	4605
7	1851	2129	1568	1070	3832	2141	1387	1933	1484	994	1593	796	2151	1458	3989
8	923	1193	1417	1016	710	2458	1224	848	1184	948	656	1005	556	1427	1052
9	588	627	785	1030	785	506	1601	827	576	806	623	471	689	410	1026
10	409	417	447	540	790	574	354	1111	563	389	512	405	339	480	303
11+	991	1004	1031	1039	1254	1488	1389	1222	1641	1449	1170	1092	1104	1028	1077

age	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
1	28490	19472	35029	38689	32247	50278	23873	22334	49199	41896	20393	25481	44239	43045	36225
2	17290	27447	17013	31747	34883	29022	46441	20638	18658	44307	38255	17843	22801	38413	39095
3	14658	13736	23180	12274	23134	24232	19550	30045	14042	12165	30381	27497	13446	16038	26877
4	10078	7075	7231	12595	6106	13001	13126	9717	15936	8304	6709	17669	17213	8137	9422
5	2950	4800	3511	3918	7284	3651	7773	8101	5530	9733	4858	3473	9656	9691	4571
6	4228	1512	2500	1915	2358	4258	2244	4633	4392	3438	5777	2870	1957	5347	5624
7	2810	2485	927	1392	1201	1541	3106	1539	2876	2921	2198	3090	1650	1105	2856
8	2357	1681	1570	547	846	787	1083	1817	1102	1902	1755	1263	1807	899	666
9	789	1432	1088	955	348	608	588	804	1172	776	1233	1012	797	1083	529
10	684	560	878	676	576	250	460	474	521	795	519	744	677	476	668
11+	922	1068	1077	1241	1286	1276	1114	1116	1018	1060	1236	1108	1258	1257	1098

age	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
1	18977	13213	14721	17337	11805	20880	18904	20508	12387	14305
2	33039	16366	11753	13172	15884	10154	19391	16745	18407	10775
3	30359	27136	13301	9327	10136	13500	7921	15118	13023	14261
4	16583	20958	20657	8933	6403	6845	10730	5318	10859	9120
5	5447	10128	13805	12975	5851	4378	4696	7316	3798	7639
6	2897	3501	6840	8718	7934	3818	3086	3328	4983	2762
7	3340	2017	2457	4529	5600	5187	2552	2004	2433	3431
8	1716	2230	1408	1677	2953	3817	3678	1655	1393	1793
9	427	1079	1540	964	1153	2059	2792	2601	1180	1053
10	317	288	731	1062	722	830	1534	2055	1889	892
11+	1209	1039	1003	1233	1569	1531	1734	2309	3245	3782

Table 18.18: Sole 27.7.d – Fishing mortality (F) at age for the 2022 SAM assessment.

age	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
1	0.010	0.009	0.009	0.009	0.009	0.010	0.010	0.010	0.011	0.011	0.010	0.010	0.010	0.010	0.010
2	0.176	0.168	0.176	0.191	0.194	0.207	0.222	0.225	0.228	0.216	0.200	0.185	0.164	0.163	0.160
3	0.384	0.404	0.437	0.469	0.514	0.548	0.566	0.566	0.522	0.505	0.450	0.434	0.448	0.510	0.556
4	0.417	0.407	0.417	0.422	0.456	0.497	0.499	0.530	0.504	0.494	0.471	0.452	0.483	0.504	0.565
5	0.263	0.292	0.293	0.307	0.341	0.398	0.428	0.477	0.459	0.445	0.444	0.431	0.438	0.474	0.520
6	0.321	0.342	0.360	0.327	0.352	0.418	0.385	0.375	0.339	0.345	0.316	0.294	0.321	0.347	0.398
7	0.321	0.342	0.360	0.327	0.352	0.418	0.385	0.375	0.339	0.345	0.316	0.294	0.321	0.347	0.398
8	0.259	0.252	0.234	0.219	0.246	0.267	0.255	0.267	0.280	0.304	0.288	0.271	0.262	0.267	0.301
9	0.259	0.252	0.234	0.219	0.246	0.267	0.255	0.267	0.280	0.304	0.288	0.271	0.262	0.267	0.301
10	0.233	0.233	0.234	0.215	0.263	0.286	0.271	0.271	0.285	0.281	0.253	0.232	0.270	0.291	0.332
11+	0.233	0.233	0.234	0.215	0.263	0.286	0.271	0.271	0.285	0.281	0.253	0.232	0.270	0.291	0.332

age	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
1	0.010	0.010	0.010	0.011	0.011	0.011	0.011	0.012	0.012	0.012	0.013	0.014	0.014	0.014	0.015
2	0.159	0.164	0.197	0.217	0.246	0.274	0.285	0.278	0.278	0.252	0.235	0.219	0.210	0.194	0.168
3	0.585	0.569	0.545	0.546	0.504	0.520	0.554	0.510	0.475	0.456	0.418	0.396	0.389	0.368	0.334
4	0.595	0.568	0.528	0.469	0.426	0.412	0.417	0.438	0.427	0.460	0.502	0.479	0.476	0.458	0.424
5	0.575	0.528	0.490	0.442	0.441	0.444	0.437	0.466	0.417	0.431	0.447	0.462	0.429	0.417	0.395
6	0.414	0.399	0.402	0.353	0.327	0.298	0.368	0.353	0.347	0.411	0.469	0.446	0.454	0.397	0.344
7	0.414	0.399	0.402	0.353	0.327	0.298	0.368	0.353	0.347	0.411	0.469	0.446	0.454	0.397	0.344
8	0.333	0.342	0.362	0.321	0.243	0.221	0.231	0.293	0.316	0.350	0.389	0.354	0.378	0.360	0.344
9	0.333	0.342	0.362	0.321	0.243	0.221	0.231	0.293	0.316	0.350	0.389	0.354	0.378	0.360	0.344
10	0.332	0.341	0.314	0.275	0.253	0.264	0.315	0.377	0.348	0.362	0.371	0.333	0.331	0.290	0.250
11+	0.332	0.341	0.314	0.275	0.253	0.264	0.315	0.377	0.348	0.362	0.371	0.333	0.331	0.290	0.250

age	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
1	0.015	0.015	0.015	0.016	0.016	0.016	0.016	0.016	0.016	0.016
2	0.145	0.132	0.132	0.134	0.129	0.136	0.146	0.147	0.147	0.143
3	0.300	0.273	0.278	0.268	0.256	0.240	0.250	0.247	0.250	0.253
4	0.390	0.359	0.351	0.318	0.285	0.274	0.269	0.256	0.247	0.239
5	0.362	0.341	0.343	0.324	0.290	0.263	0.253	0.242	0.231	0.216
6	0.315	0.306	0.307	0.304	0.270	0.254	0.248	0.214	0.207	0.195
7	0.315	0.306	0.307	0.304	0.270	0.254	0.248	0.214	0.207	0.195
8	0.315	0.289	0.272	0.240	0.219	0.202	0.196	0.175	0.155	0.154
9	0.315	0.289	0.272	0.240	0.219	0.202	0.196	0.175	0.155	0.154
10	0.234	0.225	0.237	0.242	0.234	0.195	0.174	0.139	0.114	0.093
11+	0.234	0.225	0.237	0.242	0.234	0.195	0.174	0.139	0.114	0.093

Table 18.19: Sole 27.7.d – Spawning stock biomass (SSB; tonnes) at age for the 2022 SAM assessment.

age	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	1574	1130	1871	1957	1302	2140	1027	2000	1385	3485	2417	2206	904	2327	1678
3	4700	3016	2284	3614	3223	2401	4028	1689	4324	2163	6190	4398	4114	1700	3468
4	1685	4324	2706	1766	3060	2579	1573	2716	1293	2909	1609	4840	3470	3340	1373
5	1340	1268	3336	1850	1372	2028	1616	896	1755	799	1716	1152	3300	2127	2198
6	1463	1142	908	2530	1370	1067	1433	956	570	1155	536	1340	784	2337	1644
7	903	1026	724	612	1858	976	706	831	773	465	691	474	908	577	1595
8	407	542	660	479	320	1028	545	347	477	354	262	481	243	477	369
9	286	326	402	592	382	228	858	413	272	338	277	235	323	195	432
10	197	253	262	334	429	321	207	631	303	193	246	323	175	246	146
11+	714	679	790	895	810	985	990	922	992	879	709	784	731	720	677

age	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	1375	2269	1334	2339	2755	2446	3938	1553	1523	3335	2839	1333	1789	2626	2466
3	2738	2350	4350	2157	4853	4905	4425	4948	2442	2037	4696	4806	2425	2848	4649
4	2545	1800	1680	3047	1876	3569	4108	2099	4008	1921	1417	4173	4362	2031	2261
5	916	1462	971	1387	2233	1229	3031	2082	1936	2983	1329	839	2697	2745	1388
6	1598	573	775	797	868	1767	1010	1320	1946	1210	1820	970	673	1941	1901
7	1214	1056	298	656	490	644	568	629	1340	1163	760	1029	502	401	1060
8	825	607	463	202	274	268	445	926	566	884	777	550	791	334	320
9	384	672	377	355	166	276	242	314	701	445	612	377	280	456	217
10	337	253	342	322	306	109	241	244	367	394	206	531	296	258	306
11+	645	706	621	902	752	726	677	772	599	670	758	522	763	675	617

age	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
1	0	0	0	0	0	0	0	0	0	0
2	1821	902	579	712	850	727	1141	923	946	714
3	4944	4069	1762	1519	1968	2186	1290	2462	1701	2296
4	3630	4909	4660	2093	1678	1505	2544	1184	2116	1926
5	1453	3330	3790	3725	1669	1134	1348	1930	969	2045
6	959	1190	2366	2685	2626	1164	1000	1015	1360	878
7	1292	885	973	1689	2055	1675	875	615	771	1129
8	659	928	604	563	1323	1466	1221	582	514	674
9	199	465	681	384	619	984	1036	744	542	414
10	174	120	433	404	329	422	624	742	654	374
11+	692	710	543	640	911	880	803	1055	1608	2199

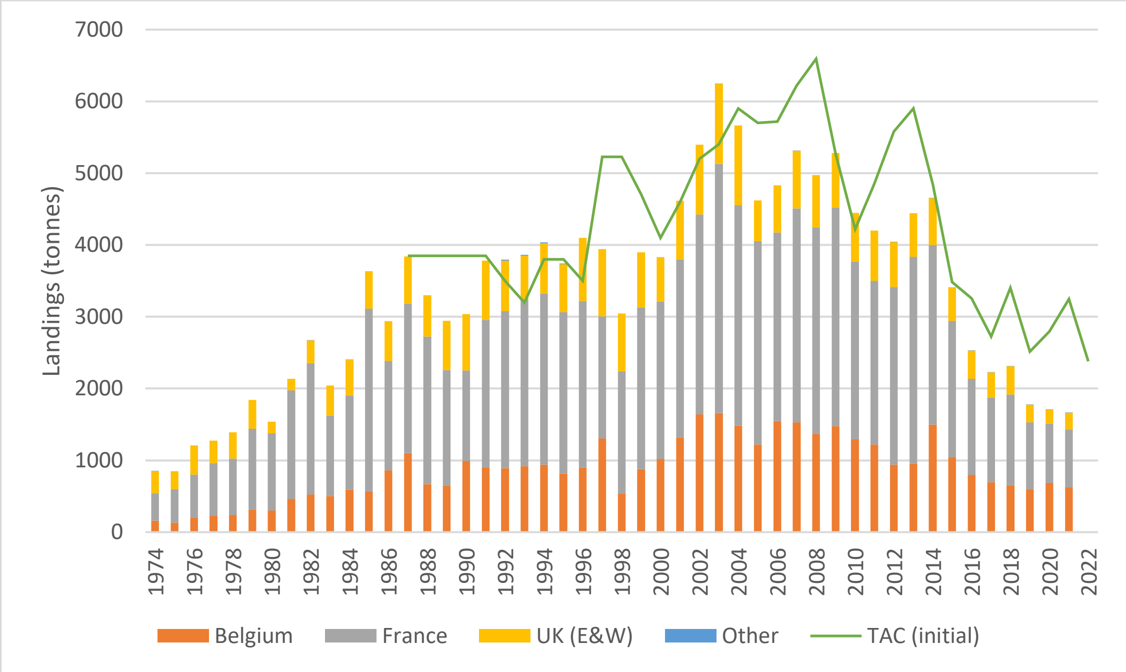

Figure 18.1: Sole 27.7.d - Official landings (tonnes) for sole in Division 27.7.d by country over the period 1974–2021, as officially reported (Rec 12) (stacked barplot; other represents landings from e.g. UK Scotland, The Netherlands, Germany or Ireland); green line represents the official TAC (landings; Note that from 2016 onwards the TAC represents catch).

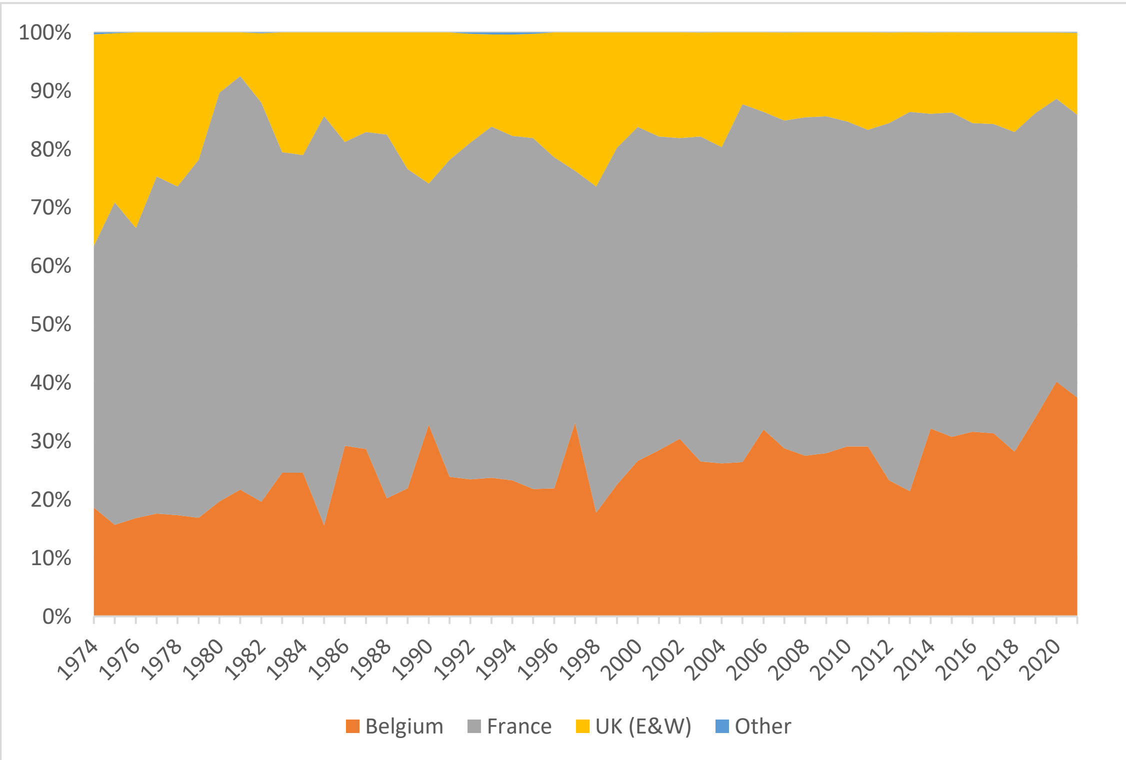

Figure 18.2: Sole 27.7.d - Relative contribution to the official landings of sole in Division 27.7.d for the main countries involved over the period 1974–2021.

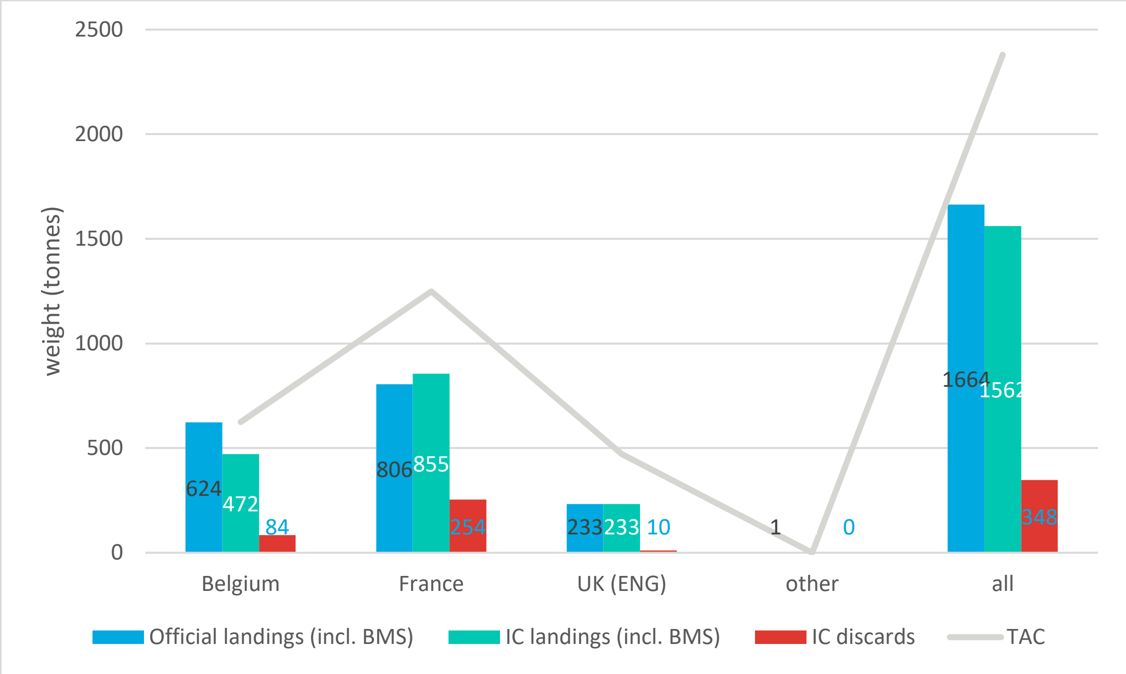

Figure 18.3: Sole 27.7.d - Uptake of the national quota and the total TAC of sole in 27.7.d in 2021 in comparison with the InterCatch landings (incl. BMS) and raised discards.

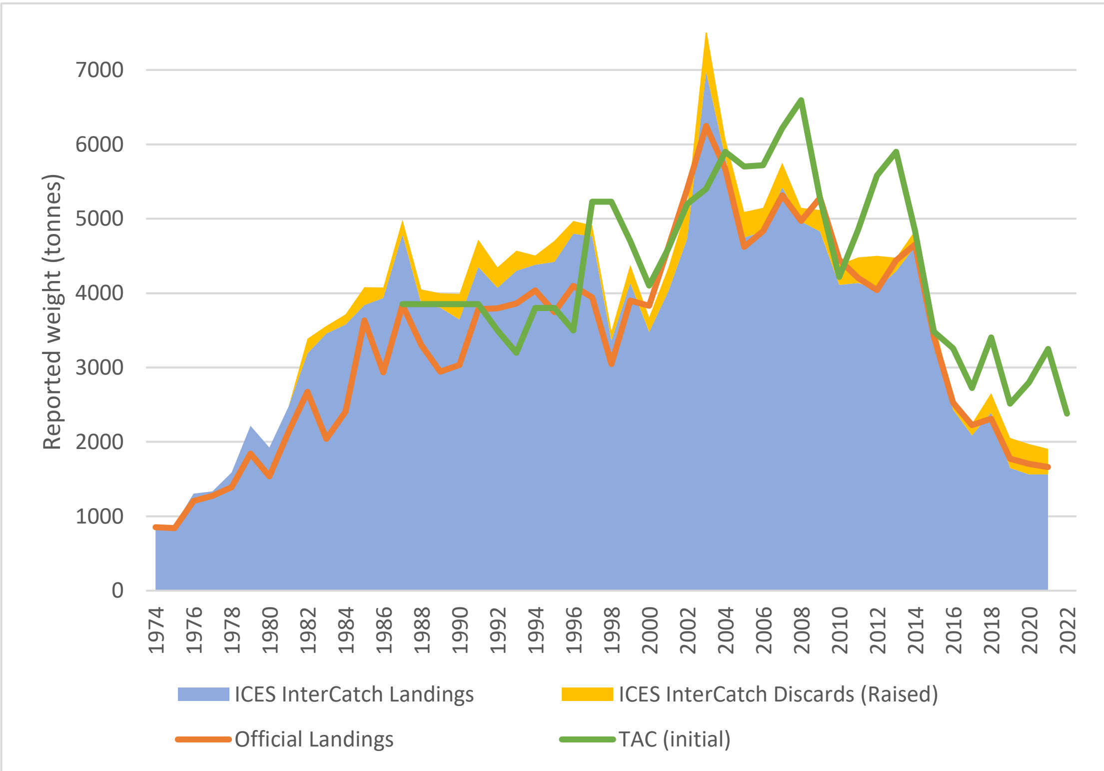

Figure 18.4: Sole 27.7.d - Historic overview (1974–2021) of the official landings, TAC and ICES estimates (InterCatch; including actual discards from 2004 onwards and extrapolated to years prior to 2004); Note that the TAC value represents catch from 2016 onwards.

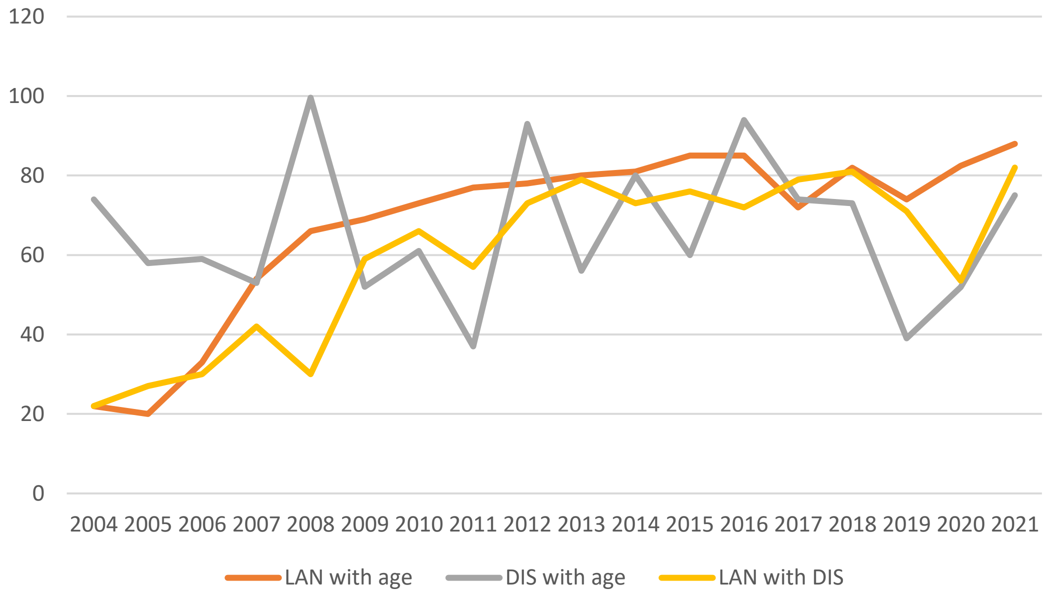

Figure 18.5: Sole 27.7.d - Overview of data coverage for data uploaded to InterCatch (from 2004 onwards).

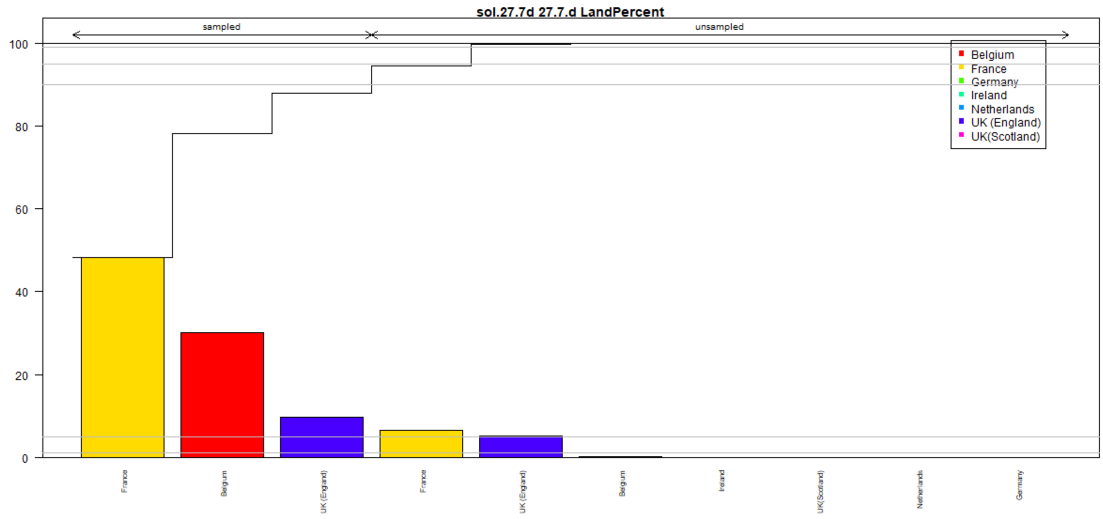

Figure 18.6: Sole 27.7.d - Overview of the proportion of 2021 landings of sole in Division 27.7.d for which samples (age) have been provided in InterCatch by country.

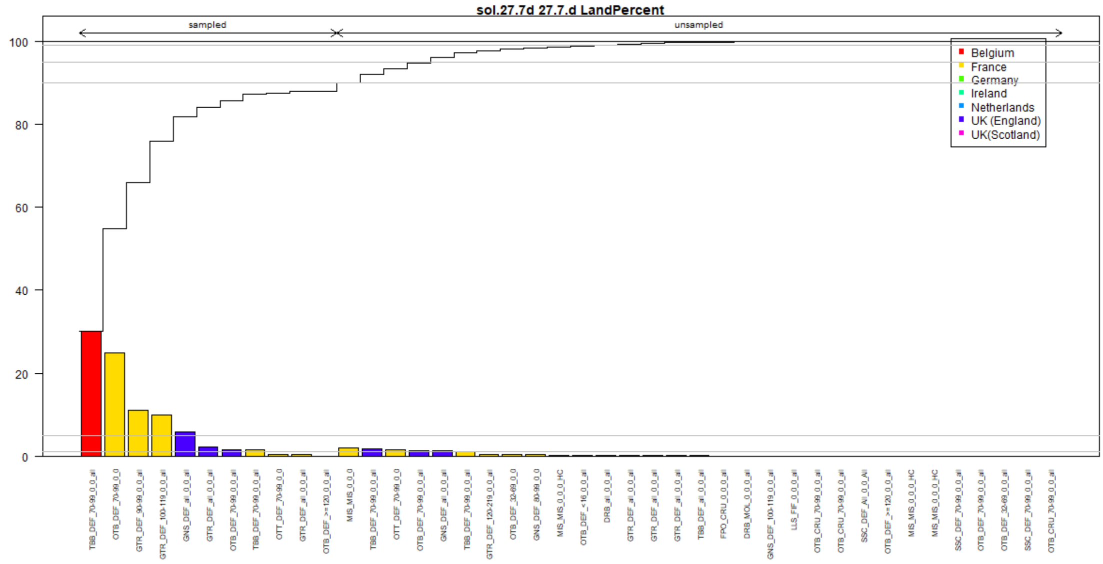

Figure 18.7: Sole 27.7.d - Overview of the proportion of 2021 landings of sole in Division 27.7.d for which samples have been provided in InterCatch by fleet and country.

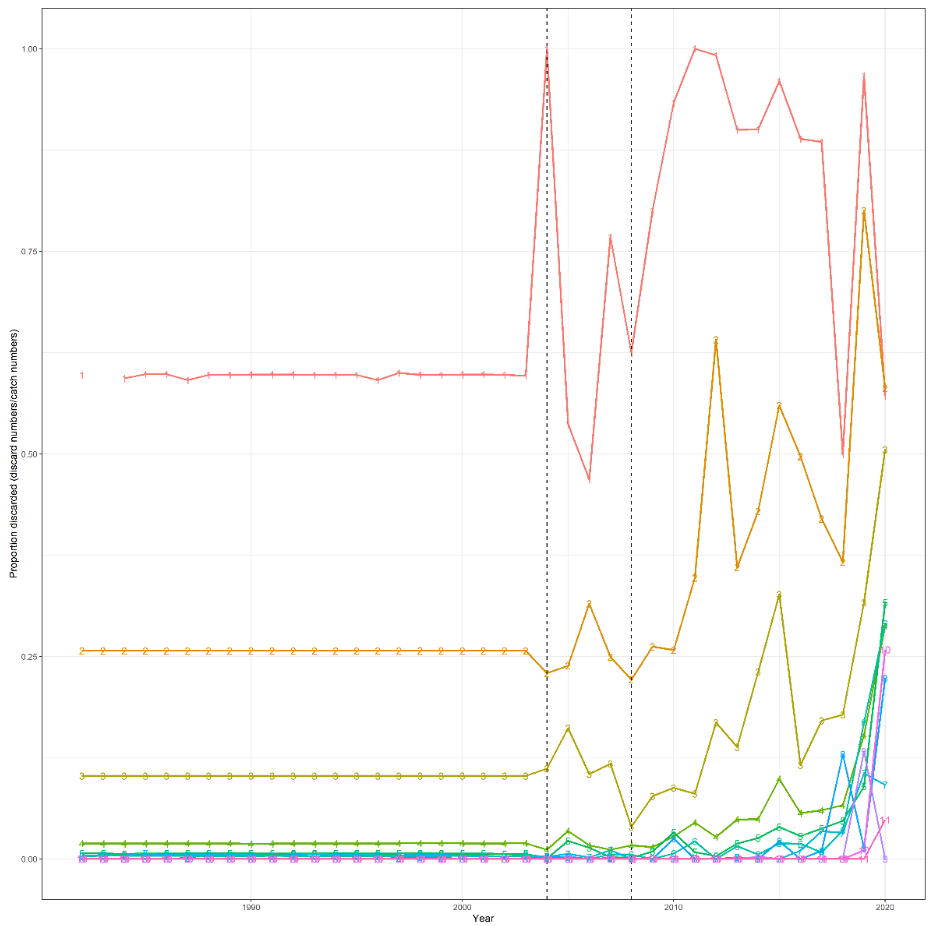

Figure 18.8: Sole 27.7.d - Proportion discarded (discard numbers at age/catch numbers at age) (data prior to 2004 are estimated using an average discard proportion at age for the period 2004-2008 (indicated by dotted lines)).

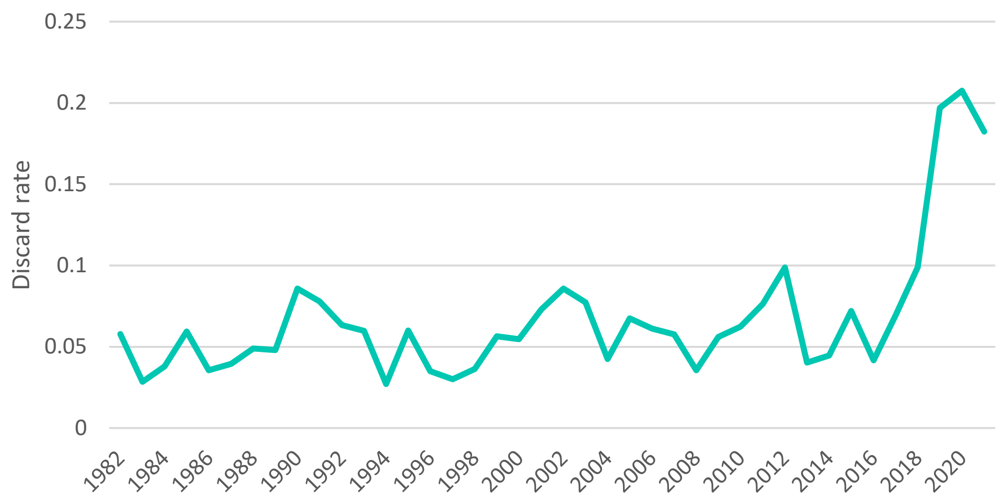

Figure 18.9: Sole 27.7.d – Discard rate (1982–2021).

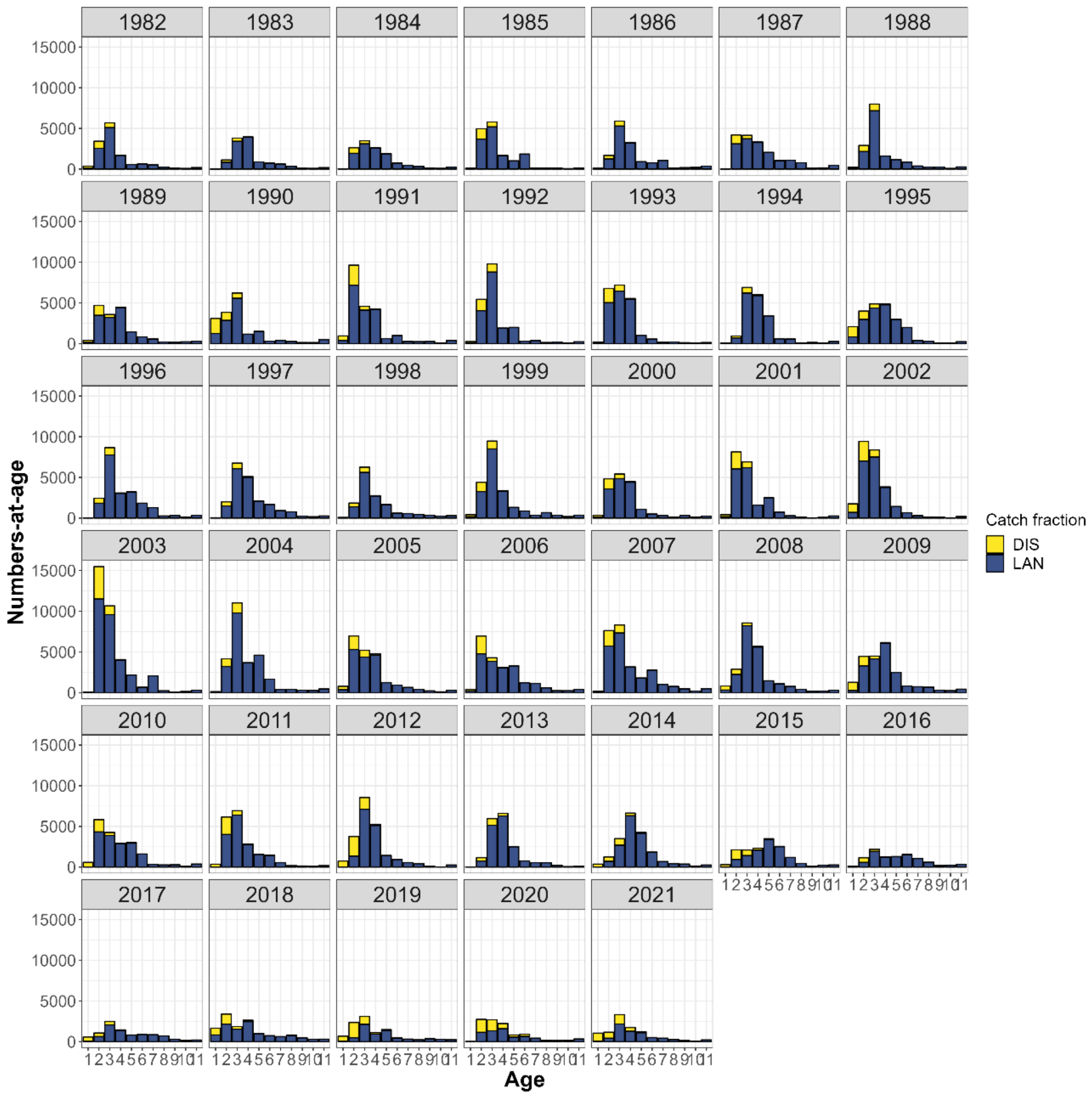

Figure 18.10: Sole 27.7.d – Landings (blue) and discard (yellow) numbers-at-age over the time series 1982–2021 for all ages (age 11 is a plusgroup).

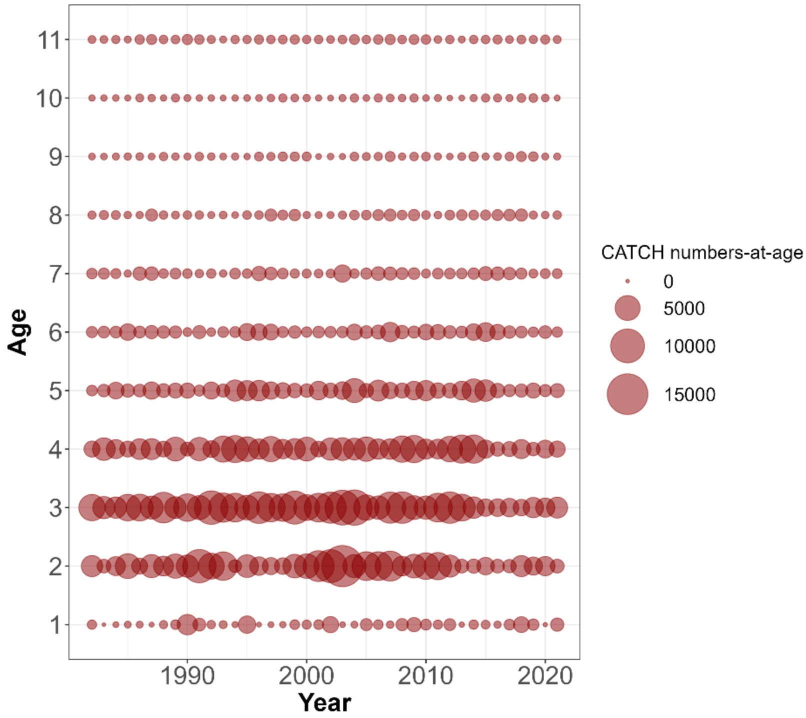

Figure 18.11: Sole 27.7.d – Catch numbers-at-age over the time series 1982–2021 for all ages (age 11 is a plusgroup).

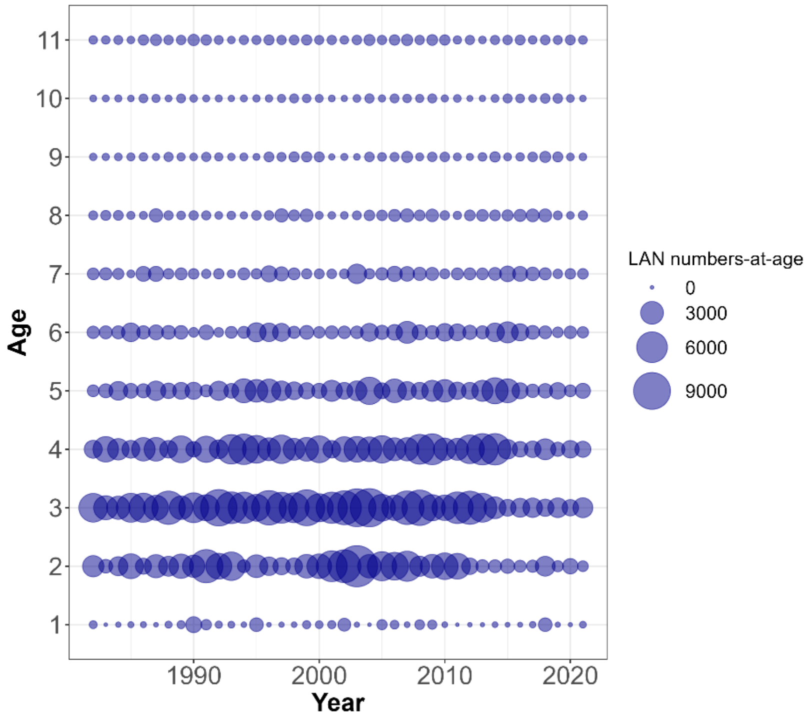

Figure 18.12: Sole 27.7.d – Landings numbers-at-age over the time series 1982–2021 for all ages (age 11 is a plusgroup).

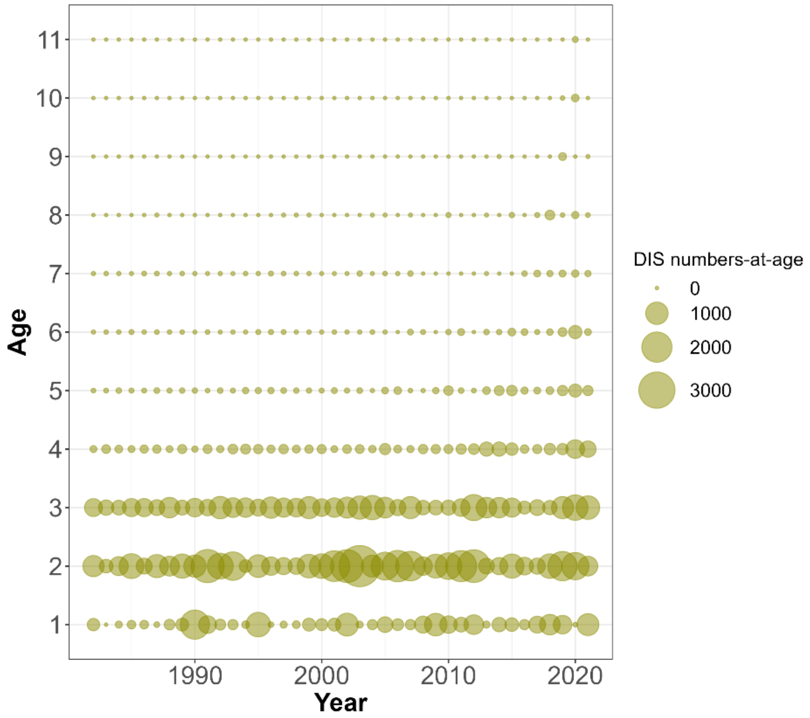

Figure 18.13: Sole 27.7.d – Discard numbers-at-age over the time series 1982–2021 for all ages (age 11 is a plusgroup).

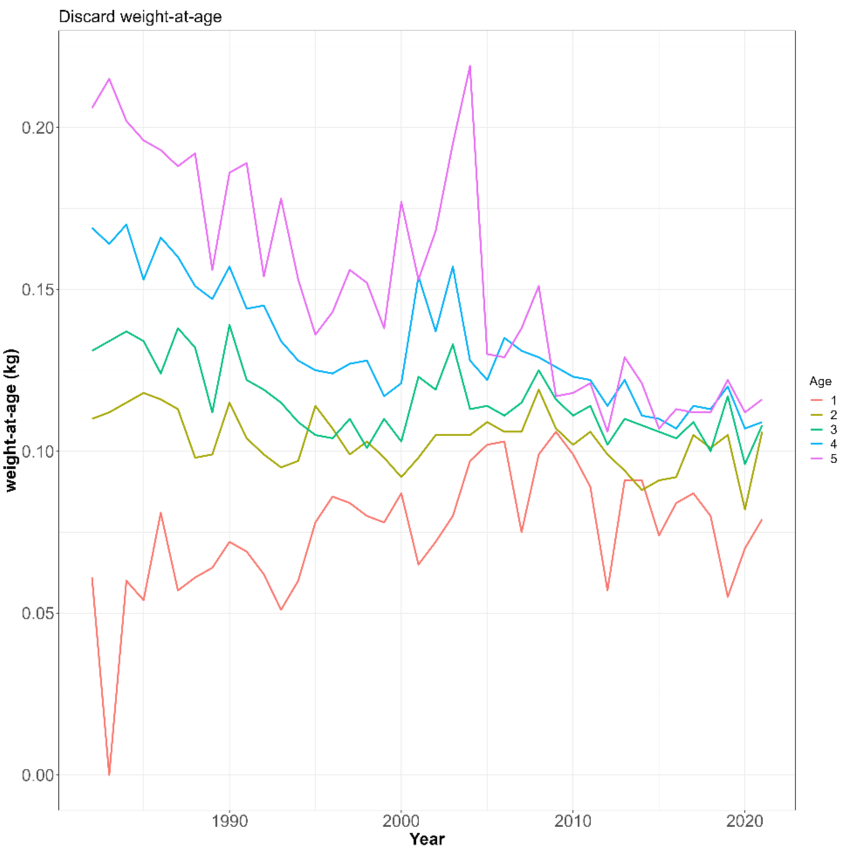

Figure 18.14: Sole 27.7.d - Discard weights-at-age (ages 1–5 are shown).

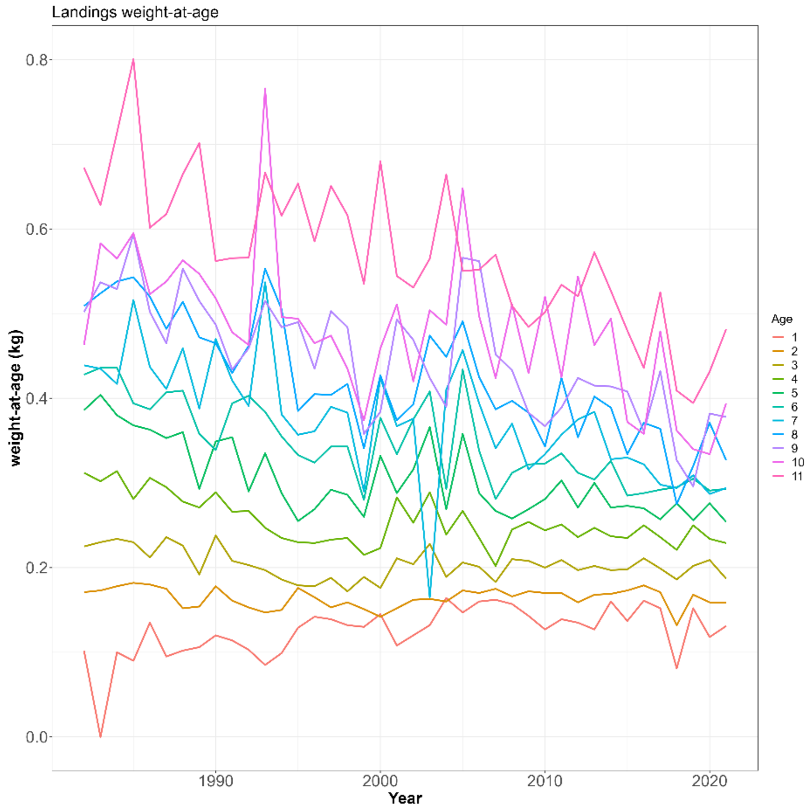

Figure 18.15: Sole 27.7.d - Landings weights-at-age (age 11 is a plusgroup).

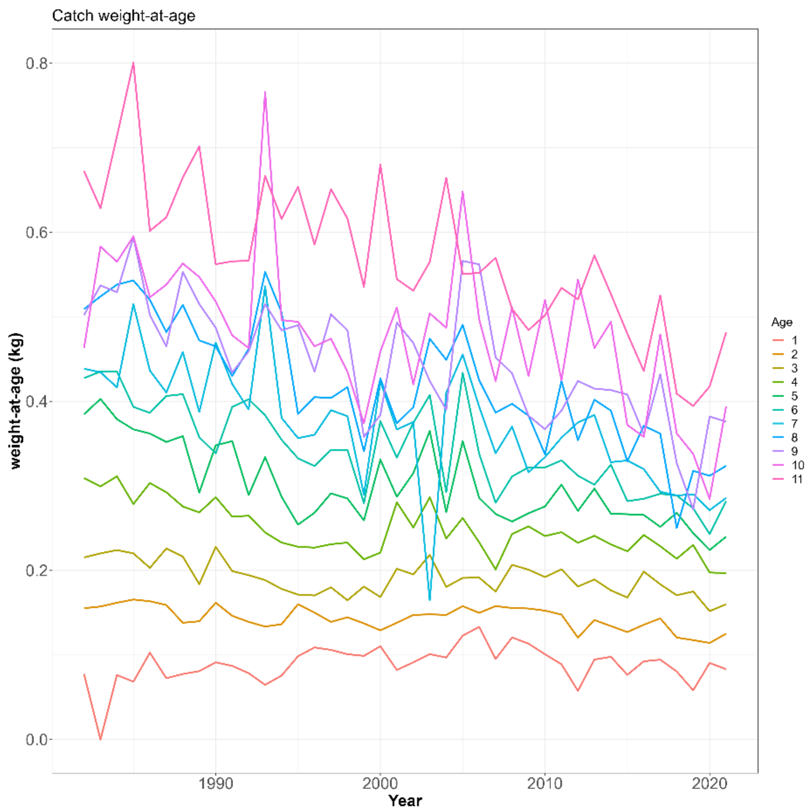

Figure 18.16: Sole 27.7.d - Catch weights-at-age (age 11 is a plusgroup).

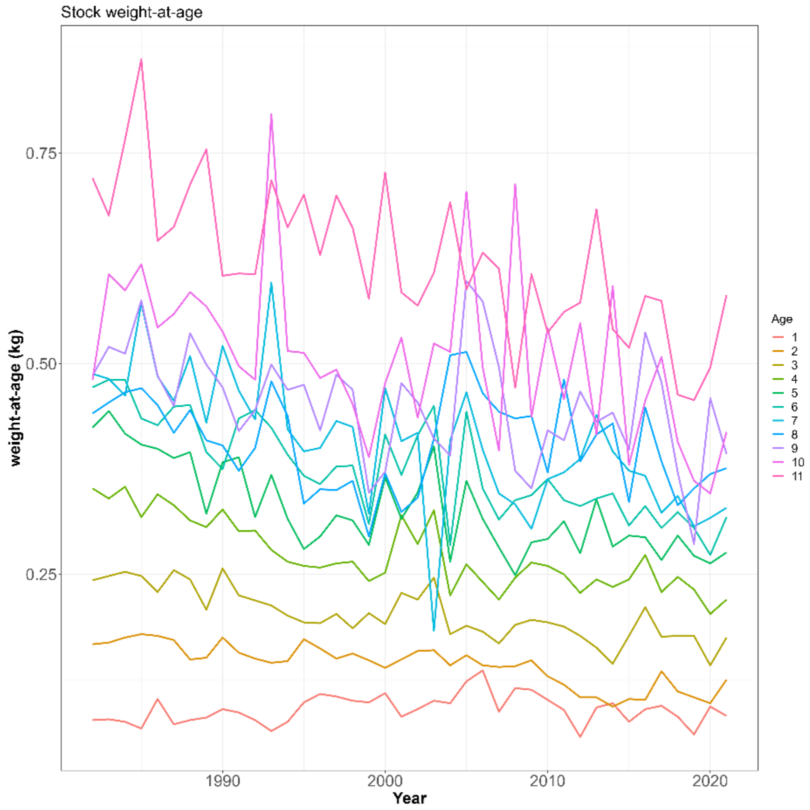

Figure 18.17: Sole 27.7.d – Quarter 1 stock weights-at-age (kg) (reconstructed for the period 1982–2003 using the ratio of quarter 1 catch weight-at-age and the overall catch weight-at-age for the period 2004–2019 multiplied by the overall catch weight-at-age for 1982–2003).

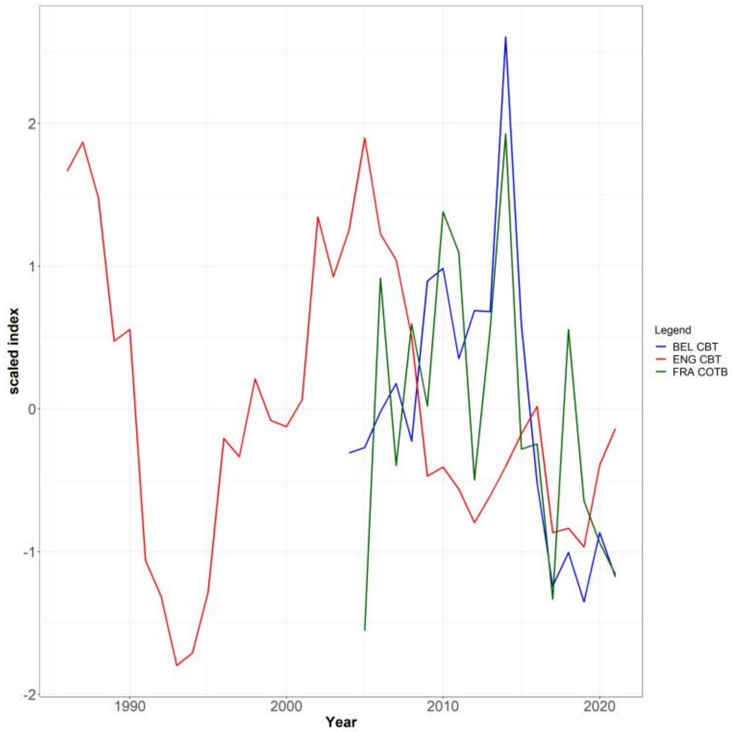

Figure 18.18: Sole 27.7.d – Scaled commercial tuning indices: Belgian (blue) and UK (red) commercial beam trawl series and French commercial otter trawl series (green).

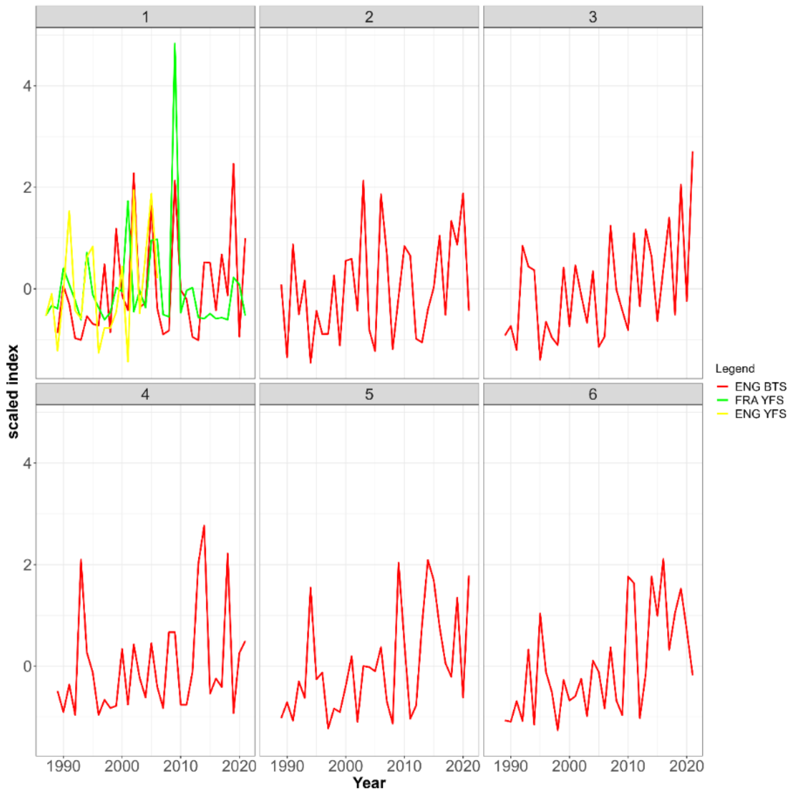

Figure 18.19: Sole 27.7.d – Scaled survey tuning indices at age: UK (E&W) beam trawl survey (red), UK Young fish survey (yellow) and French Young fish survey (green).

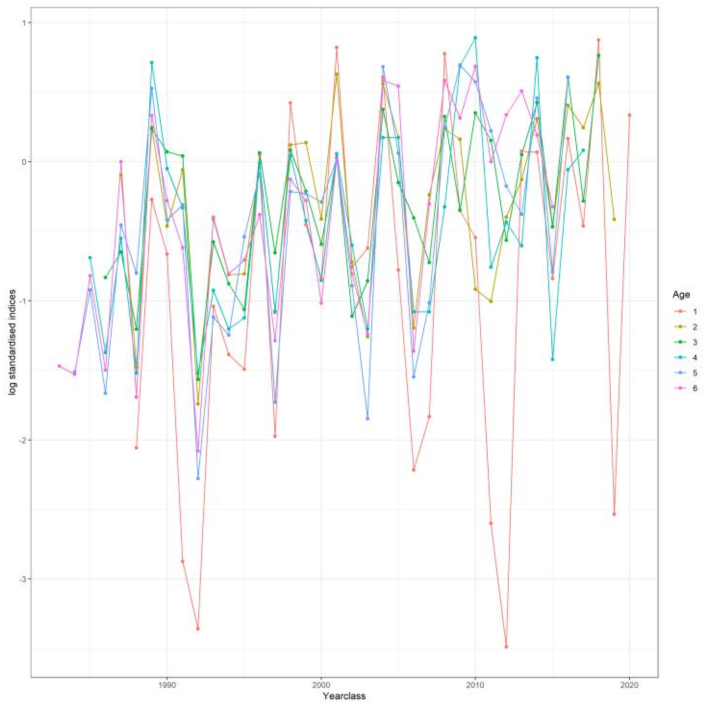

Figure 18.20: Sole 27.7.d – Log standardised indices of the UK BTS by age and year class.

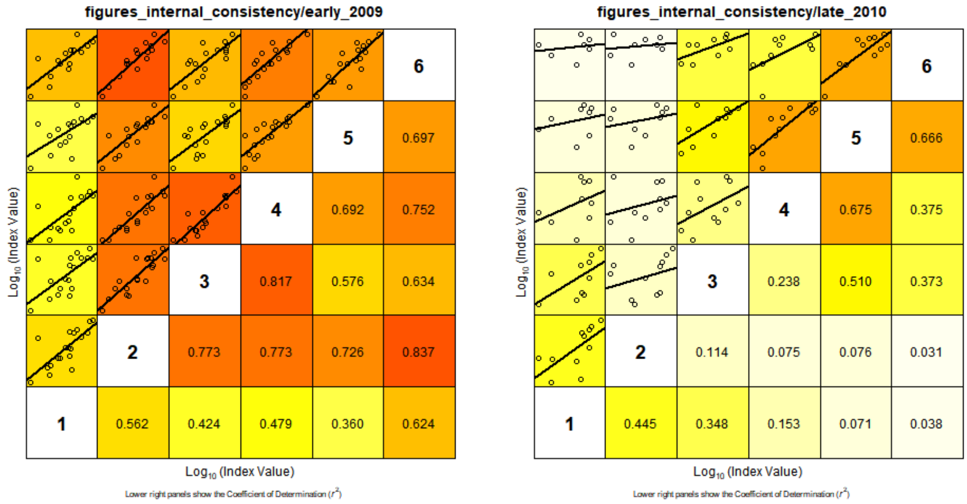

Figure 18.21: Sole 27.7.d - Internal consistency plot of the UK-BTS tuning series for the early part (1989-2009; left) and last part (2010-2021; right) of the time series

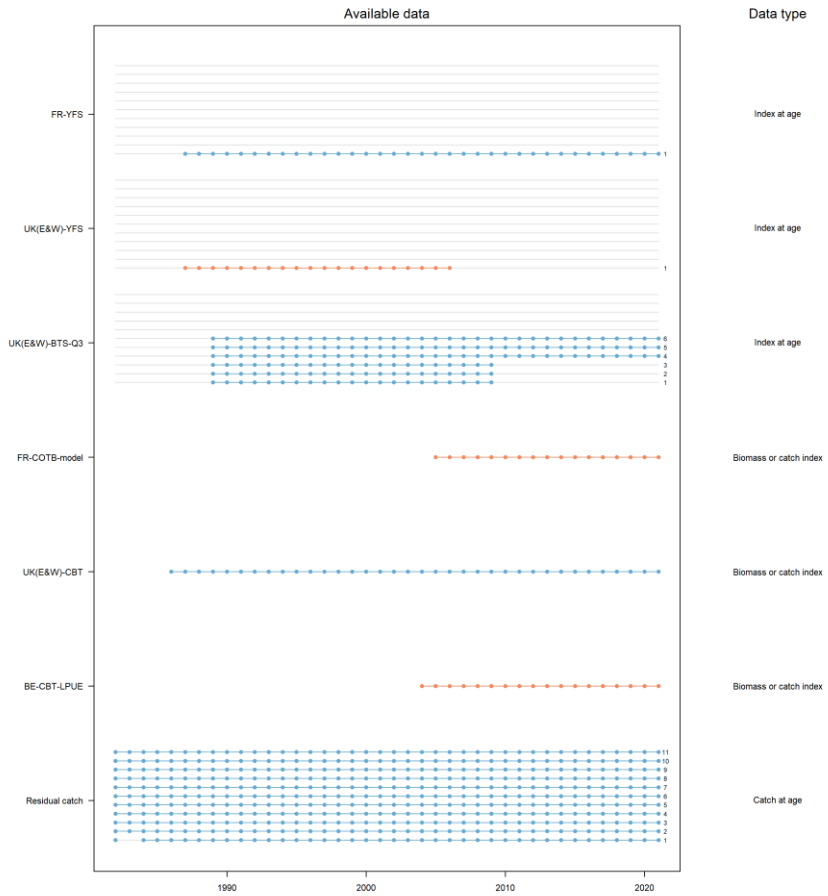

Figure 18.22: Sole 27.7.d – SAM model input.

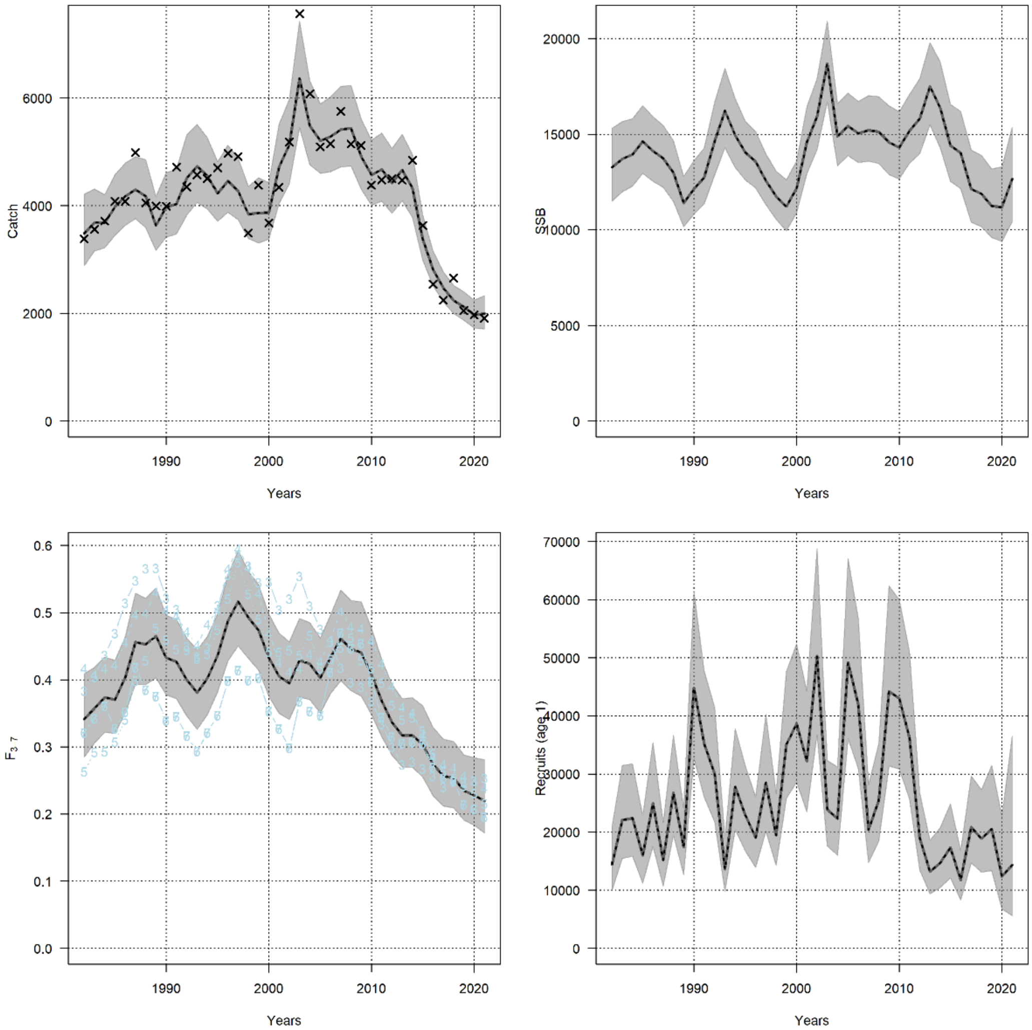

Figure 18.23: Sole 27.7.d – SAM model summary: trends in catch, spawning stock biomass (SSB), F_{bar} and recruitment (in thousands) are shown with relevant confidence intervals.

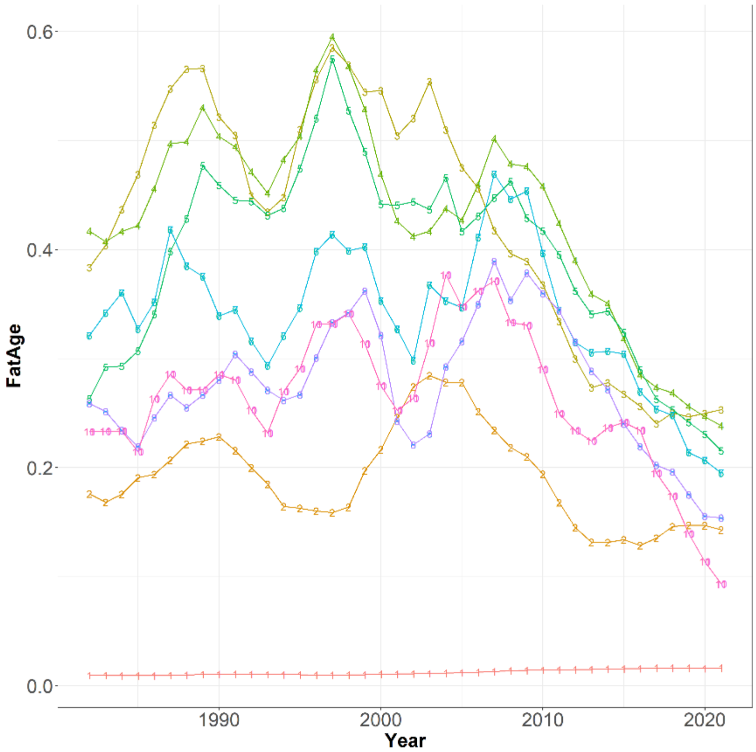

Figure 18.24: Sole 27.7.d – Fishing mortality at age as estimated by the SAM assessment; Note that age 6 and 7, 8 and 9 and 10 and 11+ overlap.

Figure 18.25: Sole 27.7.d – Process residuals for the survival (logN) and fishing mortality (logF) processes.

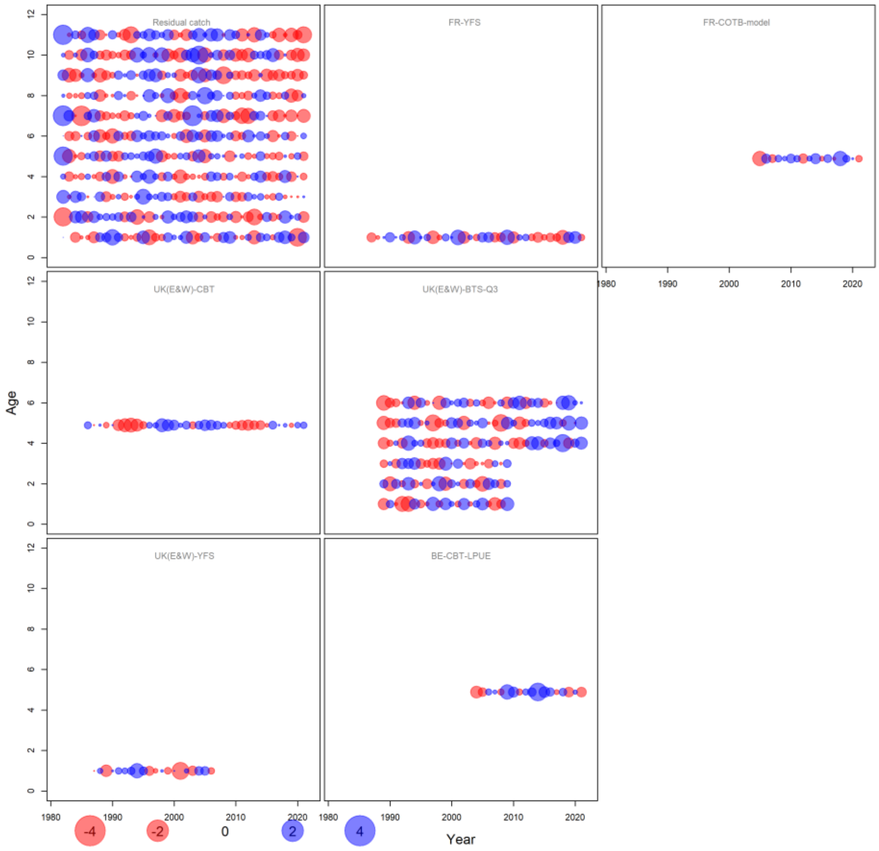

Figure 18.26: Sole 27.7.d – One step ahead residuals by data stream.

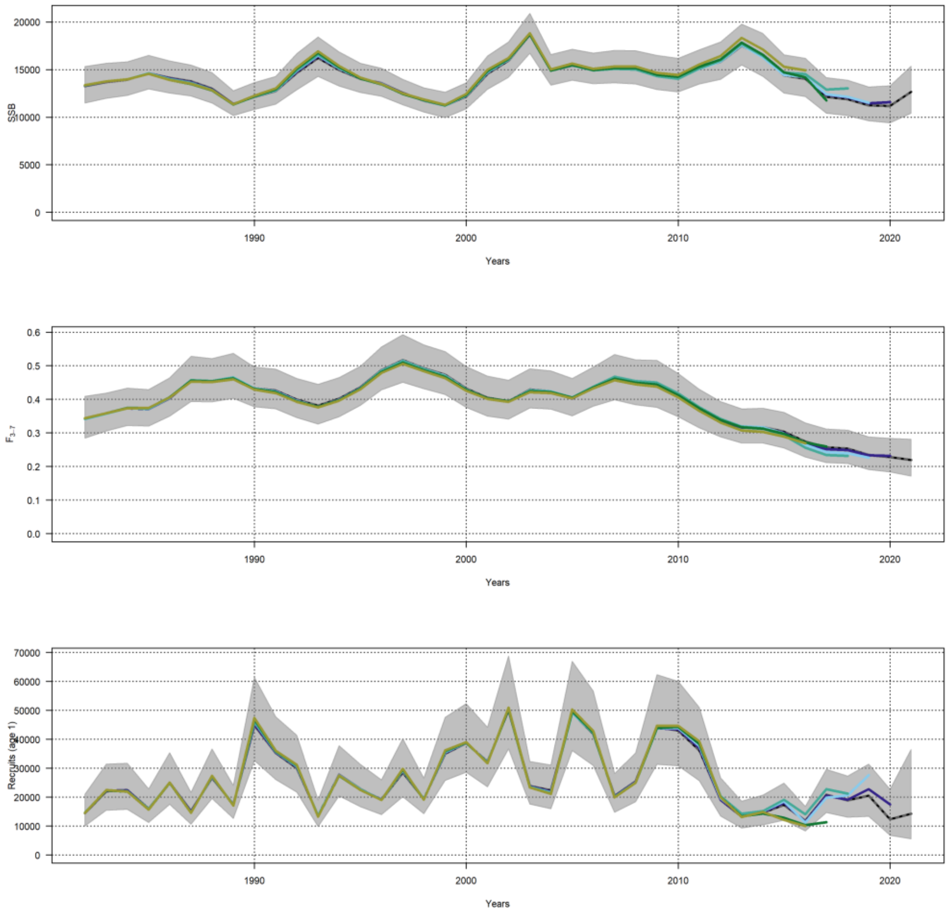

Figure 18.27: Sole 27.7.d - Retrospective pattern in SSB (Mohn's Rho = 0.0372417), F_{bar} (Mohn's Rho = -0.0229250) and recruitment (in thousands; Mohn's Rho = 0.0560053). The grey shades represent the 95% confidence intervals of the model including all data years.

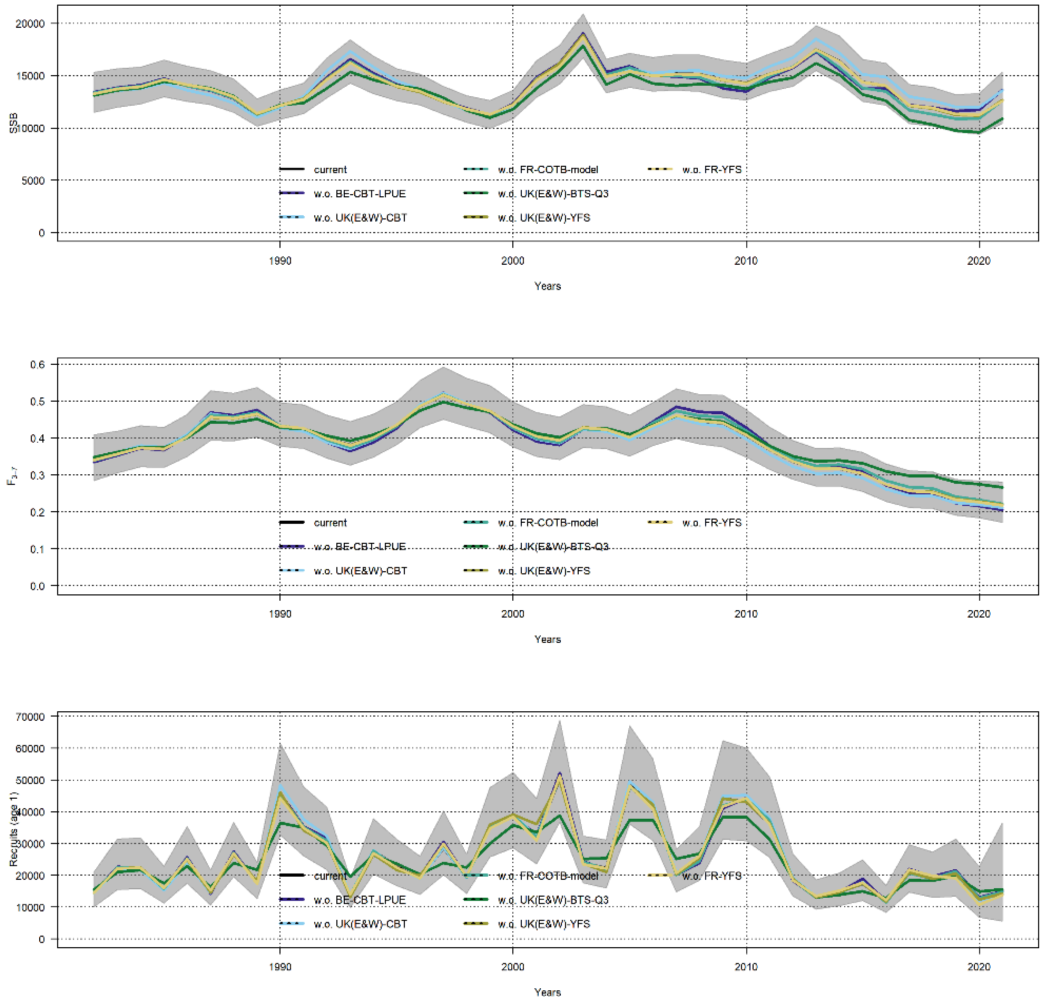

Figure 18.28: Sole 27.7.d – Leave-one-out analysis. Each coloured line refers to a model fit without the respective tuning fleet. The grey shades represent the 95% confidence intervals of the model including all tuning fleets.

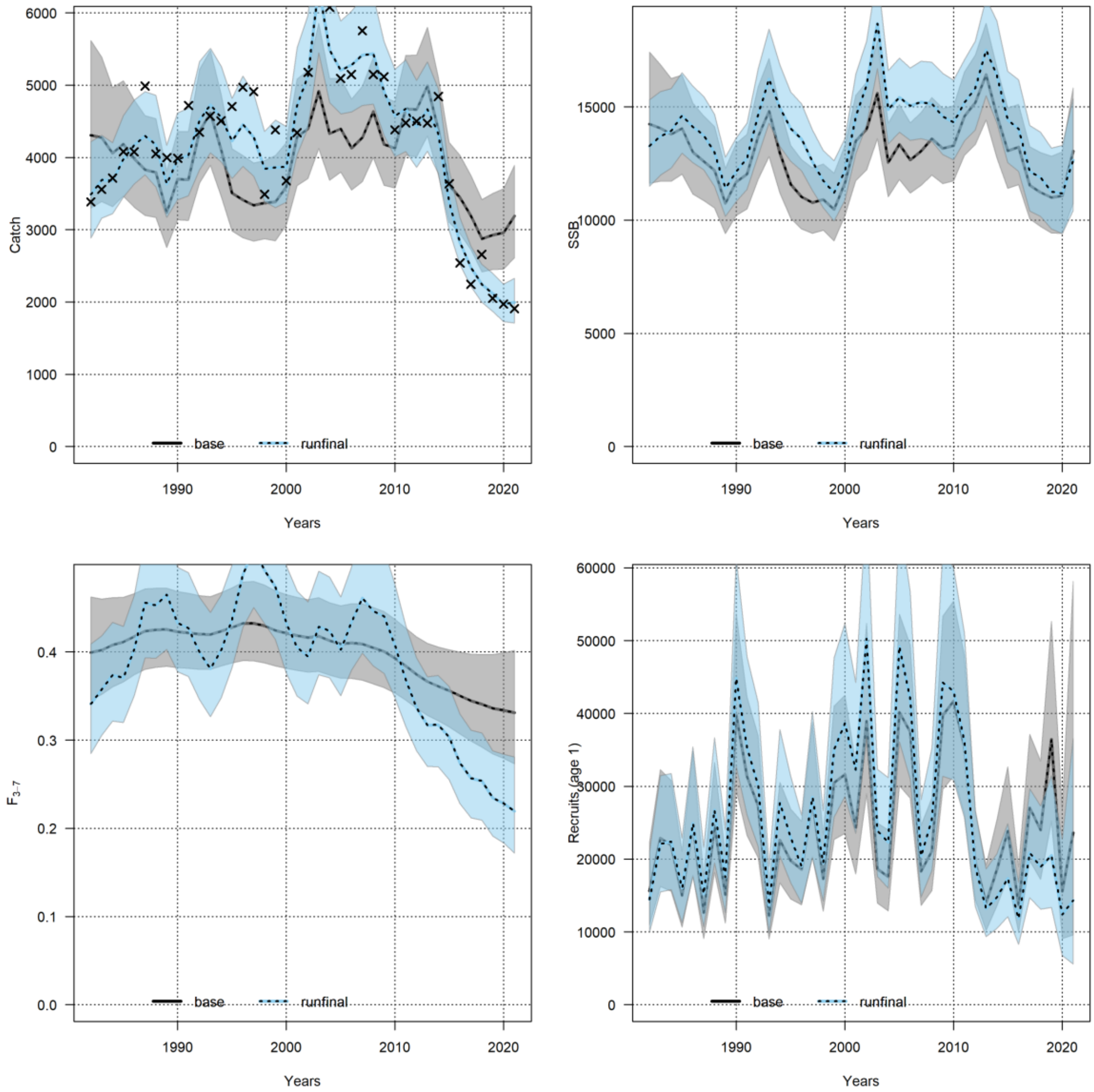

Figure 18.29: Sole 27.7.d – SAM model summary showing the current model in blue and the WGNSSK 2021 model in black. Trends in catch, spawning stock biomass (SSB), F_{bar} and recruitment (in thousands) are shown with relevant confidence intervals.

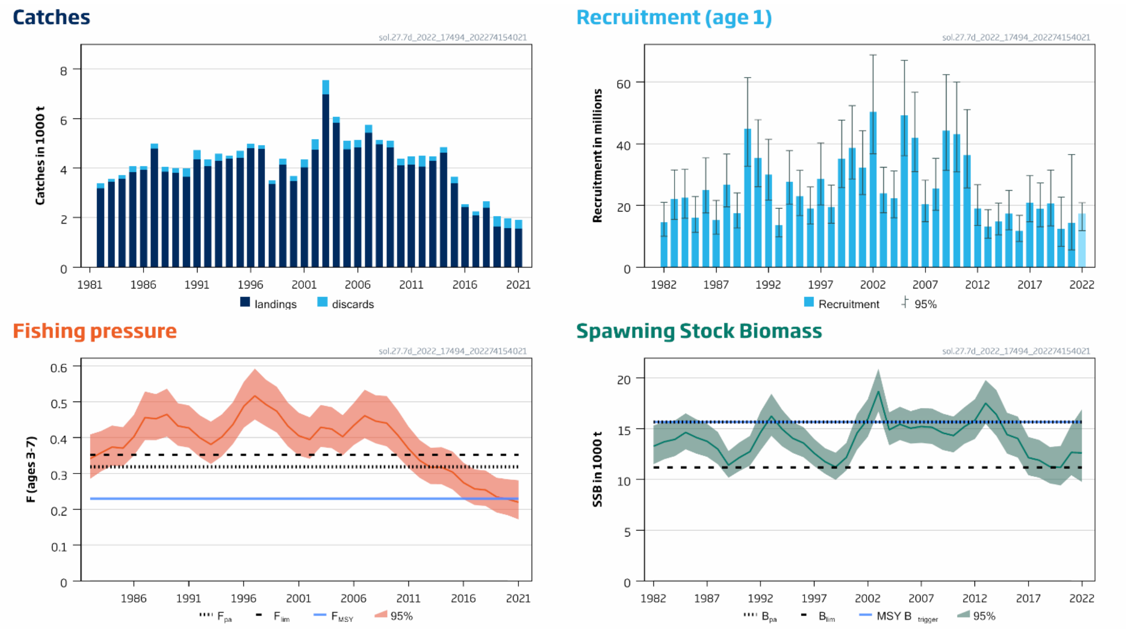

Figure 18.30: Sole 27.7.d – Summary of the 2022 assessment. Discards are reconstructed prior to 2004. Plots show the relevant confidence intervals. The assumed recruitment value for 2022 is shaded in a lighter colour. Discards include BMS landings.

19 Striped red mullet in Subarea 4 (North Sea), divisions 7.d (Eastern English Channel) and 3.a (Skagerrak, Kattegat)

This stock is under a biennial advice. No TAC is set for this stock. The last advice issued in 2017 was based on the 4:1 rule applied to the SSB estimated by the age-based model. In 2021, fishing opportunities advice was again requested following the precautionary approach. Due to incomplete survey sampling in 2020, there were issues with calculation of survey indices, a lack of length and age samples from the main fleets, including other areas and nations, and problems with model formulation; ICES stock data category of striped red mullet in Subarea 4 and divisions 7.d and 3.a was downgraded from category 3 to category 5. ICES advice on fishing opportunities was based on the average ICES catches (considering discards negligible) over the period 2004–2020. Based on length-based indicators (LBI) analysis, fishing mortality is estimated above MSY reference points, the stock size relative to reference point is unknown. For that reasons, the precautionary buffer was applied.

The general perception is that the landings have gradually decreased since 2015, the highest observed in the recent years, up to 2018. In 2019, landings have increased near to the level of 2015, mainly due to the exploitation of the strong 2018 cohort. In 2020 and 2021, landings decreased, the structure of the population is still truncated and recent catches of this stock mainly consist of age 0 and age 1 fish. The fishery for striped red mullet would benefit from improved technical measures such as sorting grids, increased mesh size, and spatial and temporal closures. These measures could reduce the catches of small fish and contribute to more stable yields.

19.1 General

Striped red mullet has been benchmarked in 2015 (ICES, 2015).

The main issues addressed during the benchmark were the quantity and representativeness of the observational data. Analyses suggested the extrapolation of the assessment results from the eastern English Channel to the southern North Sea had merit. It was less clear whether the assessment was valid for the other areas within the stock region, because the fishery catches were small and data were sparse.

The conclusion of the benchmark were, that the agreed stock assessment seemed reasonable given the available information and that it could be used for providing fisheries advice under the ICES Stock Category 3 framework.

Ecosystem aspects

Striped red mullet (*Mullus surmuletus*) is a benthic species. Young fish are distributed in coastal areas, while adults have a more offshore distribution. Benzinou *et al.* (2013) conducted stock identification studies based on otolith and fish shape in European waters and showed that striped red mullet can be geographically divided into two units: Western Unit (subareas 6 and 8, and divisions 7.a–c, 7.e–k, and 9.a) and Northern Unit (Subarea 4 (North Sea) and divisions 7.d (Eastern English Channel) and 3.a (Skagerrak, Kattegat)).

A recent review of striped red mullet stock structure in the greater North Sea was realised by CEFAS and presented to WGNSSK 2020 (Ellis, 2020). This review does not support the current stock definition used by ICES. Indeed, survey data from IBTS might indicate that striped red mullet in Division 3.a should be considered as a separate stock from the North Sea one. In addition, survey data and commercial data have highlighted migration pattern between the Western English Channel and the southern North Sea, with striped red mullet concentrating and mixing in the southern North Sea during summer. Thus, assessment of stripped red mullet in subarea 4 and division 7.d-e may need to be assessed as a single stock or a complex one with two sub-population mixing during summer.

In the English Channel, the first sexual maturity was identified on fish of 16.2 cm for the male and 16.7 cm for the female (Mahé *et al.*, 2005). Juveniles are found in waters of low salinity, while adults are found at high salinity. Striped red mullet prefers sandy sediments (Carpentier *et al.*, 2009).

Adult red mullet feed on small crustaceans, annelid worms and molluscs, using their chin barbels to detect prey and search the mud.

19.2 Fisheries

Historically, France has taken most of the landings with a targeted fishery for striped red mullet (> 90% of landings in the beginning of the 2000s). This French fishery targeting striped red mullet is conducted by bottom trawlers using a mesh size of 70–99 mm in the eastern English Channel and in the southern North Sea.

The eastern English Channel and southern North Sea areas are also fished by trawlers of various types targeting a variety of species. Striped red mullet might be a bycatch in these fisheries.

From 2000, a Dutch targeted fishery, using fly shooters, and a UK fisheries has also developed. Landings are shared by these three fleets in the latter years. The Netherlands landed about or more than half of the total landings since the 2010s.

19.3 ICES advice

Advice for 2022 and 2023.

The ICES framework for category 5 stocks was applied (ICES 2012). For stocks without information on abundance or exploitation, ICES considers that a precautionary reduction of catches should be implemented where there is no ancillary information clearly indicating that the current level of exploitation is appropriate for the stock. Discarding is considered negligible.

Fishing mortality is above proxies of the MSY reference points (as indicated by a length-based analysis). The stock size relative to reference points is unknown. For these reasons, the precautionary buffer, which was last applied in 2017, was applied again in this assessment.

ICES advises that when the precautionary approach is applied, catches should be no more than 1950 tonnes in each of the years 2022 and 2023. All catches are assumed to be landed.

Advice for 2020 and 2021.

ICES has not been requested to provide advice on fishing opportunities for this stock.

Advice for 2018 and 2019.

ICES advises that the fishery for striped red mullet should be managed through technical measures that would reduce the catches of small fish and would contribute to more stable yields.

Fishing mortality is above proxies of the MSY reference points (as indicated by a length-based analysis). The stock size relative to reference points is unknown. For these reasons, the precautionary buffer, which was last applied in 2013, was applied again in this assessment.

ICES advises that when the precautionary approach is applied, catches should be no more than 465 tonnes in each of the years 2018 and 2019. All catches are assumed to be landed.

19.4 Management

No specific management objectives are known to ICES. There is no TAC for this species.

There is no minimum landing size for this species.

Demersal fisheries in the area are mixed fisheries, with many stocks exploited together in various combinations in the various fisheries. In these cases, management advice must consider both the state of individual stocks and their simultaneous exploitation in demersal fisheries. Stocks in the poorest condition, particularly those which suffer from reduced reproductive capacity, become the overriding concern for the management of mixed fisheries, where these stocks are exploited either as a targeted species or as a bycatch.

19.5 Data available

19.5.1 Catch

Official landings data are shown by country in Table 19.5.1.1 and by area in Table 19.5.1.2. There is no indication of discard of striped red mullet. All catches are assumed to be landed. Table 19.5.1.3 presents total official landings and ICES estimates over the period 2004–2021 as well as the predicted catch corresponding to advice. In 2021, 70% of the catches were made using demersal seines and 24% using demersal trawls.

Total landings were provided under the ICES InterCatch format for the period 2003–2013 during the benchmark. However, only France provided age composition for the period 2006–2013. 2014 to 2021 landings were provided under the ICES InterCatch format. Figure 19.5.1.1 shows that only landings from France in the Eastern Channel (representing around 12% of the total landings in 2021) were provided in 2014 to 2021 with an age structure. In 2021, some landings made in area 4 were also provided by France with an age structure but only representing around 2% of the total landings in area 4. Figure 19.5.1.2 shows that IC data and official landings are consistent over years and countries.

Prior to 2009, no landings of age 0 were observed (Figure 19.5.1.3, and Table 19.5.1.4). Most of the landings are made on age 1. There is no age reading problem reported. This change in the landings might reflect a change in the reporting or a change in the fishing behaviour.

Only France provides age structured information for the area 27.7.d and 4, all landings are then raised using French age structures. Age sampling has usually a low coverage for this stock, however in 2020 and 2021, the COVID-19 pandemic significantly impacted the market sampling reducing the overall age sampling coverage of landings to 8%. To account for the lack of sampling in 2021, quarters Q1-2 were raised with all samples from Q1, and quarters 3-4 were raised using only samples from quarter 4.

19.5.2 Weight-at-age

Mean weights at age were computed as described in the Stock Annex and are presented in Figures 19.5.2.1 and 19.5.2.2 and Table 19.5.2.1.

Weights at age in the landings show a slight decrease for the oldest ages. However, sampling intensity for these ages is very low due to the low number of fishes in the catches. Stock weights do not show this slight decrease of age 3 and 4+ as for landings weight, the sampling is very low due to the low number of fishes in the landings.

19.5.3 Maturity and natural mortality

Information about maturity per age class is given with the table included in this section. At an age of one year more than 50 percent of the striped red mullet are mature.

Age	0	1	2	3	4	5	6
Maturity	0	0.54	0.65	1	1	1	1

As defined during WKNSEA (ICES, 2015), natural mortality was derived from Gislason first estimator (Gislason *et al*., 2010) leading, as expected for this species, to high natural mortality for the youngest ages (see table below).

age	M_Gislason
0	1.426
1	0.6641
2	0.4888
3	0.4164
4	0.3616
5	0.3275
6	0.3421

19.5.4 Survey data

Survey index defined during the last benchmark.

During the last benchmark in 2015, the Channel Ground Fish Survey (CGFS) and the IBTS–Q3 surveys were estimated to be good indicators of the population trends as they cover the spatial distribution of this stock. However, none of them have an exhaustive coverage of the spatial distribution.

In 2015, a change in the research vessel used for the CGFS was realised. The consequences of these changes were assessed via an inter-calibration in 2014 and some analysis of the catch data (ICES, 2017, Section "CGFS: Change of vessel from 2015 onwards and consequences on survey design and stock indices"). It appeared that for red mullet indices seem to be used without correcting factor.

Only CGFS survey allowed deriving age structured indices. Internal consistencies of the survey (Figure 19.5.4.1) show reasonable consistencies between age 1 and 4.

The age composition of the catches made during CGFS is presented in Figure 19.5.4.2. The age composition is still truncated with catches hardly only composed by age 0 and 1 individual. The abundance index shows an increase of the age 0 compared to 2015, 2016 and 2017 and is in 2018 the second highest observed.

Issues regarding CGFS survey index in 2020.

In 2020, CGFS survey design was impacted by COVID-19 pandemic and issues regarding historical index calculation were uncovered. In this section, we describe the two different issues that impact 2021 and 2022 stock assessment. In the next section, the impact of the different issues on the assessment were evaluated using data up to 2019.

- Issue with sampling coverage in 2020

In 2020, due to the COVID-19 pandemic and the lockdown in France, CGFS JNC Cruise application form was unfortunately not processed in a timely manner by the French Foreign Ministry. By consequence, the formal authorisation to operate in UK waters was not received before the starting of the 2020 CGFS survey. Therefore, only the French waters of the English Channel were sampled covering 70% of the sampling design (Figure 19.5.4.3) (ICES IBTSWG, 2021 (*in prep*)).

- Issue with historical index calculation

An error was found in the historical scripts while sorting individuals by age using an age –length key some hauls with no catch were not included in the stratified mean.

To address both issues, similar work as what is done for ple.27.7d (see Annex 08) is ongoing to try to derive indices from a delta-lognormal model.

19.6 Trend based assessment

19.6.1 Assessment model agreed on during the last benchmark

As agreed during WKNSEA (ICES, 2015), the assessment model was used for trend as the SSB estimated by the model was considered to be a more reliable indicator of stock status than the direct use of survey indices.

Sensitivity runs were explored in 2020 and different numbers of knots (from 6 to 9) were tested for the spline used to estimate fishing mortality (ICES, 2020). F_{bar} (age 1–2) estimates for 2019 remain in absolute value above 3 in all the scenarios. Scenario with 6 knots was disregarded as F for age 3 was unrealistic. It was agreed to add one more knot to the spline as compared to 2019 assessment, however other configuration of a4a needs to be investigated if we want to keep using this model as an indicator of the stock status in the future.

The settings used are described on the following table.

Setting/Data	Values/source
Catch at age	Landings (since 2004, ages 0–4+) InterCatch Discards are assumed negligible.
Tuning indices	FR CGFS (since 2004 ages 0–4+)
Plus group	4
First tuning year	2004
Fishing mortality	~ s(year, k=8) + factor(age)
Survey catchability	~ factor(age)
Recruitment	~ factor(year)

Results from the assessment are presented in Figure 19.6.1.1 Log residuals of the model are presented in Figure 19.6.1.2 and observed and predicted catches in Figure 19.6.1.3 and indices in Figure 19.6.1.4.

As observed during WKNSEA, there is still a relatively high uncertainty in this assessment. SSB is at a low level and the recruitment seems poorly estimated. Trends show a lot of variation in spawning stock biomass and a very high fishing mortality. Most of the catches rely only on the recruitment (age 0) and age 1 fishes.

19.6.2 Exploratory runs with a4a

Several formulations of a4a were tested to constrain the model. Splines were added to characterize the selectivity of catches and survey. In addition, fishing mortality at age 0 was modelled separately as the catch at age 0 remains lower than age 1 or 2. Finally, splines were added to estimates the variance at age of F and the survey indices.

The final settings tested are described on the following table.

Setting/Data	Values/source
Catch at age	Landings (since 2004, ages 0–4+) InterCatch Discards are assumed negligible.
Tuning indices	FR CGFS (since 2004 ages 0–4+)
Plus group	4
First tuning year	2004
Fishing mortality	~ s(year, k=10) + s(age, k=3) + s(year, k=5, Age 0)
Survey catchability	~ s(age, k=3)
Recruitment	~ factor(year)
Variance	F ~ s(age, k=3) & Survey ~ s(age, k=3)

Results from the alternative assessment model are presented in Figure 19.6.2.1. Log residuals of the model are presented in Figure 19.6.2.2.

With this new model formulation, residual patterns at age 0 for the catches have improved as compared to the model formulation decided during the benchmark. Adding a spline to characterise selectivity seems to allow a more realistic representation of the fishing pressure. However, F_{bar} estimated by the alternative model remains high and the uncertainty around F_{bar} and SSB is still relatively important.

More exploratory runs are required to fix the different issues of the current model used as indicative of the stock status (to test different a4a formulation, and more models).

19.6.3 Striped red mullet trend-based assessment conclusion

Due to incomplete survey sampling in 2020, issues with calculation of survey indices, the lack of length and age samples from the main fleets, including other areas and nations, and problems with model formulation, the stripped red mullet trend-based assessment was rejected. Therefore, the ICES stock data category of striped red mullet in Subarea 4 and divisions 7.d and 3.a remains category 5.

19.7 Length-based indicators screening

The ICES LBI were computed for five years of data (2014–2016 and 2018–2021), using the length distributions from InterCatch (Tables 19.7.1).

Most of the indicators appear outside the established references in 2021:

- Length at first catch L_c and Length of 25% L_{25} of catches are above L_{mat} (16 cm) in 2015, 2016, 2019 - 2021. These indicators are below L_{mat} in 2014 and 2018 (for L_c). This is directly linked with the good recruitment observed in 2014 and 2018. The good recruitment observed in 2014 and 2018 decreased L_c and L_{25}, but in the following years (2015–2016 and 2019–2021) no good recruitment was observed and L_c and L_{25} increased to be above L_{mat}.
- Ratio of the L_{max5}, mean length of 5% largest catches, to L_{inf} (40 cm) around 0.6/0.7 over the two periods 2014–2016 and 2018–2021 clearly show the lack of big/old fish in the population
- L_{mean}/L_{opt} around 0.8 give the same picture as L_{max5}, exploitation is not optimal.
- $L_{mean}/L_{F=M}$ below 1 tend to show that this stock is not exploited sustainably except for 2018 where the ratio is just above 1.

This indicates that the stock may be considered not to be exploited sustainably. The main concerns are for the big/old fish that are missing from the population. Length-based indicators based on samples from commercial catches (2014–2016 and 2019–2021) show that in relation to conservation criteria there is strong evidence of growth overfishing, meaning the fish is caught before it has realized its growth potential (Table 19.7.2).

Conclusions drawn from analyses:

The very good recruitment observed in 2014 and 2018 was confirmed by the catches in 2015 and 2019 respectively and the remaining age 1 seen in 2015 and 2019 during CGFS. There is no TAC on this species so the advice was not followed and the catches overshot the advice for 2015-2019 (5328, 3438, 2856, 1651 and 4044 tonnes against 460, 552, 552, 465 and 465 tonnes respectively in the advice). In 2018, the recruitment as seen by CGFS appears to be the second highest since 2004 and was confirmed by the catches in 2019 and the age 1 in CGFS survey. The stock age distribution appears to be still truncated.

Basis for the advice:

Length-based indicators based on samples from commercial catches (2014–2016 and 2018–2021) show in 2022 that in relation to conservation criteria there is strong evidence of growth overfishing, meaning the fish is caught before it has realized its growth potential. The SSB is dependent on recruitment.

19.8 Issues List

Data and stock ID:

- Age (length) data from other countries than France need to be provided as everything is actually raised using the French catches in the Eastern Channel and part of North Sea.
- No survey is available in the North Sea; IBTS/UK BTS should be investigated again. So work was done to assess the representativeness of the Eastern Channel data compared to the stock, but these should be investigated further
- CGFS survey data issues in index calculation needs to be fixed. GAM or GLMM methods such as the method developed by Berg et al. (2014) or Thorson et al. (2015) should be explored to account for missing data UK haul in 2020 and also better account for the change in vessel in 2014.
- Even if discards are expected to be very low (no minimum landing size, high price), discards data should be re-investigated
- Based on Ellis, J. R. (2020) stock ID should be reinvestigated.

Assessment:

- Assessment model was rejected in 2021 and a category 5 advice is given for this stock, new methods should be investigated.
- Explore methods applied to "short lived species" (two stages model)?
- New model formulations need to be explored to solve the issue relative to the recent high F estimate for 2019
- SPiCT should be explore again either as basis for advice or to estimate the stock status.
- Other models should be also explored (SAM, SURBAR, length-based models…)

Forecast and reference points:

- This stock is not category 1, so no forecast is done currently. This should be investigated if the assessment method is improved. However, there is no TAC for that stock so a forecast is not a priority, although reference points are still important.

19.9 References

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Table 19.5.1.1. Striped red mullet in Subarea 4 and divisions 7.d and 3.a: Official landings by country (tonnes).

Year	Belgium	Denmark	France	Netherlands	UK	total
1975	0	0	140	0	0	140
1976	0	0	156	3	1	160
1977	0	0	279	12	1	292
1978	0	0	207	25	3	235
1979	0	0	212	32	11	255
1980	0	0	86	25	4	115
1981	0	0	44	19	1	64
1982	0	0	32	18	2	54
1983	0	0	232	15	1	248
1984	0	0	204	0	3	207
1985	0	0	135	0	4	140
1986	0	0	84	0	3	88
1987	0	1	40	0	3	46
1988	0	1	35	0	4	41
1989	0	0	37	0	5	42
1990	0	0	524	0	13	537
1991	0	0	208	0	11	219
1992	0	0	458	0	17	475
1993	0	0	576	0	21	597
1994	0	0	362	0	18	380
1995	0	0	2537	0	69	2606
1996	0	2	2039	2	44	2087
1997	0	2	856	0	61	919
1998	0	2	2966	0	117	3085
1999[1)]	0	4	NA	0	103	107
2000	0	4	3201	464	133	3802
2001	0	10	1789	915	183	2897
2002	0	24	1658	560	141	2383
2003	28	0	3256	626	177	4087
2004	31	0	4137	1148	129	5445
2005	29	0	1918	914	136	2997
2006	16	0	1145	466	97	1724
2007	17	0	3982	1147	182	5328
2008	20	0	3723	1270	353	5366
2009	17	0	827	889	293	2026
2010	80	0	947	802	338	2167
2011	97	0	704	771	243	1815
2012	51	0	170	525	146	892
2013	40	0	122	260	40	462

Year	Belgium	Denmark	France	Netherlands	UK	total
2014	79	0	765	912	246	2002
2015	250	0	1741	2657	679	5327
2016	184	0	690	2024	540	3438
2017	120	0	887	1443	406	2856
2018	92	0.044	665	1112	167	2036
2019	232	0.037	1401	1821	589	4043
2020	220	0.124	723	1752	787	3482
2021	437	0.606	593	1188	757	2976

1) No data reported by France in 1999.

Table 19.5.1.2. Striped red mullet in Subarea 4 and divisions 7.d and 3.a: Official landings by area (tonnes). Note: Most of the Subarea 4 catches are made in Division 4.c.

Year	4	3.a	7.d	Total 2)
1975	0	0	140	140
1976	4	0	156	160
1977	19	0	273	292
1978	30	0	205	235
1979	49	0	206	255
1980	29	0	86	115
1981	20	0	44	64
1982	21	0	33	54
1983	41	0	207	248
1984	22	0	185	207
1985	10	0	130	140
1986	6	0	82	88
1987	7	0	38	46
1988	7	0	33	41
1989	5	0	37	42
1990	33	0	504	537
1991	26	0	193	219
1992	60	0	415	475
1993	126	0	471	597
1994	116	0	264	380
1995	1054	0	1552	2606
1996	528	0	1559	2087
1997	278	0	641	919
1998	778	0	2307	3085
1999 1)	70	0	37	107
2000	1764	0	2038	3802
2001	1600	0	1297	2897

Year	4	3.a	7.d	Total [2]
2002	1234	0	1149	2383
2003	1618	0	2469	4087
2004	1820	0	3625	5445
2005	1404	0	1593	2997
2006	642	0	1083	1725
2007	1546	0	3782	5328
2008	1830	0	3536	5366
2009	910	0	1115	2025
2010	699	0	1468	2167
2011	609	0	1206	1815
2012	387	0	505	892
2013	196	0	266	462
2014	526	0	1476	2002
2015	1601	0	3727	5328
2016	1649	0.03	1789	3438
2017	1304	0	1552	2856
2018	769	0.002	1267	2036
2019	1282	0.022	2761	4043
2020	1379	0.157	2103	3482
2021	1231	0.065	1745	2976

1) No data reported by France in 1999.

2) Differ from Table 19.5.1.1 and Table 19.5.1.3 due to rounding.

Table 19.5.1.3 Striped red mullet in Subarea 4 and divisions 7.d and 3.a: History of ICES advice, the agreed TAC, and ICES estimates of landings.

Year	ICES Advice	Predicted catch corresp. to advice	Official landings [1]	ICES Estimates
2004			5445	4674
2005			2997	2350
2006		-	1725	1476
2007		-	5328	4604
2008		-	5366	2064
2009		-	2025	1513
2010		-	2167	1919
2011		-	1815	1511
2012	No increase in catch	-	892	726
2013	No increase in catches (average 2009–2010)	< 1700	462	408
2014	Reduce catches by 36% compared to 2012	< 460	2002	1718
2015	No new advice, same as for 2014	< 460	5328	4487
2016	Precautionary approach	<552	3438	2579
2017	Precautionary approach	<552	2856	2195

Year	ICES Advice	Predicted catch corresp. to advice	Official landings [1)]	ICES Estimates
2018	Precautionary approach	<465	2036	1640
2019	Precautionary approach	<465	4044	4048
2020	No Advice	-	3483	3503
2021	No Advice	-	2976	2611
2022	Precautionary approach	<1950		
2023	Precautionary approach	<1950		

Weights in tonnes.

[1)] Differ from Table 19.5.1.1 and Table 19.5.1.2 due to rounding.

Table 19.5.1.4. Striped red mullet in Subarea 4 and divisions 7.d and 3.a: landing numbers at age (thousands).

	0	1	2	3	4	5	6	4+
2004	0	43076	1826	940	75	111	0	186
2005	0	16557	2448	262	56	199	0	255
2006	0	3900	2325	1674	109	78	0	187
2007	0	36872	1120	551	94	33	0	127
2008	0	1316	10459	1248	313	221	0	534
2009	45	13256	1075	540	83	0	0	83
2010	12971	13384	593	125	70	19	1	90
2011	0	9310	1453	639	76	4	0	80
2012	6	1337	1246	1479	181	2	0	183
2013	1170	2342	395	244	0	0	0	0
2014	9904	10556	1300	14	14	14	0	28
2015	1728	35360	5952	18	2	32	0	34
2016	38	3498	9680	2129	148	51	0	199
2017	872	10314	2974	1105	223	130	100	453
2018	511	6630	3017	234	140	0	0	140
2019	1582	31105	1511	466	119	0	0	119
2020	590	27386	512	31	0	0	0	0
2021	740	15708	2966	345	8	0	0	8

Table 19.5.2.1. Striped red mullet in Subarea 4 and divisions 7.d and 3.a: Stock weights (kg).

	0	1	2	3	4	5	6	4+
2004	0	0.09	0.222	0.27	0.434	0.66	0	0.569
2005	0	0.105	0.172	0.3	0.383	0.419	0	0.411
2006	0	0.146	0.188	0.241	0.379	0.35	0	0.367
2007	0	0.107	0.313	0.422	0.446	0.677	0	0.506
2008	0	0.096	0.139	0.226	0.326	0.41	0	0.361
2009	0.046	0.07	0.16	0.177	0.423	0	0	0.423
2010	0.042	0.077	0.112	0.24	0.225	0.149	0.215	0.209

	0	1	2	3	4	5	6	4+
2011	0	0.052	0.15	0	0	0.323	0	0.016
2012	0.023	0.091	0.169	0.255	0.229	0.772	0	0.235
2013	0.025	0.063	0.118	0.115	0	0	0	0
2014	0.029	0.093	0.144	0.259	0.294	0.323	0	0.309
2015	0.038	0.1	0.114	0.37	0.42	0.187	0	0.2
2016	0.038	0.114	0.138	0.319	0.42	0.187	0	0.360
2017	0.038	0.114	0.138	0.319	0.42	0.187	0	0.260
2018	0.046	0.143	0.166	0.273	0.315	0	0	0.315
2019	0.033	0.111	0.144	0.158	0.156	0	0	0.156
2020	0.038	0.114	0.110	0.320	0	0	0	0
2021	0.038	0.089	0.138	0.231	0.400	0	0	0.400

Table 19.7.1. Striped red mullet in Subarea 4 and divisions 7.d and 3.a: length-based indicators.

Data Type	Value/Year	Source
Length at maturity	162 162 162	Mahé *et al.*, 2013
von Bertalanffy growth parameter (Linf)	400 400 400	Mahé *et al.*, 2013
Catch at length by year	2014–2016 2018–2021	Length data from IC
Length-weight relationship parameters for landings	2014–2016 2018–2021	Mean weight at length from IC

Table 19.7.2. Striped red mullet in Subarea 4 and divisions 7.d and 3.a : Traffic light table for length-based indicators. Conservation criteria for small fish: L_c (length at first catch) and 25% percentile relative to L_{mat} (length at 50% maturity); and for large fish: mean length of the largest 5% in the catch ($L_{max5\%}$) relative to asymptotic length L_{inf} and the proportion of mega spawners (P_{mega}). Optimising yield criterion: the mean length L_{mean} is compared to the theoretical length of optimal biomass (L_{opt}). MSY criterion: L_{mean} is compared to $L_{F=M}$, the MSY proxy. "Ref" indicates the reference criterion: green colour for meeting the criterion, and red flagging issues (e.g. dome-shaped vs. overexploitation). "Ref" indicates the criterion required for a green light. Each year is evaluated separately.

	Conservation				Optimizing Yield	MSY
	L_c/L_{mat}	$L_{25\%}/L_{mat}$	$L_{max5\%}/L_{inf}$	P_{mega}	L_{mean}/L_{opt}	$L_{mean}/L_{F=M}$
Ref	**>1**	**>1**	**>0.8**	**>30%**	**~1 (>0.9)**	**≥1**
2014	0.87	0.93	0.66	0.01	0.72	0.96
2015	1.2	1.17	0.64	0	0.82	0.89
2016	1.2	1.23	0.68	0.01	0.84	0.91
2018	0.83	1.17	0.73	0.01	0.8	1.06
2019	1.2	1.11	0.64	0	0.81	0.87
2020	1.2	1.17	0.62	0	0.8	0.87
2021	1.2	1.17	0.67	0	0.81	0.88

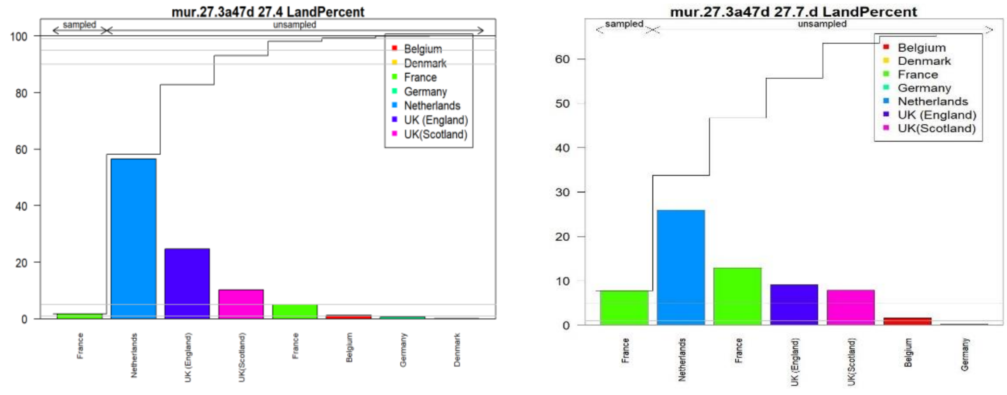

Figure 19.5.1.1. Striped red mullet in Subarea 4 and divisions 7.d and 3.a: ICES landings by country (percentage over the total area).

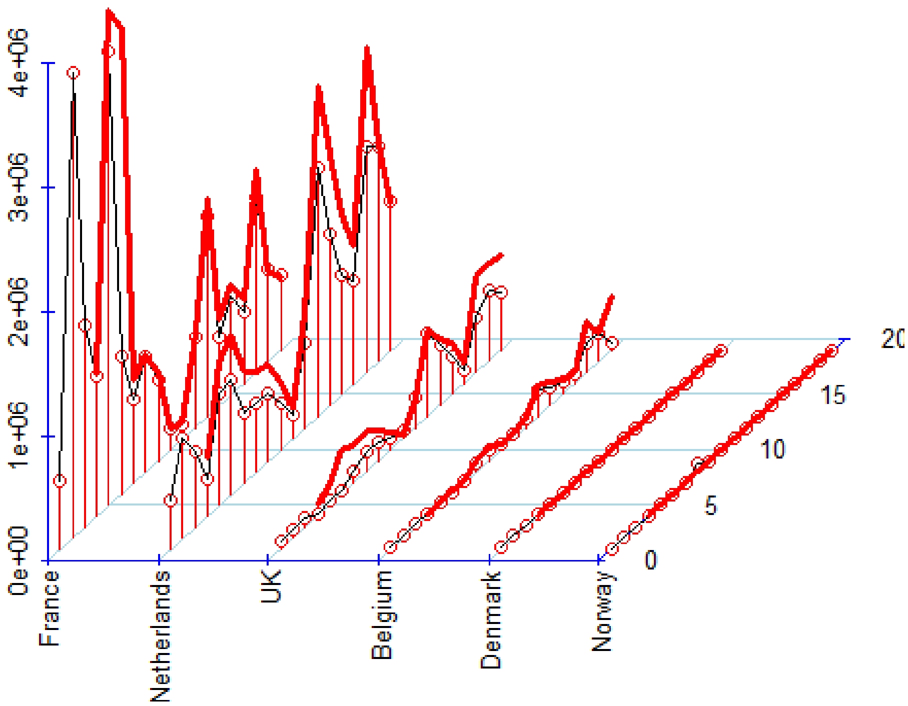

Figure 19.5.1.2. Striped red mullet in Subarea 4 and divisions 7.d and 3.a: (comparison between IC data, red line) and official catch statistics (black and blue for provisional).

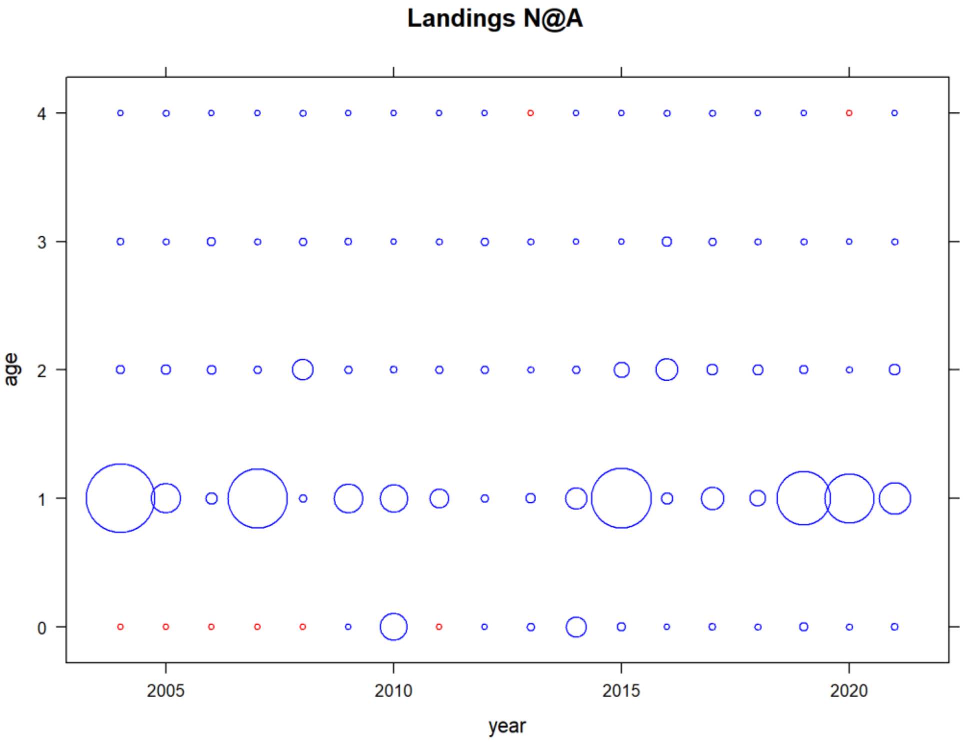

Figure 19.5.1.3. Striped red mullet in Subarea 4 and divisions 7.d and 3.a: age structure (in numbers) as provided in the landings.

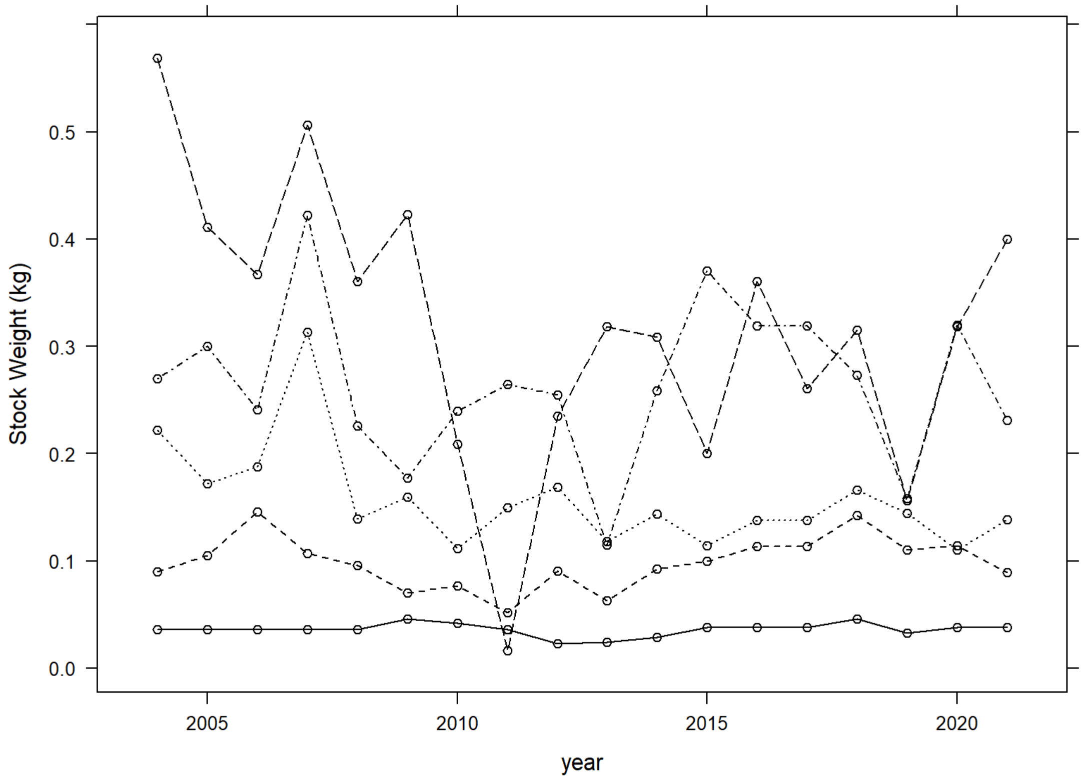

Figure 19.5.2.1. Striped red mullet in Subarea 4 and divisions 7.d and 3.a: Weight at age in the stock.

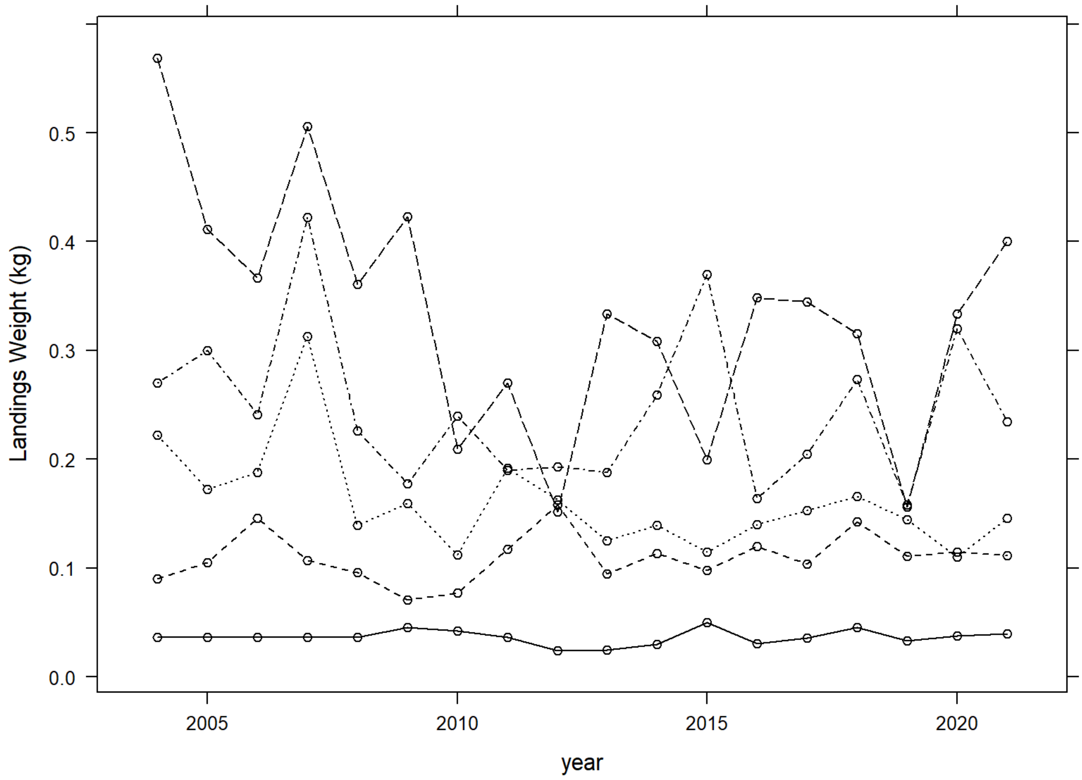

Figure 19.5.2.2. Striped red mullet in Subarea 4 and divisions 7.d and 3.a: Weight at age in the landings.

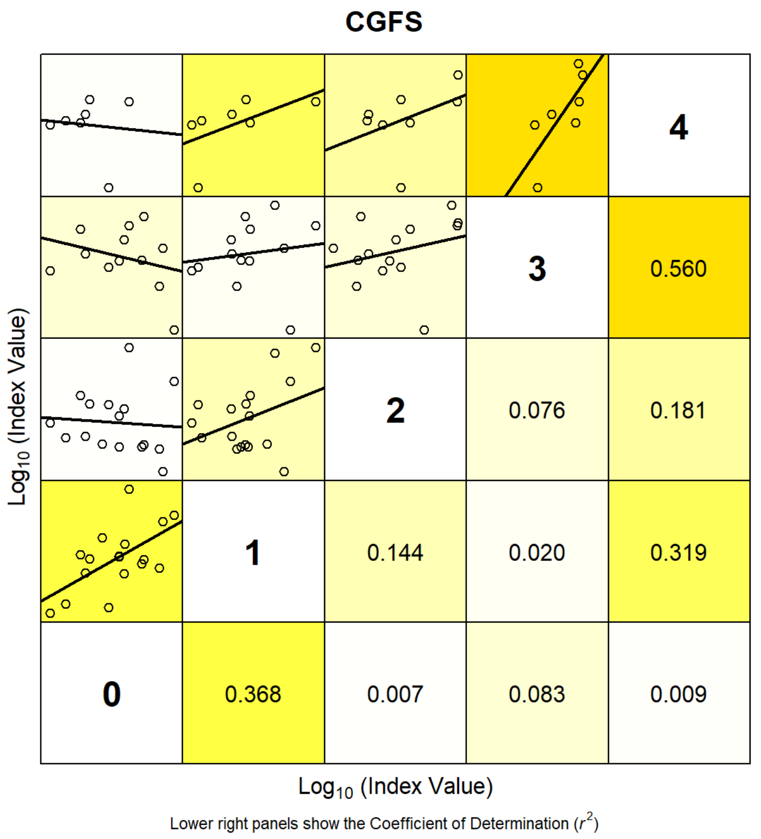

Figure 19.5.4.1. Striped red mullet in Subarea 4 and divisions 7.d and 3.a: CGFS internal consistencies.

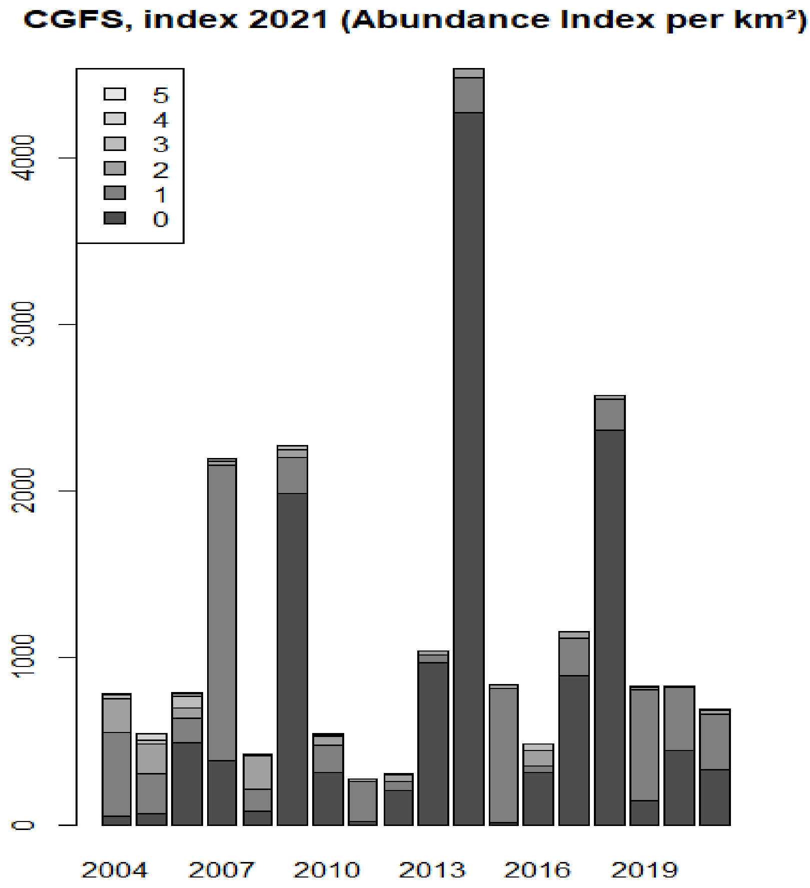

Figure 19.5.4.2. Striped red mullet in Subarea 4 and divisions 7.d and 3.a: CGFS catch age composition.

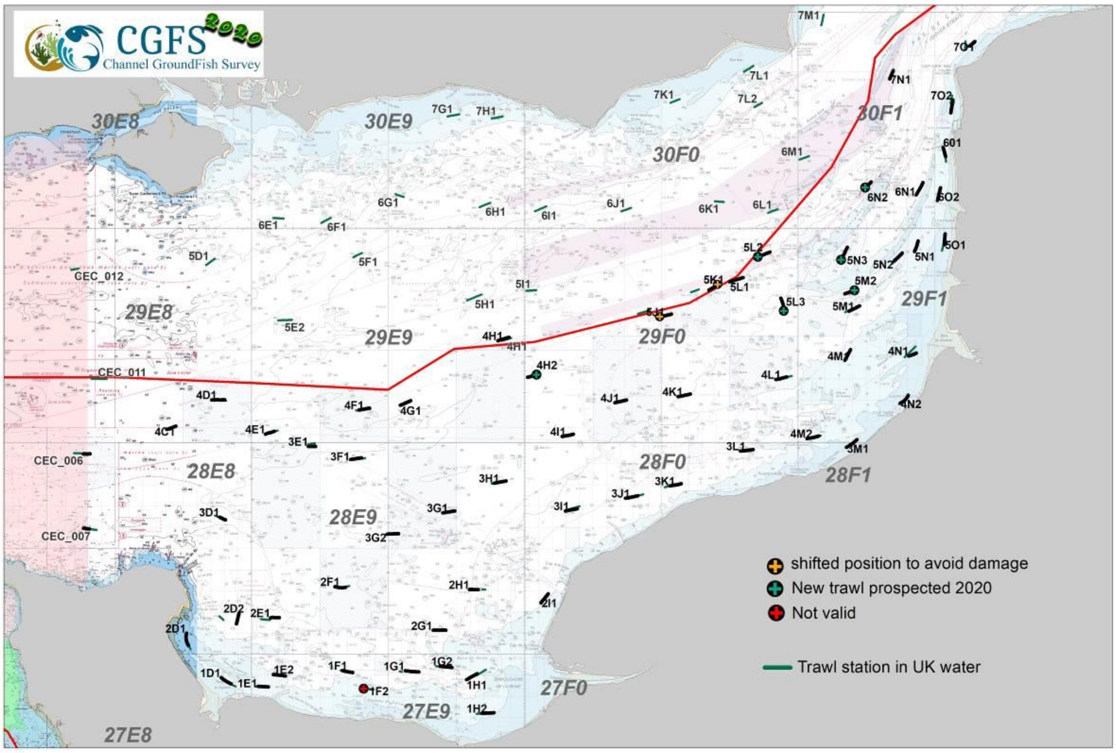

Figure 19.5.4.3. Striped red mullet in Subarea 4 and divisions 7.d and 3.a: CGFS hauls positions in 2020, north of the redline is the UK EEZ with stations not sampled in 2020 (ICES IBTSWG, 2021 (*in prep*).

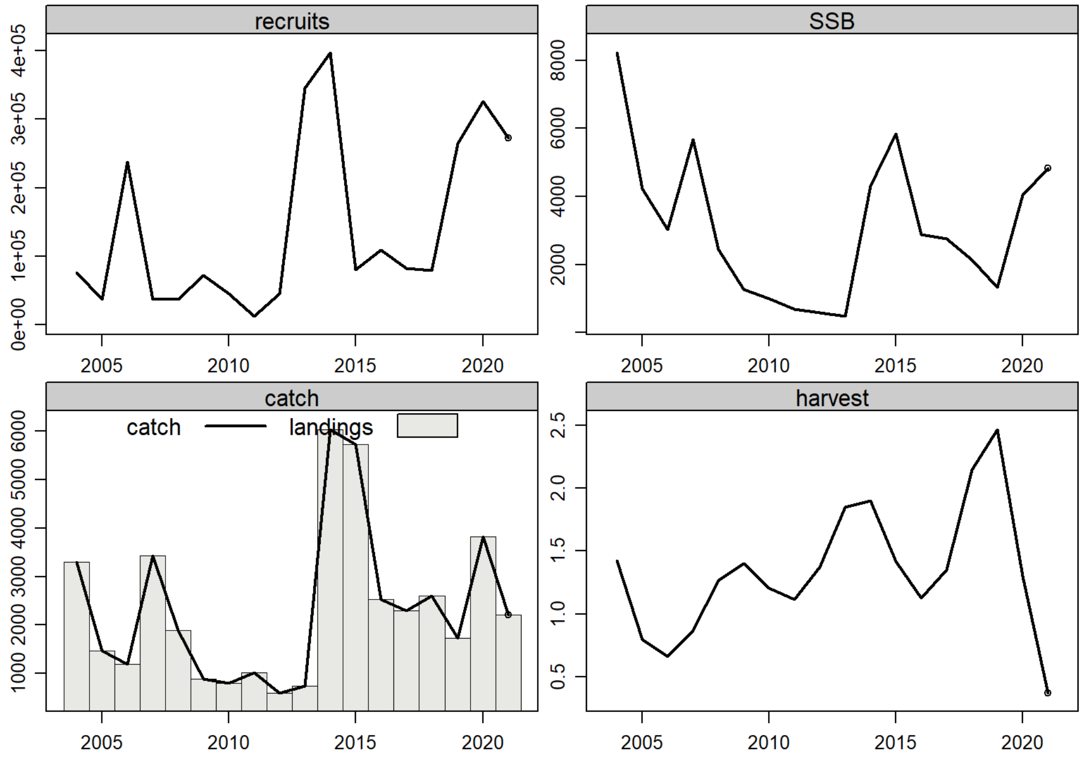

Figure 19.6.1.1 Striped red mullet in Subarea 4 and divisions 7.d and 3.a: Absolute value of recruitment, SSB, catch and $F_{bar(1-2)}$ estimate using a4a model formulation approved during the last benchmark.

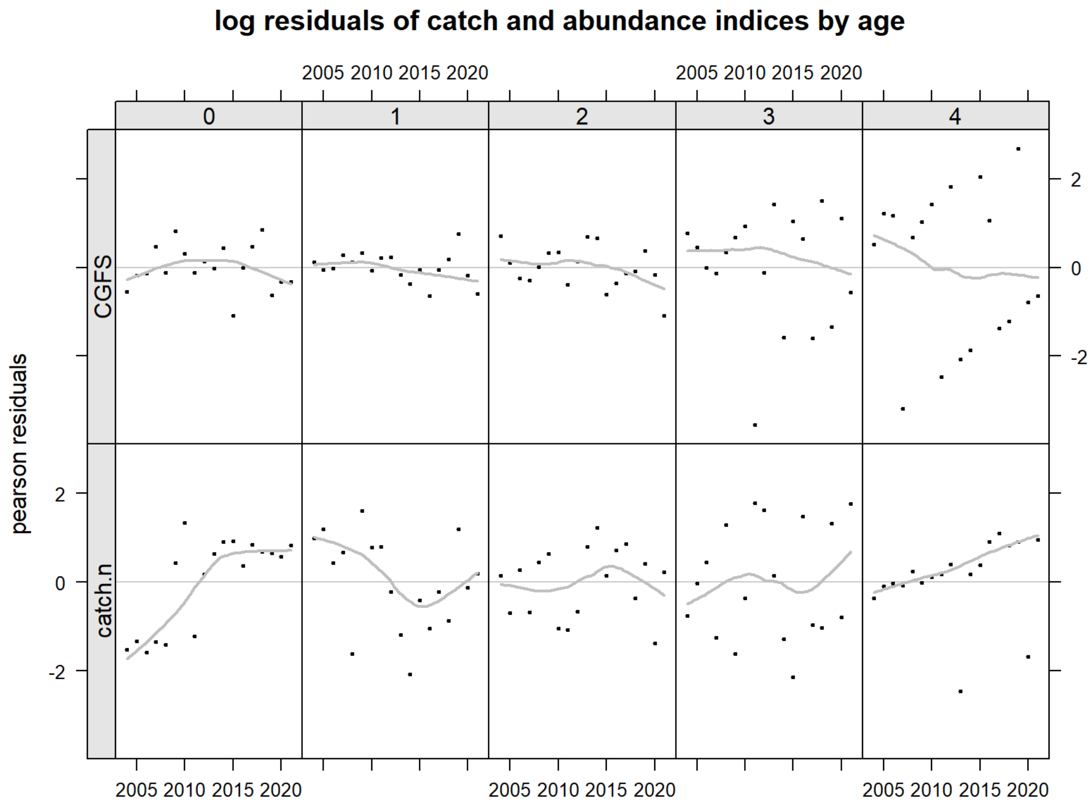

Figure 19.6.1.2. Striped red mullet in Subarea 4 and divisions 7.d and 3.a: Log residuals of the assessment.

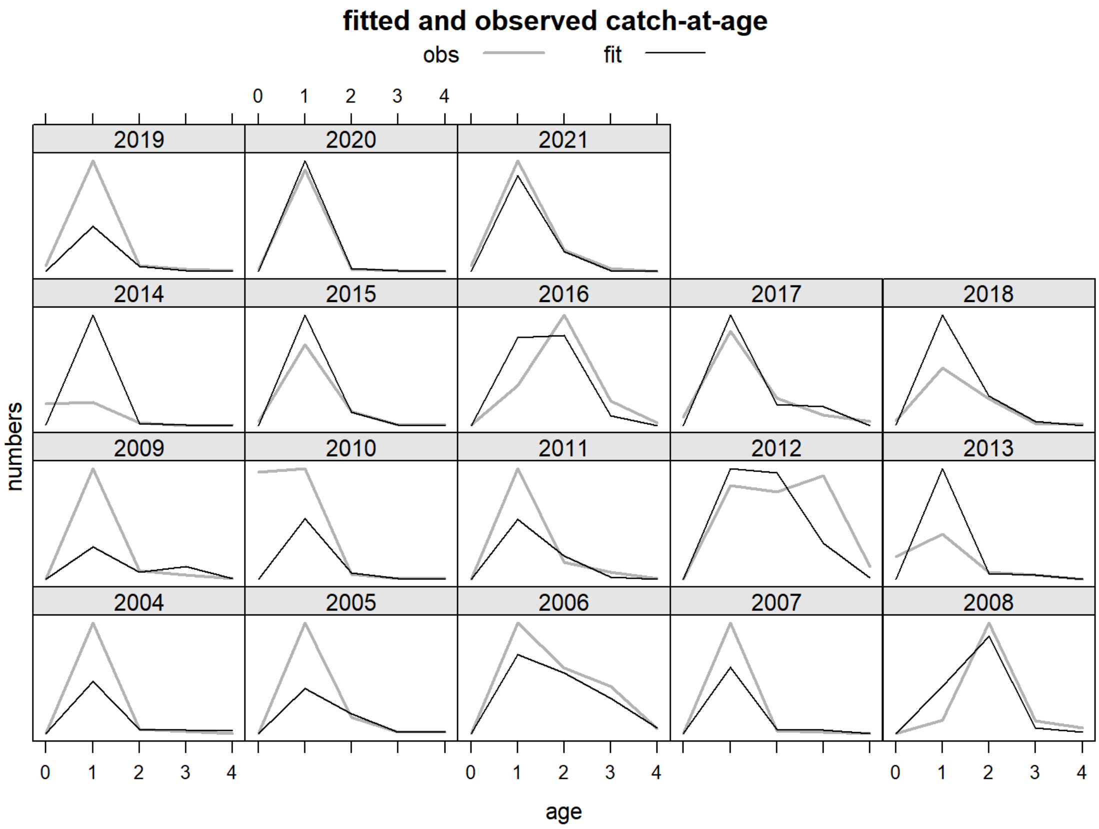

Figure 19.6.1.3. Striped red mullet in Subarea 4 and divisions 7.d and 3.a: Observed (grey) and estimated (black) catch number-at-age.

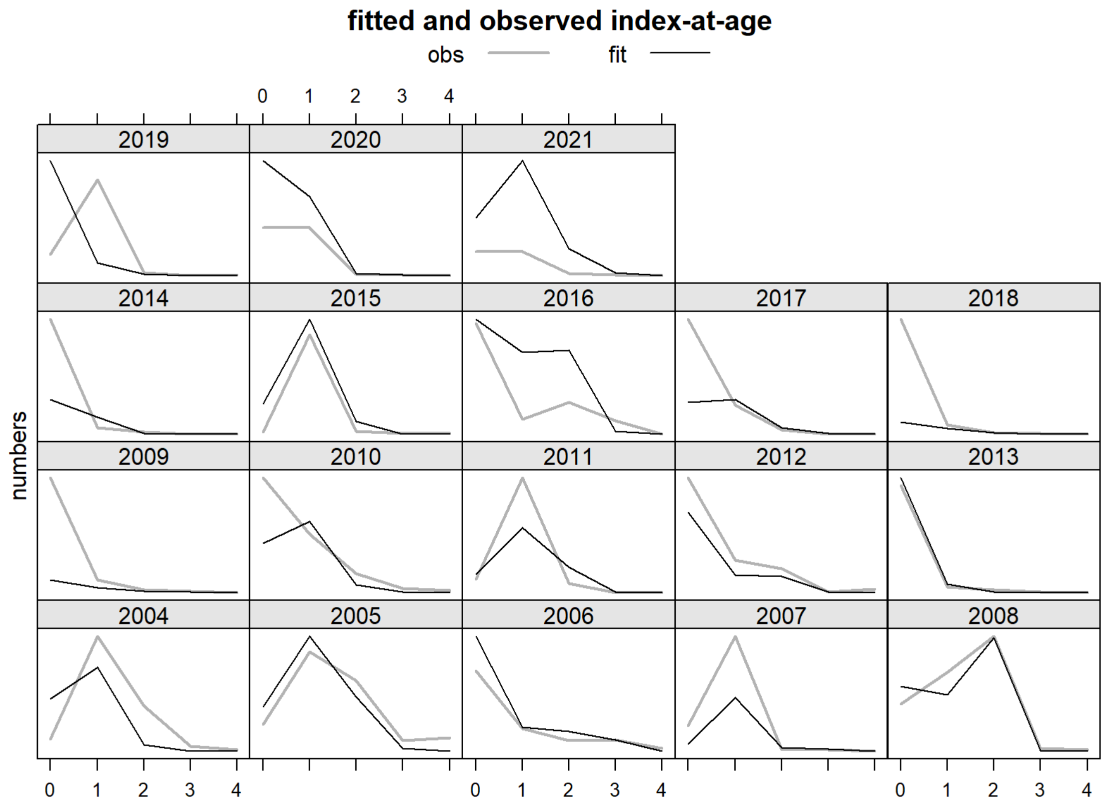

Figure 19.6.1.4. Striped red mullet in Subarea 4 and divisions 7.d and 3.a: Observed (grey) and estimated (black) indices at age.

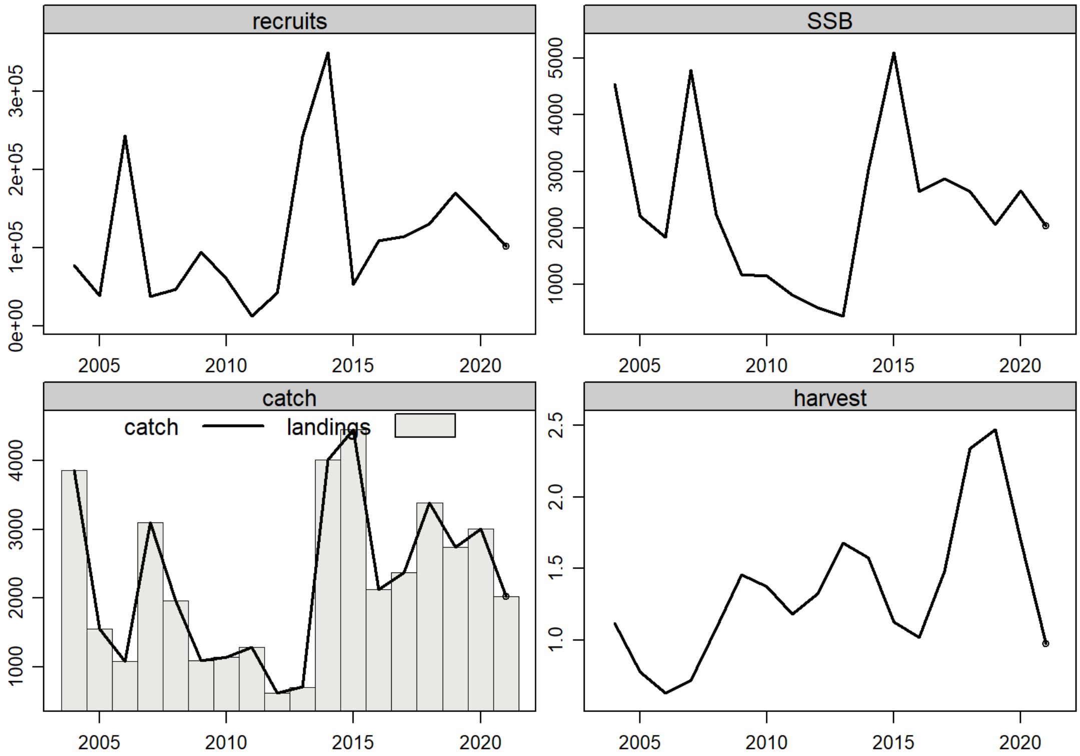

Figure 19.6.2.1. Striped red mullet in Subarea 4 and divisions 7.d and 3.a: Absolute value of recruitment, SSB, catch and $F_{bar(1–2)}$ estimate using alternative formulation of a4a to constrain selectivity at age and consider variance at age.

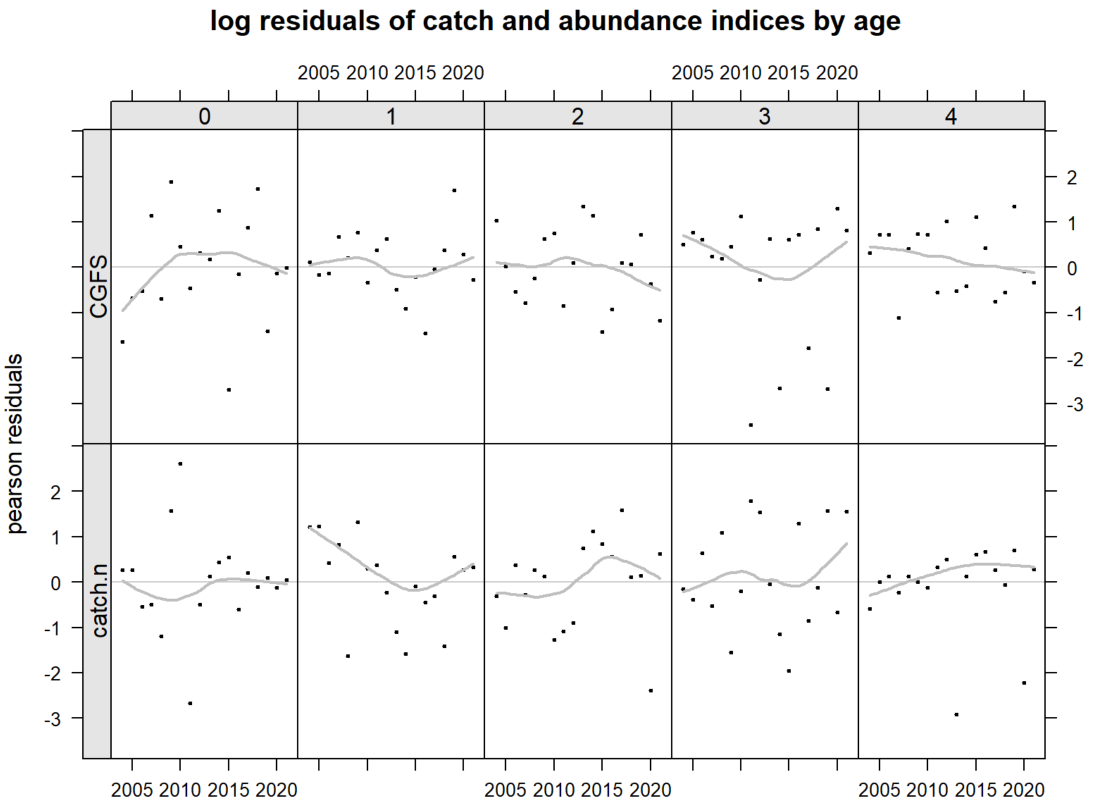

Figure 19.6.2.2. Striped red mullet in Subarea 4 and divisions 7.d and 3.a: Log residuals of the alternative a4a model.

20 Turbot in 3.a (Kattegat, Skagerrak)

The last advice issued in 2017 for the years 2018 and 2019 was based on the "2/3 rule" for category 3 stocks, applied to the IBTS Q1 and Q3 biomass indices. In 2019 and 2020, ICES was not requested to provide advice on fishing opportunities for this stock, so the advice sheet reported only on the status of the stock. From 2021 onwards, ICES was requested to provide advice again.

The general perception is that landings have fluctuated without trends over a long period. In 2019, the survey indices were of poor quality, with low catch rates and large annual fluctuations, and they showed no clear trends. In 2017, length-based indicators (LBI) and exploratory SPiCT runs were examined, pointing out that the stock may be exploited sustainably. In 2019, the LBI indicators were not updated due to poorer length information available following reduced sampling since 2017. The stock went through benchmark in 2020 where a SPiCT assessment was accepted to provide stock status (ICES, 2020a). That assessment is used since 2021 to provide catch advice according to the MSY approach (Category 2 stock).

20.1 Management regulations

Turbot in 3.a. is not managed using a TAC. The catch advice for 2022 was 224 tonnes.

There is no official EC minimum landing size, but Denmark has a minimum size at 30 cm. In the Netherlands, various restrictions and MLS for North Sea turbot have been applied by Dutch POs over time, which may also affect the Dutch discarding of turbot caught in Skagerrak.

20.2 Fisheries data

Turbot is now only caught as by-catch in the trawl and gillnet fisheries. Table 20.1 and Figure 20.1 summarize turbot landings in ICES Division 3.a. Over the period 1975–2021, total landings (3.a) ranged from 95 t to 736 t per year. The lowest landings were recorded in the 1960s and the highest peaks are observed in the late 1970s and in the early 1990s. The peak in the 1970s is linked to exceptionally high records from the Netherlands for four years. No official landings are reported from the Netherlands prior to 1975.

The Danish catches, which are present throughout the time series, have fluctuated without trends around 100–200 t per year.

In the last decades, the total annual landings of turbot in 3.a declined from 300–400 tonnes in the early 1990s to around 100 t in the early 2010s, but have increased again in the most recent years. In 2021, the total landings imported in InterCatch were 195 tonnes (192 t reported as official landings).

The procedure to raise discards for métiers that do not have them reported is done by grouping these fleets into three groups. For each group the mean discard rate is calculated from metiers in that group that have reported discards and that mean is used to raise discards for the rest of the métiers. Métiers that have discard rate above 2 are not included in the calculation of the mean. The three groups are: all fleets in subdivision 20, all fleets in subdivision 21, métiers from the Netherlands by Division 3.a. The Norwegian fleet and the industrial fleet are assumed to have no discards. There is a total of 8 tonnes of imported and raised discards in 2021. The total catch in 2021 was 203 tonnes (Table 20.2; Table 20.3).

The stock was benchmarked in early 2020, which included a data call for turbot in Division 3.a that lead to new landings and discard data being uploaded into InterCatch. This allowed a compilation of information by area and metier. During the benchmark, reported discard ratios were available across 2002–2018, and the average discard ratio (10.49%) was used to reconstruct the discards for earlier years (1950–2001). Details of the benchmark are provided in the associated report (ICES, 2020).

Discard coverage in 2020 was lower in subdivision 3a.20 (47%), but comparable to previous years in 3a.21 (59%). The discard coverage in 2021 was higher in both subdivisions, 71% and 69% in subdivision 3a.20 and 3a.21, respectively. The beam trawl fleet from the Netherlands and the gillnet fleet from Denmark are the largest metiers without discard information (Figure 20.2). Discarding is clearly related to fish size, most individuals below 30 cm are being discarded (Figure 20.3).

As turbot in 3a is mainly a bycatch species, a change in catch over time can be influenced by changes in effort levels and targeting of the fleets in the area that catch it. Further investigation is needed into targeting of the species in the area through time.

20.3 Survey data, recruit series and analysis of stock trends

During the benchmark, a new index for exploitable biomass was developed. The index was based on a compilation of five surveys covering Division 3a. Specifically, the surveys included the beam trawl survey (BTS), the North Sea International Bottom Trawl Survey (NS-IBTS), the Baltic International Trawl Survey (BITS), a Danish national survey targeting cod and the Danish part of a Swedish-Danish survey targeting sole, all covering parts of Division 3.a. (ICES, 2020). Since the index was intended for use in SPiCT, only the vulnerable sizes of the individuals caught in the surveys were included in the calculation of the index, leading to an exploitable biomass index. The vulnerable sizes refer to fish sizes that are caught by the commercial fleets. The standardised exploitable biomass index is shown in Figure 20.4, along with 3 retrospective runs, calculated by leaving out the last 1–3 years of available data. The SPiCT model combined the new exploitable biomass index and updated fisheries data and was approved during the benchmark (ICES, 2020).

20.4 Assessment and short term forecast

The surplus production model in continuous time (SPiCT, Pedersen and Berg 2017) is used for the assessment of the stock. The main settings are:

Fixed values

Shaefer model (shape parameter n=2)

Priors

Initial depletion: log(bkfrac)~N (log(0.5), 0.5^2)

Uncertainty ratio of index (observation) to biomass process: log(alpha)~N (log(1), 2^2)

Uncertainty ratio of catch (observation) to fishing mortality process: log(beta)~N(log(1), 2^2)

Catch: 1975–2021

Index (estimated for Q1): 1983—2021

Discretisation time step (dteuler): 1/16 year

A short-term forecast is performed using SPiCT. The assumption for the short term forecast intermediate year (2022) is that the fishing mortality process continues, essentially keeping status quo fishing mortality. This leads to the following short-term forecast in the intermediate year:

Variable	Value	Notes
F_{2022}/F_{MSY}	0.63	Status quo F
B_{2023}/B_{MSY}	1.32	Short term forecast (STF) under status quo F
Catch (2022)	202	STF of catch under status quo F
Discard rate (2022, 2023)	9 %	Average 2019—2021. Percentage
Projected landings (2022)	184	Based on the average discard rate
Projected discards (2022)	18	Based on the average discard rate

The assessment results are shown in Figure 20.5 and summarised in Table 20.5. The diagnostics of the goodness of fit of the model are based on the one-step-ahead residuals (Figure 20.6). There are some issues with autocorrelation of the residuals of the index time series. This is a result of including an already smoothed biomass index based on a GAM model. During the benchmark of the stock in 2020, an approach of removing every other index observation was used as an attempt to alleviate the autocorrelation issue. The results showed improvement in the autocorrelation, but only small differences in the estimated stock status. The decision was to include all data to avoid issues with the retrospective analysis and the short-term forecast. Another issue with the assessment is the low estimated observation error for the exploitable biomass index ($\sigma_I = 0.019$) which is probably unrealistic, but stems from the fact that a smoothed index is used.

The retrospective analysis is done using the recalculated index by consecutively removing the last three years of survey information and then fitting the assessment model. The relative fishing mortality and biomass estimates have acceptable retrospective bias: Mohn's rho: 0.049 for B/B_{MSY}, 0.057 for F/F_{MSY} (Figure 20.7).

To provide advice following the MSY approach, the recommendation of WKLIFE X (ICES, 2020b) is followed. The basis for the advice assumes fishing mortality $F=F_{MSY}$ during the management year (2023). Then the TAC advice is the 35th percentile of the projected catch distribution. The use of that percentile instead of the median leads to a more precautionary advice, with no loss of long-term yield and incorporates the uncertainty into the advice. For 2023, the catch advice is 269 tonnes. The results for the baseline management scenario and alternatives that are included in the advice sheet are shown in Figure 20.8 and Table 20.4.

20.5 Issue list

The stock was benchmarked in 2020, but a number of issues remain:

- Stock identity. The benchmark indicated that Division 3.a is not a separate stock, but connected to both the North Sea and the Baltic Sea. There is genetic differentiation between the North Sea and the Baltic Sea with a genetic hybrid zone within Division 3.a The new exploitable biomass index and the landings data indicated elevated abundances and landings on the borders between Division 3.a and the North Sea and the Baltic Sea, further supporting connectivity between Division 3.a and neighbouring areas. The stock identity of Division 3.a should therefore be evaluated.
- The amount of length distribution data significantly reduced since 2017. Discussions should take place within Denmark for options within the framework of the next data collection programs after 2021. Denmark is responsible for approximately 3/4 of the turbot landings in Division 3.a.

- The application of the new exploitable biomass index via SPiCT indicated residual autocorrelation issues that should be addressed.
- The index includes only the Danish part of the cod survey in subdivision 3a. In the future the Swedish data should also be included.
- Cardinale *et al.* (2009) reconstructed a long time series of survey data. It would be interesting to update this time series and investigate options to include it in further SPiCT runs. The paper indicated historic declines in abundance and maximum body sizes of turbot in Division 3.a.

20.6 Summary

The turbot stock in Division 3.a was benchmarked in 2020, and the resulting SPiCT model was used for the present assessment and report. A major improvement for the SPiCT model was the development of a new index for the relative exploitable biomass based on five different surveys covering Division 3.a. The analyses indicated that the relative exploitable biomass (B/B_{MSY}) remained above the reference point of 0.5 and relative fishing mortality (F/F_{MSY}) below the reference point of 1.

Table 20.1. Turbot in 27.3a. History of commercial landings 1975–2021; official values are presented by area for each country participating in the fishery. All weights are in tonnes. * Preliminary

Year	Belgium	Germany	Denmark	UK	Netherlands	Norway	Sweden	Total
1950	0	13	212	0	0	1	73	299
1951	0	6	191	0	0	6	62	265
1952	0	6	114	0	0	3	58	181
1953	0	4	80	0	0	4	51	139
1954	0	0	78	0	0	1	61	140
1955	0	4	77	0	0	0	49	130
1956	0	7	75	0	0	0	41	123
1957	0	3	108	0	0	0	30	141
1958	0	7	112	0	0	0	41	160
1959	0	6	132	0	0	3	43	184
1960	0	11	115	0	0	2	46	174
1961	0	4	130	0	0	0	45	179
1962	0	5	157	0	0	0	0	162
1963	0	4	124	0	0	0	0	128
1964	0	5	89	0	0	0	0	94
1965	0	6	79	1	0	0	0	86
1966	0	2	104	0	0	0	0	106
1967	0	4	68	1	0	0	0	73
1968	0	0	64	0	0	0	0	64
1969	0	1	75	0	0	0	0	76
1970	0	1	76	0	0	0	0	77
1971	0	1	100	0	0	0	0	101
1972	0	2	130	0	0	0	0	132
1973	0	2	98	0	0	0	0	100
1974	0	1	116	0	0	0	0	117
1975	0	2	167	0	7	0	7	183
1976	7	2	178	0	190	0	6	383
1977	7	4	331	0	389	0	5	736
1978	2	4	327	0	186	0	6	525
1979	8	0	307	0	87	0	4	406
1980	7	0	205	1	14	0	6	233
1981	2	0	183	2	12	0	8	207
1982	1	0	164	1	9	0	7	182
1983	4	0	171	0	24	0	10	209
1984	0	0	176	0	0	0	12	188
1985	1	0	224	0	0	0	16	241
1986	2	0	180	0	0	0	11	193
1987	5	0	147	0	0	0	9	161
1988	2	0	115	0	11	0	10	138

Year	Belgium	Germany	Denmark	UK	Netherlands	Norway	Sweden	Total
1989	2	0	173	0	0	0	9	184
1990	5	0	363	0	0	0	18	386
1991	4	0	244	0	0	7	21	276
1992	4	0	278	0	0	8	19	309
1993	3	2	336	0	0	10	0	351
1994	2	1	313	0	0	15	22	353
1995	4	1	268	0	0	17	11	301
1996	0	1	185	0	0	13	11	210
1997	0	0	200	0	0	9	11	220
1998	0	1	148	0	0	7	8	164
1999	0	1	139	0	0	10	6	156
2000	0	1	180	0	0	6	6	193
2001	0	0	227	0	0	8	3	238
2002	0	1	205	0	0	11	5	222
2003	0	0	128	0	13	14	4	159
2004	0	0	119	0	14	7	7	147
2005	0	0	108	0	7	6	6	127
2006	0	1	95	0	8	8	9	121
2007	0	1	138	0	15	7	12	173
2008	0	1	121	0	4	6	11	143
2009	0	1	94	0	2	6	17	120
2010	0	0	72	0	6	4	13	95
2011	0	1	78	0	0	7	13	99
2012	0	< 0.5	167	0	0	8	14	189
2013	0	< 0.5	91	0	0	5	15	111
2014	0	1	94	0	3	6	18	122
2015	0	< 0.5	135	0	20	8	11	174
2016	0	< 0.5	137	< 0.5	25	6	11	179
2017	0	< 0.5	154	0	16	7	12	189
2018	0	0	109	0	24	8	10	151
2019	0	0	117	<0.5	69	5	7	198
2020*	0	< 0.5	124	0	55	5	7	191
2021*	0	1	139	0	39	5	8	192

Table 20.2. Turbot in 27.3a: Landings and discards (in kg) by year and area after discard raising in InterCatch (using CATON estimate). No BMS nor logbook registered discards reported in InterCatch.

Year	Discards	Landings	Total	discard ratio
2002	**17593**	**214745**	**232338**	**7.60%**
27.3.a	9	135	144	6.20%
27.3.a.20	906	152506	153412	0.59%

Year	Discards	Landings	Total	discard ratio
27.3.a.21	16679	62104	78783	21%
2003	**15273**	**153228**	**168501**	**9.10%**
27.3.a	1468	14080	15548	9.40%
27.3.a.20	227	83702	83929	0.27%
27.3.a.21	13578	55446	69024	19.70%
2004	**9463**	**146736**	**156199**	**6.10%**
27.3.a	990	15674	16664	5.90%
27.3.a.20	2524	72802	75326	3.40%
27.3.a.21	5950	58260	64210	9.30%
2005	**10672**	**125757**	**136429**	**7.80%**
27.3.a	516	6928	7444	6.90%
27.3.a.20	3277	73824	77101	4.30%
27.3.a.21	6880	45005	51885	13.30%
2006	**11600**	**116895**	**128495**	**9.00%**
27.3.a	833	8838	9671	8.60%
27.3.a.20	246	55105	55351	0.44%
27.3.a.21	10522	52952	63474	16.60%
2007	**32300**	**171442**	**203742**	**15.90%**
27.3.a	1597	16098	17695	9.00%
27.3.a.20	880	100442	101322	0.87%
27.3.a.21	29823	54902	84725	35%
2008	**7183**	**139685**	**146868**	**4.90%**
27.3.a	172	4635	4807	3.60%
27.3.a.20	0	91024	91024	0.00%
27.3.a.21	7011	44026	51037	13.70%
2009	**9363**	**120692**	**130055**	**7.20%**
27.3.a	142	2661	2803	5.10%
27.3.a.20	727	73619	74346	0.98%
27.3.a.21	8494	44412	52906	16.10%
2010	**11264**	**96525**	**107789**	**10.50%**
27.3.a	658	6346	7004	9.40%
27.3.a.20	163	43069	43232	0.38%
27.3.a.21	10443	47110	57553	18.10%
2011	**25532**	**94354**	**119886**	**21%**
27.3.a	59	258	317	18.60%
27.3.a.20	4192	54053	58245	7.20%
27.3.a.21	21281	40042	61323	35%
2012	**22621**	**194736**	**217357**	**10.40%**
27.3.a	29	289	318	9.10%
27.3.a.20	3562	164297	167859	2.10%

Year	Discards	Landings	Total	discard ratio
27.3.a.21	19030	30150	49180	39%
2013	**7110**	**110945**	**118055**	**6.00%**
27.3.a	0	2	2	0.00%
27.3.a.20	1469	75803	77272	1.90%
27.3.a.21	5641	35140	40781	13.80%
2014	**14520**	**122406**	**136926**	**10.60%**
27.3.a	0	0	0	0.00%
27.3.a.20	3874	82446	86320	4.50%
27.3.a.21	10646	39960	50606	21%
2015	**33938**	**179737**	**213675**	**15.90%**
27.3.a	0	1	1	0.00%
27.3.a.20	8426	141894	150320	5.60%
27.3.a.21	25511	37842	63353	40%
2016	**19246**	**190829**	**210075**	**9.20%**
27.3.a	3492	34530	38022	9.20%
27.3.a.20	9617	111770	121387	7.90%
27.3.a.21	6136	44529	50665	12.10%
2017	**31669**	**191667**	**223336**	**14.20%**
27.3.a	2928	17528	20456	14.30%
27.3.a.20	17404	122493	139897	12.40%
27.3.a.21	11337	51646	62983	18.00%
2018	**22528**	**153398**	**175926**	**12.80%**
27.3.a	4000	24842	28842	13.90%
27.3.a.20	11506	82913	94419	12.20%
27.3.a.21	7022	45643	52665	13.30%
2019	**41903**	**204356**	**246259**	**17.00%**
27.3.a	15857	74430	90287	17.60%
27.3.a.20	21409	102564	123973	17.30%
27.3.a.21	4637	27362	31999	14.50%
2020	**13458**	**201698**	**215156**	**6.3%**
27.3.a	4673	65140	69813	6.7%
27.3.a.20	3210	106819	110029	2.9%
27.3.a.21	5575	29740	35315	15.8%
2021	**7682**	**195050**	**202732**	**3.8%**
27.3.a	1663	42090	43753	3.8%
27.3.a.20	1211	117820	119031	1.02%
27.3.a.21	4807	35140	39947	12.0%

Table 20.3: Turbot in 27.3a. Summary of the imported/raised data for 2021. Stock exported without length allocation. Weights are in kilograms.

Discards	**7682**	
Imported Data	4252	55.4%
Raised Discards	3430	44.6%
Landings	**195050**	
Imported Data	195050	
Grand Total	**202732**	

Table 20.4: Turbot in 27.3a. Forecast table for the baseline and alternative scenarios. The percent biomass change refers to the biomass in 2024 relative to 2023.

Basis	**Total catch (2023)**	**Projected landings (2023)**	**Projected discards (2023)**	**Fishing mortality F_{2023}/F_{MSY}**	**Stock size B_{2024}/B_{MSY}**	**% B change**
MSY approach (35th percentile of predicted catch distribution under F = F_{MSY})	269	245	24	0.84	1.31	-1.06
Other scenarios						
F = F_{MSY}	320	291	29	1.00	1.29	-2.2
F = F_{sq}	203	184	18	0.63	1.32	0.38
F = 0	0	0	0	0	1.38	4.5
F = F_{MSY}, all fractiles	208	189	19	0.64	1.32	0.26

Table 20.5: Turbot in 27.3a. Assessment results, summary table. The 2022 biomass is the short-term forecast during the intermediate year, assuming that the F process continues unchanged from the last year with observations (Fsq).

Year	Relative exploitable biomass			Landings	Discards	Relative fishing pressure		
	B/B_{MSY}	High	Low	tonnes	tonnes	F/F_{MSY}	High	Low
1975	1.58	3.1	0.81	183	22	0.72	2.0	0.25
1976	1.55	2.9	0.82	383	46	1.55	4.3	0.57
1977	1.42	2.7	0.76	736	88	2.1	5.8	0.75
1978	1.3	2.5	0.69	525	63	1.63	4.6	0.58
1979	1.24	2.4	0.64	406	49	1.13	3.3	0.39
1980	1.22	2.4	0.63	233	28	0.81	2.4	0.27
1981	1.23	2.4	0.63	207	25	0.72	2.1	0.24
1982	1.24	2.4	0.64	182	22	0.71	2.1	0.24
1983	1.26	2.5	0.64	209	25	0.72	2.2	0.24
1984	1.29	2.5	0.66	188	23	0.74	2.2	0.25
1985	1.33	2.6	0.68	241	29	0.75	2.2	0.25
1986	1.38	2.7	0.7	193	23	0.58	1.76	0.194
1987	1.42	2.8	0.73	161	19	0.48	1.45	0.157
1988	1.43	2.8	0.73	138	17	0.49	1.54	0.159
1989	1.39	2.7	0.71	184	22	0.86	2.6	0.28
1990	1.32	2.6	0.67	386	46	1.20	3.6	0.40
1991	1.2	2.3	0.61	276	33	1.11	3.4	0.36
1992	1.13	2.2	0.58	309	37	1.31	3.9	0.44
1993	1.14	2.2	0.58	351	42	1.38	4.1	0.47
1994	1.16	2.3	0.59	353	42	1.30	3.8	0.44
1995	1.14	2.2	0.58	301	36	1.03	3.1	0.34
1996	1.07	2.1	0.55	210	25	0.94	2.9	0.31
1997	0.98	1.91	0.5	220	26	0.92	2.8	0.30
1998	0.91	1.78	0.46	164	20	0.80	2.5	0.26
1999	0.89	1.74	0.45	156	19	0.88	2.6	0.29
2000	0.89	1.74	0.45	193	23	1.10	3.2	0.37
2001	0.89	1.74	0.46	238	28	1.18	3.5	0.40
2002	0.92	1.8	0.47	215	18	0.87	2.6	0.29
2003	0.99	1.94	0.51	153	15	0.65	1.94	0.22
2004	1.07	2.1	0.55	147	9	0.57	1.69	0.193
2005	1.13	2.2	0.58	126	11	0.45	1.33	0.150
2006	1.17	2.3	0.6	117	12	0.56	1.65	0.189
2007	1.18	2.3	0.6	171	32	0.65	1.93	0.22
2008	1.15	2.2	0.59	140	7	0.48	1.42	0.161
2009	1.09	2.1	0.56	121	9	0.45	1.33	0.151
2010	1.05	2.1	0.54	97	11	0.40	1.19	0.134
2011	1.05	2	0.54	94	26	0.64	1.90	0.22
2012	1.1	2.1	0.56	195	23	0.64	1.91	0.22

Year	Relative exploitable biomass			Landings	Discards	Relative fishing pressure		
	B/B_{MSY}	High	Low	tonnes	tonnes	F/F_{MSY}	High	Low
2013	1.2	2.4	0.62	111	7	0.37	1.11	0.124
2014	1.37	2.7	0.7	122	15	0.51	1.51	0.174
2015	1.52	3	0.78	180	34	0.59	1.76	0.20
2016	1.52	3	0.78	191	19	0.60	1.76	0.20
2017	1.38	2.7	0.7	192	32	0.58	1.72	0.195
2018	1.24	2.4	0.63	153	23	0.65	1.93	0.22
2019	1.22	2.4	0.62	204	42	0.81	2.4	0.28
2020	1.3	2.5	0.67	202	13	0.64	1.91	0.22
2021	1.31	2.6	0.68	195	8	0.63	1.90	0.21
2022	1.32	2.6	0.68					

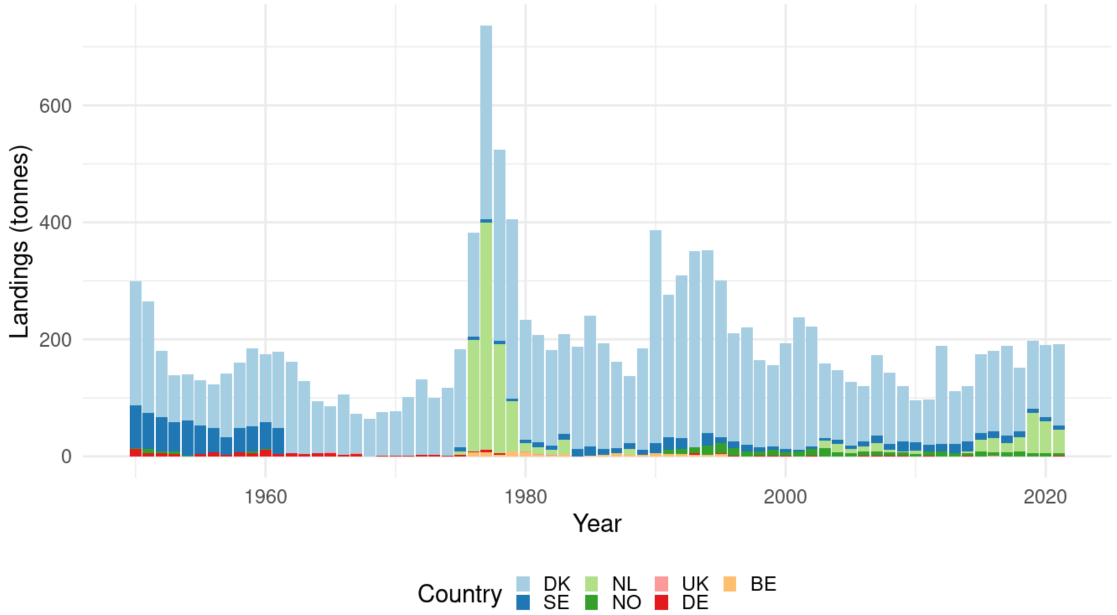

Figure 20.1. Turbot in 27.3a: Official landings by country from 1950 to 2021.

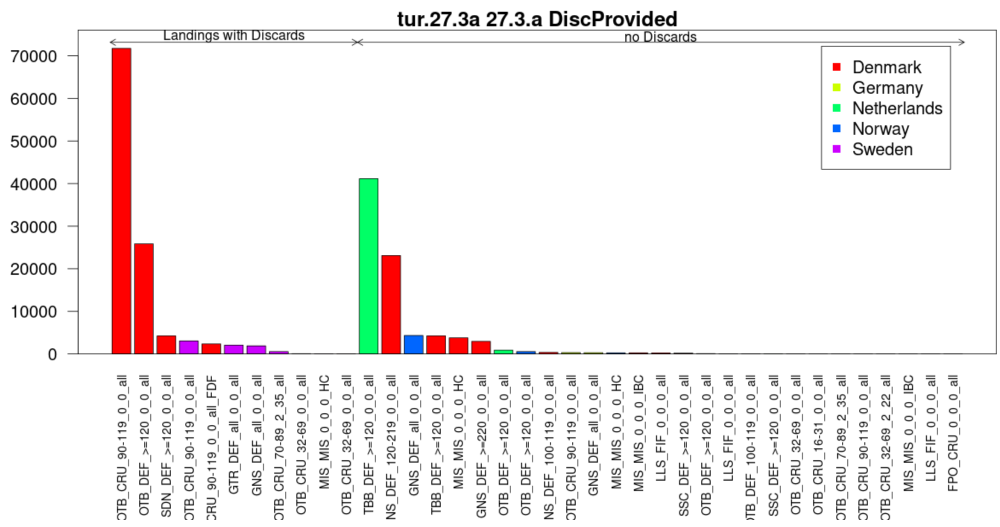

Figure 20.2. Turbot in 27.3a. Summary of the information provided to InterCatch for 2021. Landings by metier and country, distinguishing between strata with and without corresponding discard information provided.

Figure 20.3. Turbot in 27.3a: Length distribution in landings and discards across 2002–2019. Most individuals below 30 cm are discarded (vertical dashed line).

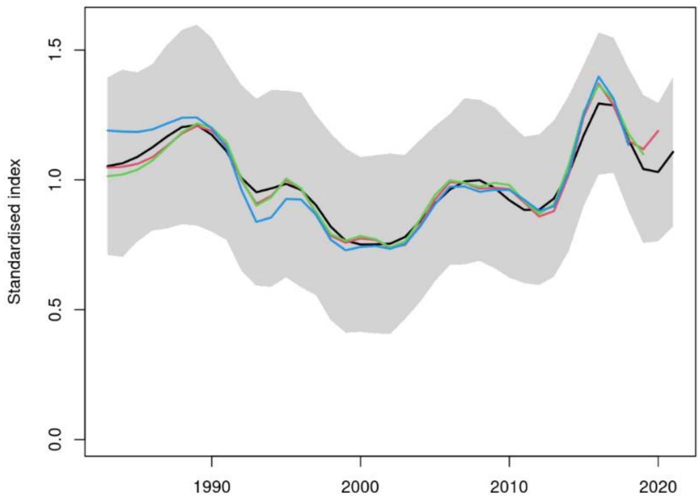

Figure 20.4. Turbot in 27.3a. Exploitable biomass survey index (black, base run) and 3 retrospective fits. The shaded area shows 95% confidence intervals of the base run.

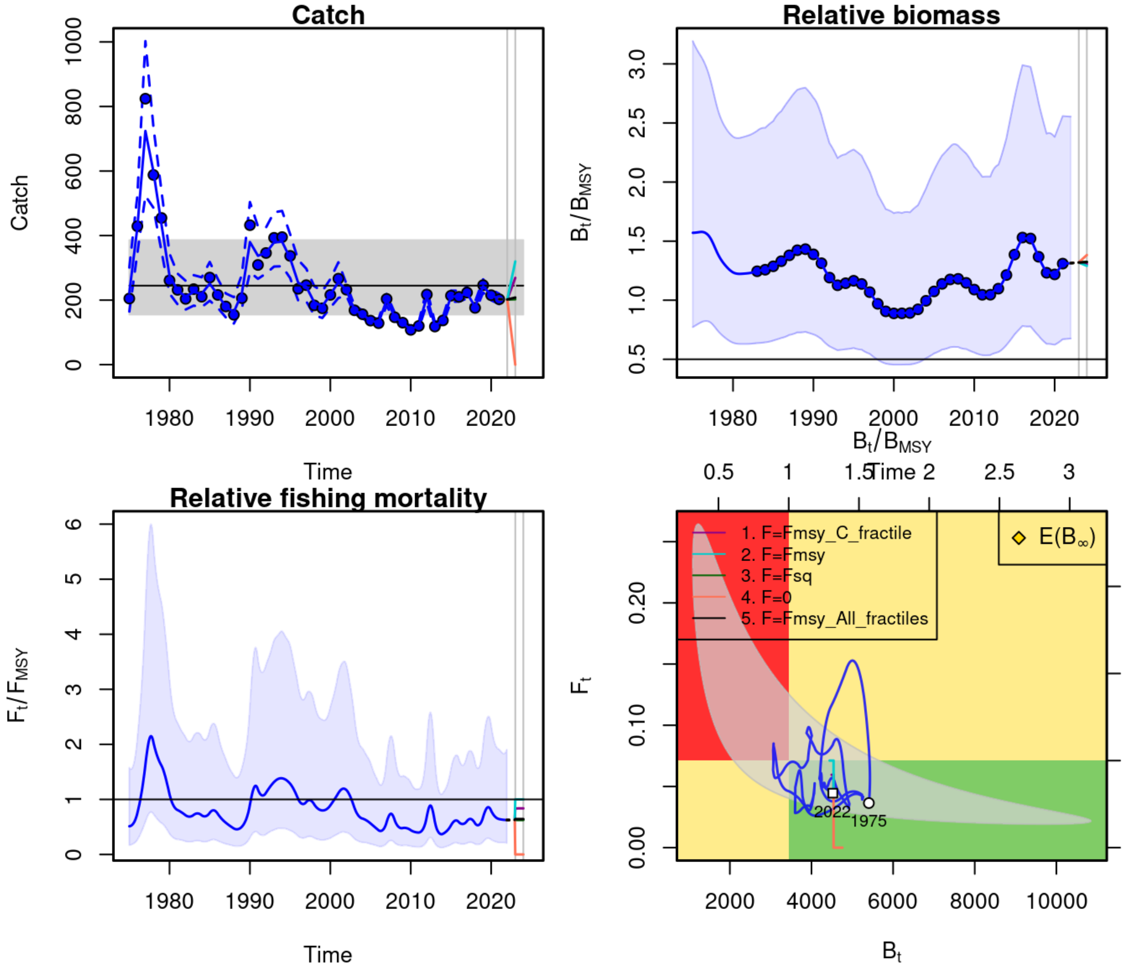

Figure 20.5. Turbot in 27.3a. SPiCT assessment running to the end of 2021, with 5 different short term forecast scenarios. The vertical grey lines in the catch, relative biomass and relative fishing mortality plots indicate the intermediate year (2022) and the horizontal lines show the corresponding reference points (MSY, B/B_{MSY}=0.5 and F/F_{MSY}=1). The shaded areas and dashed lines in all plots show 95% confidence intervals. The assessment is based on settings agreed upon during the benchmark (ICES, 2020).

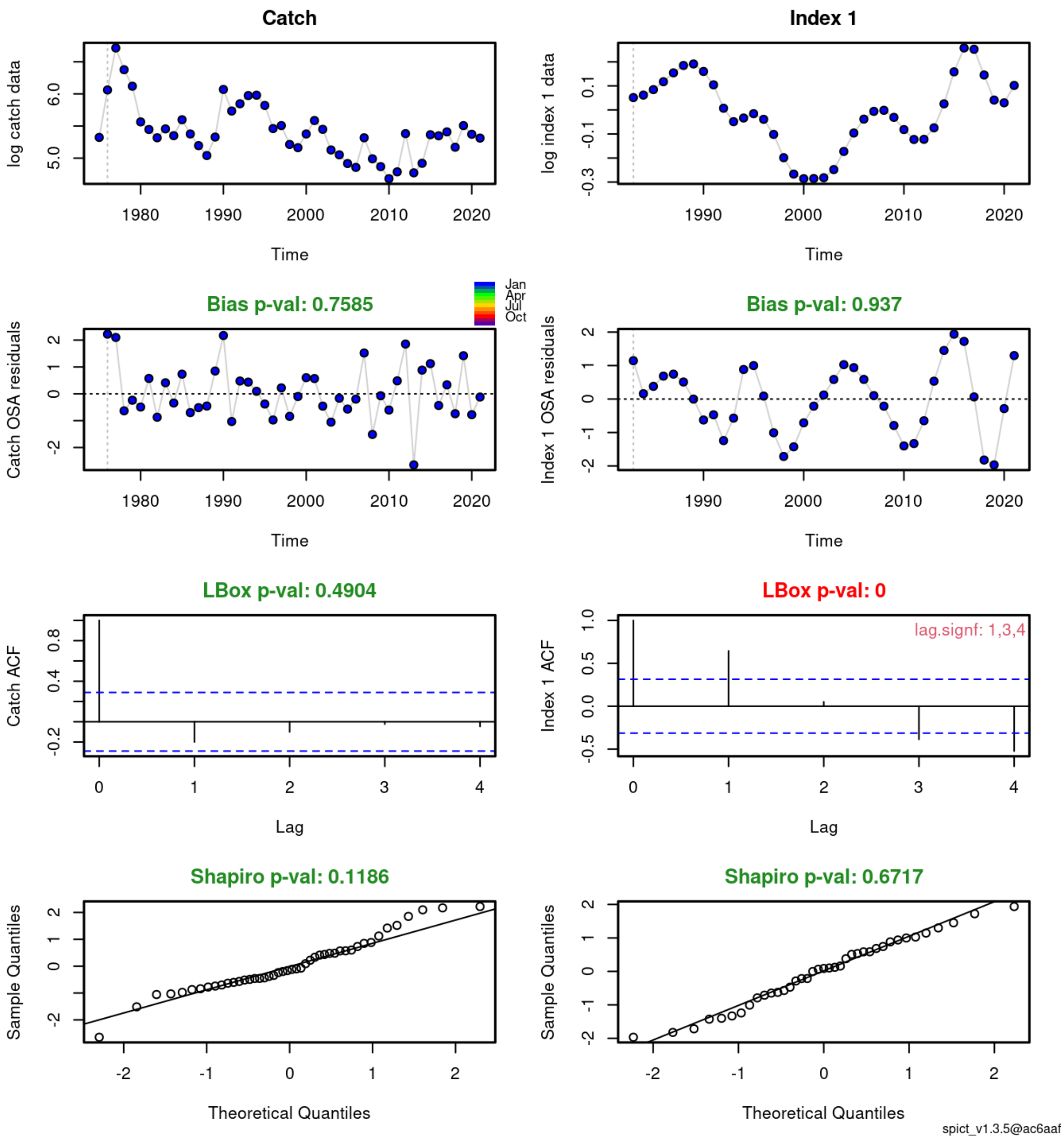

Figure 20.6. Turbot in 27.3a. Evaluation of SPiCT assessment running to the end of 2021. The residual diagnostics are shown for the two input time series (catch: left, exploitable biomass index: right). From the top to bottom it is shown: the log-transformed input time series, the one-step-ahead residuals with a bias test, the autocorrelation function with a Ljung-Box test, and a QQ-plot with a Shapiro test for normality. The application of the new exploitable biomass index via SPiCT indicated residual autocorrelation issues.

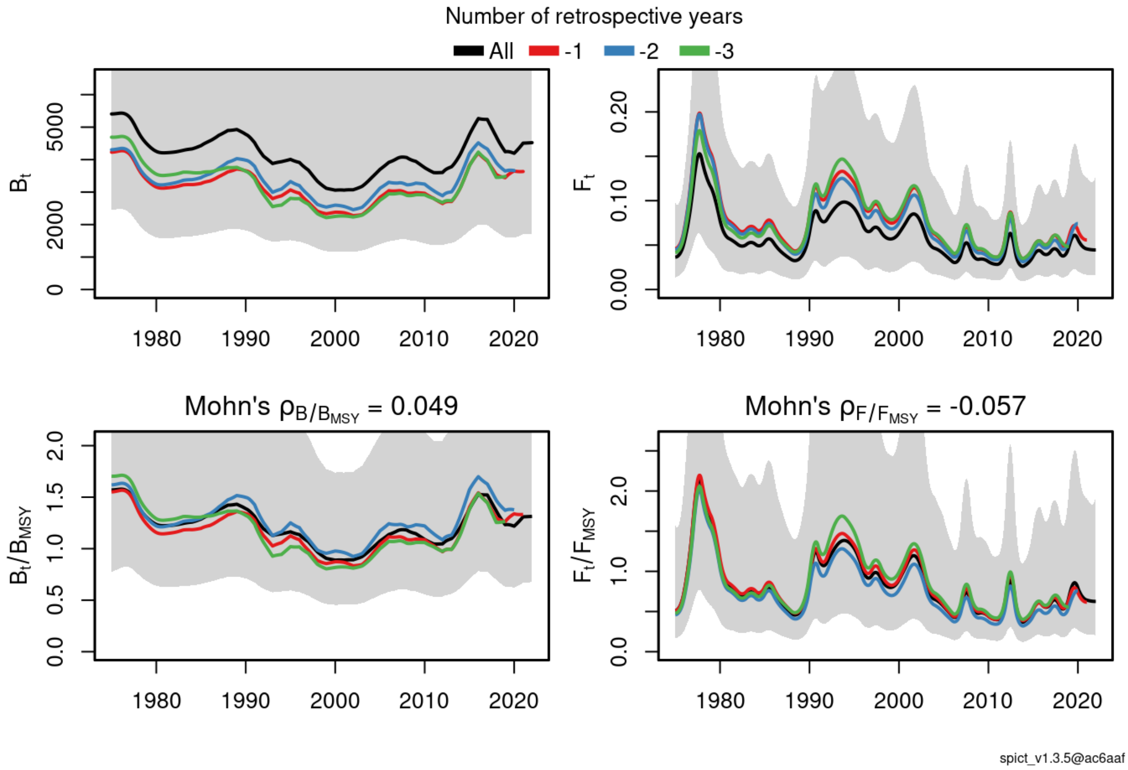

Figure 20.7. Turbot in 27.3a. Retrospective analysis showing the baseline (black lines) with 95% confidence intervals (shaded area). The survey index is re-calculated by consecutively removing the last three years of data and the assessment is shown in red, blue and green. The Mohn's rho for the relative quantities is shown on top of their corresponding panels.

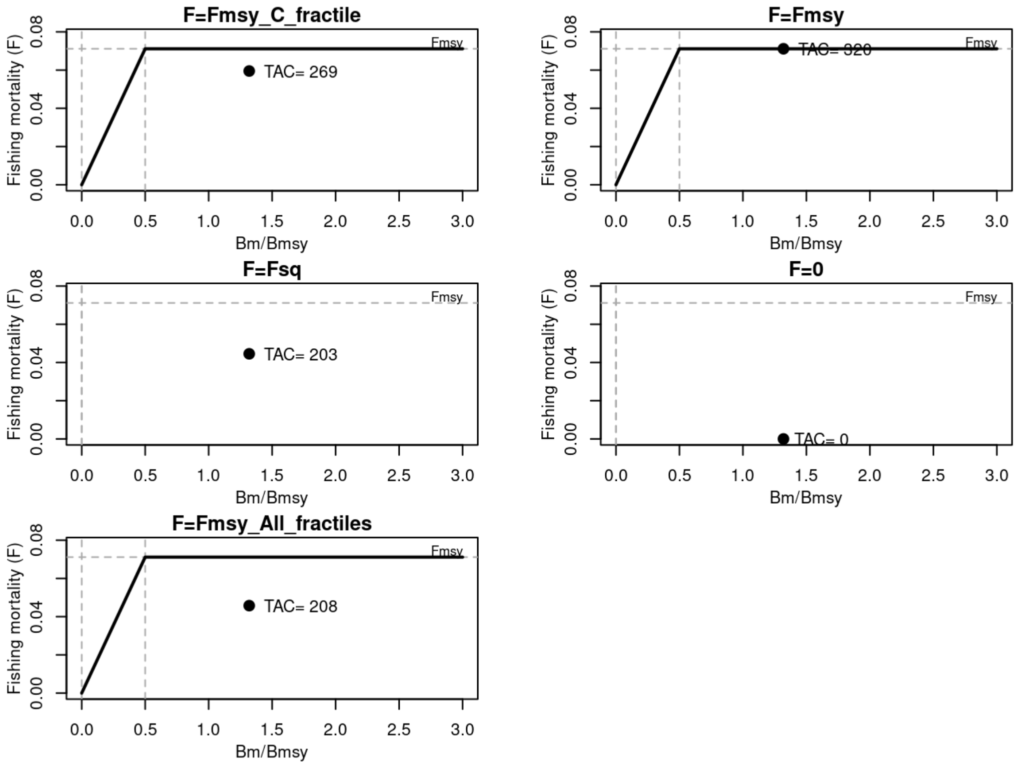

Figure 20.8. Turbot in 27.3a management scenarios. The solid line shows the harvest control rule without any fractiles, i.e. fishing at F_{MSY} when B is above $B_{trigger}$, and reducing F linearly to zero when the biomass is lower. Scenarios that are based on a specific fishing mortality (F = Fsq and F = 0) do not have a HCR. The vertical lines show $B/B_{trigger}$= 0.5. The basis for the advice follows that recommendation of WKLIFE X (ICES, 2020b) and is shown in the top left corner.

21 Turbot in Subarea 4

This report presents the stock assessment carried out for turbot (*Scophthalmus maxima*) in Subarea 4 in 2022. Following an inter-benchmark procedure for this stock in 2015, a state-space assessment model SAM (Nielsen and Berg, 2014) is used (ICES 2016). During WGNSSK 2017, questionable model settings used since the 2015 Inter-benchmark were detected. This led to the decision that a further inter-benchmark was needed in 2017 (ICES, 2017), screening all available input data, including a new LPUE index from UK (not included in the final assessment), a Dutch LPUE index, a Delta-GAM survey index combining several BTS surveys (not included in the final assessment) and, for the first time, age-based catch data from Denmark for most recent years.

During WGNSSK 2018 a mistake was found in the inter-benchmark 2017 results. The mistake related to how one of the surveys was being treated, i.e. as an index of SSB instead of exploitable biomass. The mistake led to questions on the persistence of the retrospective pattern on F and assessment category used to provide advice. Therefore, an inter-benchmark was organised in 2018. This inter-benchmark corrected the mistake in the 2017 inter-benchmark settings, checked the plus-group settings of the catch as well as surveys and re-evaluated the parameter bindings in the assessment configuration (ICES, 2018).

Under the new assessment resulting from the 2018 inter-benchmark, the retrospective has improved substantially and F was deemed to be estimated reliably. Therefore, the inter-benchmark decided to upgrade turbot in 27.4 to a Category 1 stock. In this context, the inter-benchmark also estimated reference points for a Category 1 stock and provided a short-term forecast. Since WGNSSK 2019, the assessment is conducted and advice for turbot in 27.4 is provided based on the assessment configuration, reference points and short-term forecast derived during the 2018 inter-benchmark.

21.1 General

21.1.1 Biology and ecosystem aspects

Turbot is broadly distributed from Iceland in the North, along the European coastline, to the Mediterranean and Adriatic Sea in the south. In general, turbot is a rather sedentary species, but there are some indications of migratory patterns. For example, in the North Sea, migrations from the nursery grounds in the south-eastern part to more northerly areas have been recorded. IBPNEW (ICES, 2012a) concluded that turbot in the North Sea (Subarea 4) can be considered as a distinct stock for management purposes. However, recent genetic studies and species distribution mapping show that the Skagerrak part of the stock could potentially be merged with the North Sea stock and the Kattegat with the Baltic Sea stock (ICES, 2020).

Turbot is typically found at a depth range of 10 to 70 m, on sandy, rocky or mixed bottoms and is one of the few marine fish species that inhabits brackish waters. It is a typical visual feeder and could be regarded as a top predator. Turbot feeds mainly on bottom living fishes (e.g. common gadoids, sandeels, gobies, sole, dab, dragonets, sea breams, etc.) and small pelagic fish (e.g. herring, sprat, boarfish, sardine) but also, to a lesser extent, on larger crustaceans and bivalves.

21.1.2 Fisheries

In the 1950s, the UK was the biggest contributor to the landings (~50% of the landings). In recent years, most of the landings stem from the Netherlands (~60%). In most countries, turbot is caught in trawls of mixed fisheries, with most of the landings in the Netherlands coming from the 80 mm beam trawl fleet (BT2) fishing for sole and plaice (~74% of Dutch landings). In Denmark, the second largest contributor to the landings in recent times, there is a directed fishery for turbot using gillnets (~7 % of the total landings in 2021).

See the Stock Annex for more details.

21.1.3 Management

A combined EU TAC for turbot and brill is set for EU waters in areas 2.a and 4. This TAC only applies to the EU fisheries. This management area (particularly the inclusion of Area 2.a) does not correspond to either of the stock areas defined by ICES for turbot and brill.

No specific management objectives or plans are known to ICES.

As a primarily bycatch species, regulations relating to effort restrictions for the primary métiers catching turbot (e.g. beam trawlers) are likely to impact on the stock. Fishing effort has been restricted in the past for demersal fleets in a number of EC regulations (e.g. EC Council Regulation Nos. 2056/2001, 51/2006, 41/2007, and 40/2008).

The Dutch Producer Organisations (POs) have introduced a minimum landings size of 27 cm in 2013. In 2016 catches of turbot increased substantially and the minimum landing size was increased to 30 cm at first, followed by a further increase to 32 cm in May 2016. In the summer of 2016, the POs decided to prohibit landing the smallest market category and in October and November the weekly landings were capped to respectively 375 kg and 600 kg wk^{-1}. These measures were taken to keep the landings in line with the available national quota. In 2018, the TAC for turbot and brill was substantially increased; however, Dutch PO measures were still in place with a minimum landing size of 30 cm and limiting the landings to 2000 kg wk^{-1}. Since 2019, the PO measures were relaxed due to the sufficiently available quota.

Measures taken by the Dutch Producer Organisations from 2016 up to present.

Dutch PO-measures			
Year	**Date**	**Max kg per week/trip**	**MLS**
2016	January - March	-	27 cm
2016	April – May	-	30 cm
2016	May – September	-	32 cm
2016	October – November	375 kg	32 cm
2016	November – December	600 kg	32 cm
2017	January – February	-	32 cm
2017	March – October	800 kg	32 cm
2017	November - December	2000 kg	30 cm
2018	January – August	2000 kg	30 cm
2018	September - October	2500 kg	30 cm
2018	October - December	3000 kg	27 cm
2019	January – December	3000 kg	27 cm
2020	January - December	3000 kg	27 cm
2021	January – December	3000 kg	27 cm

21.1.4 Data used

Following the inter-benchmark conducted in the summer of 2018 (ICES, 2018), the assessment of North Sea turbot requires three main types of data:

Catch data: estimates of removals of turbot by the fishery.

Survey data and commercial LPUE (landings per unit effort): indices of trends in population abundance over time from fisheries independent and fisheries dependent sources, respectively.

Biological data: estimates and/or assumptions on growth, maturation and natural mortality.

Since the assessment is age-based, data for the above is required for each age. See the Stock Annex for more details on the data used in the assessment, sources and historical values.

21.1.5 Catch data

Figure 21.2.1 shows the trend in total landings (InterCatch) and discards (InterCatch) over time. ICES estimated landings of turbot decreased during the 1990s and 2000s. Since 2012 landings have been fluctuating around 3000 tonnes. In this period, effort by the Dutch beam trawl fleet, which contributes most to the landings (ca. 45%), has decreased notably. Since turbot is primarily a bycatch species, this indicates that abundance of turbot has likely increased over this period. In 2016 and 2017, landings have been slightly higher, exceeding 3400 tonnes. Since 2018, official landings in Subarea 4 decreased slightly. In 2020, 3187 tonnes has been officially reported in Division 2.a and Subarea 4. In 2021, landings further decreased by 14%. In the last five years, the combined TAC for turbot and brill has not been fully utilized. In 2021, only 64% of the combined TAC (5848 tonnes) was taken of which turbot had the largest share (48%).

Landings in numbers at age are presented in Table 21.2.1 and Figure 21.2.2. Following a decrease in minimum market size for turbot in the Netherlands in 2002, there has been a notable increase in the amount of age 1 and 2 turbot landed, accounting for half of the landings in some years. This proportion has been decreasing in recent years due to some poor year classes in 2012, 2013 and 2016. Since turbot are only fully mature at age 4, a high proportion of immature fish are in the landings. Since 2015, however, a larger proportion of age 5+ fish in the landings is observed; these are now of the same order of magnitude as the estimates in the 1980s. This could reflect the recent reduction in F leading to an increasing proportion of older fish in the landings. However, since the landing data up to 2016 are raised using only the Dutch 80 mm TBB fleet, signals in landings at age data may not be accurate reflections of true removals from the population over time. In 2021, there are no landings of age 1 which may indicate a weak incoming year class. In 2021, there is an increase of ages 3 to 5 in the landings coming from relatively good year classes since 2018.

The weights at age in the landings of turbot in Subarea 27.4 (Table 21.2.2a) come from the "weca" file of the InterCatch landings export. These are measured weights from the various national catch and market sampling programmes. Mean stock weights at age (Table 21.2.3a) are the average weights from the 2nd quarter landings and are derived from the "Catch and Sample Data Table" file from InterCatch. As discards are not included in this assessment, discard weight-at-age are not imported. Given the lack of weight data in the period 1991–2003, modelling[1] was required to infer the trend in stock and landings weight-at-age data (Table 21.2.2b and 21.2.3b).

[1] see Stock Annex for turbot 27.4 for full details

21.1.6 Discards

The assessment of this stock does not include discards as there is very limited age sampling of the discards. In 2018, 4% of the imported discard data were sampled, coming from discards of some Danish (< 8 fish per métier) and Belgian beam trawl fleet (138 fish). These data were considered insufficient to be used in the age allocation of international discards. Since 2019 no age structure information was submitted for the discard estimates as sample sizes were too low for raising and to be submitted to InterCatch.

There was a sudden increase in the landing of age two turbot following the decrease in minimum market size in the Netherlands in 2002. Given that there was no known change in the fishing behaviour of the main fleets at this time, this could indicate that, previously, more age 1 fish must have been caught than were actually landed. These were either discarded or, as a much-sought-after fish, kept by the fishermen for personal use. This would mean that the discards could be underestimated in the period up to 2002 relative to the period following this. Alternatively, subsequent to the change in MLS, more targeting of small turbot may have occurred. Without a useable time-series of discards before and after this change it is difficult to determine which of these explanations holds.

The discard rate (discards: 129 293 / (discards + landings: 2 788 375) was 4.6% in 2021. Since 2019 the discard ratio has been lower (~6%) compared to the period 2016–2018 with an average of 14%. The discard rate in recent three years is more in line with the discard rate observed in the period 2013–2015, when discard ratios were approximately 5%.

In 2021, BMS landings were reported by the UK (England); however, the submitted values were low (666 kg) and were therefore not raised in InterCatch.

21.1.7 Logbook registered discards

In 2021, no logbook registered discards were reported to InterCatch. They are not raised.

21.1.8 InterCatch

InterCatch was used for the first time for the North Sea turbot stock at WGNSSK 2014, and has been used since.

In 2021, most countries provided estimates of discards to InterCatch. Where possible, discards were raised within métier by quarter. In the towed gear group, a distinction was made between otter trawlers, seines, and beam trawlers. Beam trawlers and otter trawlers targeting crustaceans (CRU) with a mesh size smaller than 99 mm were grouped together. The remainder, which consisted of métiers which did not fit in any of the above groups, were then raised with all available discard estimates.

Unsampled fleet*	Sampled fleet**
TBB < 100mm	Within metier, by quarter
TBB > 100 mm	Within metier, all quarter
OTB/TBB < 70 mm (DEF and CRU)	Within metier, all quarter
OTB < 100 mm	Within metier, all quarter
OTB > 100 mm	Within metier, by quarter
SSC/SDN > 100 mm	Within metier, all quarter
SSC/SDN < 100 mm	TBB/OTB < 100 mm
Passive gears (GNS/GTR)	All métiers, all quarter
Others	All métiers, all quarter

*** Unsampled fleet are those fleets for which no discards are submitted.**

**** Sampled fleet are those fleets for which discards ratios are known.**

Out of the 129 tonnes of estimated discards, 87 tonnes (67%) was reported data and 42 tonnes are raised in InterCatch. The proportion of landings with discards associated (same strata) is 61%.

For the landings, Dutch (for data from 2004–present), Danish (2014–present) and Belgian (2017–present) samples, accounting for auctions, quarters and market categories, are provided. The number of age samples has gradually increased since 2018 (2359), having 6086 samples in 2021. This increase is mainly due to an increase in sampling of landings in different Danish métiers. In total, Denmark supplied 5447 samples collected in various metiers, while the Dutch (541) and Belgian (98) samples only consist of the TBB_DEF_70-99 fleet. All data are used for estimating the age structure of the landings. Prior to 2004, the landings-at-age information is from an old Dutch monitoring scheme from the 1980s. Figure 21.2.3 shows the métiers with numbers at age samples for the landings in 2021. Approximately 59% of the landings in weight are sampled in Subarea 4. Allocations to calculate the age structure were done separately for discards and landings and were done within métier per quarter where possible. If by quarter was not possible, available quarters were grouped. As no age structure information for discards was available in 2021, the allocation for discards were done separately, making use of available age samples of the landings.

Unsampled fleet*	Sampled fleet**
TBB < 100mm	Within metier, by quarter
TBB > 100 mm	Within metier, by quarter
OTB/TBB < 70 mm (DEF and CRU)	Within metier, by quarter
OTB < 100 mm	Within metier, by quarter
OTB > 100 mm	Within metier, by quarter
SSC/SDN < 100 mm	TBB/OTB < 100 mm, by quarter
SSC/SDN > 100 mm	Within metier, by quarter
Passive gears (GNS/GTR)	Within metier, by quarter
Others	All métiers, all quarter

*** Unsampled fleet are those fleets for which no age structure is known.**

**** Sampled fleet are those fleets for which age structure is known.**

21.1.9 Survey data and commercial LPUE

Two survey abundance indices, the Sole Net Survey (SNS (B3498)) and the Beam Trawl Survey (BTS ISIS (B2453)), and one standardised commercial LPUE unstructured abundance index based on the Dutch 80 mm beam trawl fleet (BT2), are used to tune the assessment (Table 21.3.1–3 and Figure 21.2.4).

All abundance indices indicate an increase in the amount of older fish since 2015, which would indicate either strong recruitment or a decrease in mortality (e.g. fishing pressure) exerted on the stock. Between 2005 and 2015 no strong year classes have been observed. Since 2015, with the exception of 2016, relatively strong year classes are seen, resulting in an increase of fish of age 2 to 6 to appear in the survey catches. In 2021, the recruitment (age 1) is the lowest observed since the late 1980s and is well below the long-term mean. The Dutch BT2 LPUE index shows a continuous gradual increase since 2000. While the LPUE is higher compared to the LPUE's observed before 2012, the 2021 LPUE value decreased with 13% compared to 2020.

There is fairly close agreement between the two survey indices regarding general trends in abundance at age, but the data are noisy from year to year. This can be seen in the low R^2 values in the internal consistency correlations in the BTS_ISIS and SNS surveys (Figure 21.2.5). The SNS survey is particularly poor at picking up cohort signals, with low R^2 values for cohort from one age to the next. Though all correlations between successive ages are positive, estimated numbers at age, particularly for the younger ages, fluctuate a lot from year to year. The BTS-ISIS is more internally consistent for ages 3 and up, but is still lacking sufficient older fish leading to a poor tracking of the cohorts over time.

Noisy indices that are more indicative of general trends are best used in an assessment model that is able to smooth over the noise in the data. The SAM model used for this stock is able do this, but nevertheless, inputting noisy data into the assessment will increase uncertainty in the outputs.

By removing the age-structure from the NL BT2 LPUE index, the clearest cohort signals in the assessment of this stock are coming from the catch at age matrix. The Dutch BT2 LPUE time-series is now standardised by building a statistical model that includes interactions in space, time and gear. Raw LPUEs are calculated per trip and per ICES rectangle. The fishing effort per rectangle is then taken as a weighting factor in the analysis. Only those rectangles where fishing occurred in eleven or more years are then used. This dataset amounted to 99% of all turbot catches since 1995. There is a possibility of excluding ages 1–2 from the Dutch LPUE data. However, currently, this would mean shortening the time-series of the LPUE-index considerably, because disaggregated data to distinguish market categories/ages are not available before 2002. Work on providing such data further back in time could be beneficial for the assessment.

21.1.10 Biological data

All biological data used in the assessment are presented in Tables 21.2.3–5.

Weight at age

Constant annual catch and stock weights at age (long term means of all available data) were previously used in the assessment because of large gaps in the time series of weight at age data for turbot in the North Sea (Figure 21.2.6). What data is available is also very noisy, due to low sample sizes for most ages. The data that are available, and trends in other flatfish species in the same areas, suggest that there have been potentially significant changes in weight at age over time. At the 2015 Interbenchmark, a method was developed to model the growth parameters over time, allowing smooth changes over the time series (see Stock Annex for full details) (ICES, 2016). The results indicate an increase in weight at age from the start of the time series, peaking in the early 1990s. Since then, weights at age have decreased again and are slightly lower than the weights observed in the 1970s.

Maturity

See Stock Annex for full details.

Natural mortality

A constant value of M = 0.2 for all ages and years is applied for this stock. See Stock Annex for full details.

21.2 Stock assessment model

After the inter-benchmark protocol of 2017 and 2018, a new assessment model (SAM, FLSAM) is used. More details on the data used, assumptions made and the assessment model settings can be found in the Stock Annex, in the inter-benchmark protocol report (ICES, 2018a and b) as well as on the github website (https://github.com/ices-eg/wg_IBPTur.27.4).

21.2.1 Model settings

The assessment model was conducted using the settings and configuration given below. Details of the assessment model can be found in the Stock Annex and 2018 Inter-benchmark report (ICES, 2018).

Model settings used in the final assessment

Year	2021
FLSAM version	2.1.1
FLCore version	2.6.15
R version	4.0.2 (2020-06-02)
Platform	x86_64-w64-mingw32
Run date	2021-04-21
Model	SAM
First tuning year	1981
Last data year	2021
Ages	1–8+
Plus group	Yes
Stock weights at age	Von Bertalanffy growth curve with time varying Linf
Catch weights at age	Von Bertalanffy growth curve with time varying Linf
Total Landings	Not used
Landings at age	1981–1990, 1998, 2000–present
Discards	Not used (assumed 0)
Abundance indices	BTS-ISIS 1991–present SNS 2004–present
	Standardized NL-BT2 LPUE age-aggregated catchable biomass 1995– present
Catchability in catch at age matrix independent of age for ages >=	7
Coupling of fishing mortality STATES (Row represent Catch, columns represent ages)	0 1 2 3 4 5 6 6
Use correlated random walks for the fishing mortalities (0 = independent, 1= correlation estimated)	2
Coupling of catchability PARAMETERS (Surveys)) Row represent fleets (SNS and BTS-only, LPUE age-aggregated), Columns represent ages)	0 0 1 2 2 2 -1 -1 3 3 4 4 5 5 5 -1 6 -1 -1 -1 -1 -1 -1 -1
Coupling of fishing mortality RW VARIANCES	0 1 2 2 3 3 4 4
Coupling of log N RW VARIANCES	0 1 1 1 1 1 1 1
Coupling of OBSERVATION VARIANCES (Row represent fleets (Catch, SNS, BTS, LPUE age-aggregated), Columns represent ages)	0 1 2 2 3 3 4 4 5 5 6 7 7 7 -1 -1 8 8 8 9 10 10 10 -1 11 -1 -1 -1 -1 -1 -1 -1
Coupling of Survey Correlation correction by age (Row represent fleets (Catch, SNS, BTS, LPUE age-aggregated), Columns represent ages)	-1 -1 -1 -1 -1 -1 -1 -1 0 0 0 0 0 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
LPUE time-series indicator (0=SSB, 1 = catch, 2 = exploitable biomass)	2
Stock-recruitment model code (0=RW, 1=Ricker, 2=BH)	0
Fbar ranges	2–6

21.3 Assessment model results

The stock summary is given in Table 21.4.1a-c, while fishing mortality at age and abundance at age estimated by the assessment model are presented in Tables 21.4.2 and 21.4.3, respectively.

21.3.1 Status of the stock

Fishing mortality has been below 0.361 (F_{MSY}) since 2012. In 2018 and 2019, fishing mortality was estimated at 0.354 and 0.359, respectively, being close to F_{MSY}. In 2020 and 2021, fishing mortality slightly decreased, and was estimated at 0.350 and 0.349, respectively. The SSB in 2021 was estimated to be 8756 tonnes, a minor increase (2%) from 2020 which was estimated at 8577 tonnes (Table 21.4.1b). SSB has been above MSY $B_{trigger}$ (6353 tonnes) since 2013. During WGNSSK 2022 the 2019 recruitment estimate was further revised downward from 8095 (in 2020 WGNSSK) to 7094 (in 2021 WGNSSK) to 6605. Despite the revision, this recruitment is still one of the highest in the time-series (9598 in 2015). Also, the assessment showed a downward revision of the estimated recruitment (age 1) for 2020 from 6374 thousand to 4014 thousand. The estimated recruitment in 2021 (2197 thousand) is the lowest observed in the entire time-series and is well below the geometric mean of the time-series (4447 thousand) (Table 21.4.1c). However, this estimate is based on limited amount of data and is unlikely to be a reliable estimate.

21.3.2 Historic stock trends

SSB was at its highest in the early 1980s (possibly higher before that time for which no reliable data is available). From the mid–1980s up until the early 2000s, SSB declined gradually and F increased gradually (Figure 21.4.1). The lowest estimated SSB was in 2004; SSB subsequently increased and has continued to increase to >9000 t in 2017. In the past 3 years the SSB has been relatively stable around 8650 t. Recruitment has been variable over the time-series without a clear trend. The large recruitment in 2014 and 2015 have been well above the long term mean and contributed to the increase in SSB in 2017 and 2018.

Mean F peaked in 1994 at 0.83, but then declined to 0.62 in 1999, before rapidly increasing again to 0.76 in 2002. After 2002, there is a steep decline in F to 0.41 in 2010. Between 2012 and 2017, F has fluctuated around 0.34. In the last two years F has been stable at 0.349. These trends correspond well with the trends in fishing effort of the beam trawl fleet.

There are no clear patterns in recruitment, though values are estimated at a slightly higher level, but with more uncertainty, during the years of missing landings at age data (1990s). Since 2020, recruitment has been below the long-term geometric mean of the time series, and is been estimated to be the all-time low in 2021.

21.3.3 Retrospective assessments

The results of five retrospective assessments, using the same model settings but removing one year of data from the end of the time series, are plotted in Figures 21.4.2–4. The retrospective plots in SSB, F and recruitment do not exhibit a strong negative or positive pattern. The Mohn's rho associated with this retrospective is -6.2% on SSB and 5.2% on F, which are considered to be low, and -28.3% on recruitment.

21.4 Model diagnostics

Model diagnostics are provided in Tables 21.5.1–6 and Figures 21.5.1–7.

The stability and estimatability of a stock assessment model depends on the degree of collinearity between the parameters. When parameters are co-linear or correlated, the model can be sensitive to minor changes. A parameter correlation plot helps to identify the correlation between parameters. The correlation coefficient (varying between -1 and 1) is shown as a colour intensity as a function of the corresponding parameters. Ideally, the correlation between the parameters (except for a parameter with itself) should be 0, indicating the parameters are independent of each other. The parameter correlation plot for turbot shows some positive correlation between the catchability parameters (F_{par}), but no strong correlation between the other parameters (Figure 21.5.1).

To see how the SAM model has converged on the observation variances, the estimated observation variance (CV) of each data source in the assessment is plotted against the coefficient of variance of the estimate (Figure 21.5.2). Ideally all parameters should have a low CV. For turbot, the observation variance of the Dutch LPUE index as well as the landing at age 3 and 4 is lowest, while the associated CVs are highest. As such, the model assumes most information is available in these parameters giving them more weight in the assessment (Figure 21.5.3).

Please refer to the Turbot Inter-benchmark 2017 and 2018 reports for more detailed specifications on the model diagnostics, in particular, for the configuration on the survey catchabilities for all surveys with more than 1 age group (ICES, 2018a, b; see also Figure 21.5.4).

The estimated selectivity at age from 1981 to 2021 is shown in Figure 21.5.5. The selectivity at-age do show some trend in the past decade, whereby after 2013 the selectivity has shifted slightly towards older ages (i.e. age 4). The values presented in Figure 21.4.5 are the actual F-at-age.

Residual plots of landings, the SNS and Dutch LPUE index do not show clear systematic patterns in either positive or negative residuals. The BTS-ISIS survey, however, shows some consistent negative residuals for the ages 2,4 and 6 (Figure 21.5.6 and 21.5.7).

21.5 Reference Points

Reference points were estimated during the 2018 inter-benchmark using the R-script template provided by ICES, which was developed during early 2018 to ensure that a correct procedure in estimating reference points was followed.

The simulations were executed during IBPTurbot (ICES, 2018b) with the entire time-series of SR-pairs (1981–2017) and were run with 2000 iterations and applying a mixture of two SR-models, namely Segmented Regression and Ricker (sampling from 2000 fits) (Figure 21.6.1). Productivity and stock-recruit pairs over time are shown in Figures 21.6.2–3.

In 2020, ACOM decided that the basis of F_{pa} should be $F_{P.05}$ (with Advice rule). $F_{p.05}$ is the value of F, including modification with biomass criteria that, if applied as target in the advice rule would lead to SSB ≥ B_{lim} with a 95% probability. $F_{P.05}$ provides an upper F limit that is considered precautionary for management plans and MSY rules. However, for turbot the $F_{P.05}$ value (0.856) is well above the value of F_{lim} (0.606).

The table below shows the estimated reference points using the final IBP 2018 assessment. [See the IBPTurbot report (ICES, 2018b) for more details.]

Reference point	Estimate
1. MSY $B_{trigger}$	6353
2. B_{pa}	4163
3. B_{lim}	2974
4. F_{lim}	0.606
5. F_{pa} = $F_{P.05}$ with AR	0.856
6. $F_{P.05}$ without AR	0.473
7. F_{MSY}	0.361
8. $F_{MSY\ lower}$	0.252
9. $F_{MSY\ upper}$	0.482

21.6 Short-term-forecast

The short-term forecast was implemented in FLR (Kell *et al.*, 2007) using the routines available in the FLasher package (https://flr-project.org/FLasher). Terminal year estimates from the SAM assessment were used as starting conditions. Since there is no clear relationship between SSB and Rec, it was decided to set recruitment to follow a geometric mean for the entire time-series, including the latest estimate.

Since stock and catch weight-at-age are modelled, we assume in the forecast that weights are identical to the weights used in the final assessment year. As such, we do not introduce a break in the smoothness of the weight-at-age time-series. Maturity at age and time of spawning are fixed over time, and these values are used in the forecast. Selectivity-at-age is with minimal trends in recent years, but has changed in the past decade. Hence, a 3-year average was used for future years in the simulations.

In the past 4 years, the TAC has not been exhausted, i.e. on average 64% of the combined TAC was used, therefore, using a % TAC was deemed inappropriate. Hence, the assumption for the intermediate year was made to not use a catch constraint but a status-quo F (F_{sq}) instead. This was also supported by the recent years in which F has been relatively stable at around 0.35.

Assumptions made for the interim year and in the forecast. All weights are in tonnes, recruitment in thousands:

Variable	Value	Notes
$F_{ages\ 2–6}$ (2022)	0.349	F_{sq} = Average exploitation pattern (2019–2021), scaled to $F_{ages\ 2–6}$ 2021
SSB (2023)	7726	Short-term forecast (STF) at *status quo* (F_{sq})
R_{age1} (2022, 2023)	4447	Geometric mean (GM, 1981–2021)
Projected landings (2022)	2440	STF assuming an F *status quo* (F_{sq})

The options table summarizes the outcomes of the short-term forecast. The numbers presented are the rounded values; actual calculations are performed with the exact numbers.

Basis	Total catch * (2023)	Projected landings ** (2023)	Projected discards *** (2023)	F (2-6) (2023)	SSB (2024)	% SSB change ^	% advice change ^^
MSY approach: F_{MSY}	2432	2289	143	0.361	7103	-8.1	-33
F_{MSY} upper = 0.48	3095	2913	182	0.482	6480	-16.1	-14.2
F_{MSY} lower = 0.25	1774	1670	105	0.252	7725	0	-51
F = 0	0	0	0	0	9422	22	-100
F_{pa} ($F_{p.05}$ with AR)	4778	4497	281	0.856	4926	-36	32
$F_{p.05}$ without AR	3048	2869	180	0.473	6524	-15.6	-15.5
F_{lim}	3710	3492	219	0.606	5908	-24	2.8
F_{sq}	2364	2225	139	0.349	7167	-7.2	-34
SSB (2023) = B_{lim}	6977	6566	411	1.6	2974	-62	93
SSB (2023) = B_{pa}	5624	5292	331	1.1	4163	-46	56
SSB (2023) = MSY $B_{trigger}$	3232	3041	190	0.51	6353	-17.8	-10.5
Rollover advise	3609	3396	213	0.58	6002	-22	0
Multi-options table							
F = 0	0	0	0	0.00	9422	22	-100
F= 0.05	383	361	23	0.05	9054	17.2	-89
F = 0.10	750	706	44	0.10	8701	12.6	-79
F = 0.15	1102	1037	65	0.15	8365	8.3	-69
F = 0.20	1439	1354	85	0.20	8044	4.1	-60
F = 0.25	1762	1658	104	0.25	7737	0.137	-51
F = 0.30	2071	1949	122	0.30	7443	-3.7	-43
F = 0.35	2368	2229	140	0.35	7163	-7.3	-34
F = 0.40	2653	2497	156	0.40	6895	-10.8	-26
F = 0.45	2926	2754	172	0.45	6638	-14.1	-18.9
F = 0.50	3189	3001	188	0.50	6393	-17.3	-11.6

*** (projected landings) / (1 – average discard rate); average discard rate 2019–2021 = 5.9%**

**** Marketable landings**

***** Including BMS landings (EU stocks), assuming recent discard rate (5.9%).**

^ SSB 2024 relative to SSB 2023.

^^ Total catch in 2023 relative to advice value for 2022 (3609 t).

21.7 Management considerations

There are a number of EC regulations that affect the flatfish fisheries in the North Sea, e.g. as a basis for setting the TAC, limiting effort, and minimum mesh size. Since 2019 turbot falls under the landing obligation. The joint recommendation suggests a survivability exemption until 2023 for turbot caught by TBB gears with a cod end more than 80 mm in ICES Subarea 4 (Commission Delegated Regulation (EU) 2019/2238).

21.7.1 Effort regulations

The overall fleet capacity and deployed effort of the North Sea beam trawl fleet has been substantially reduced since 1995, due to a number of reasons, including the effort limitations for the recovery of the cod stock. In 2008, 25 vessels were decommissioned.

21.7.2 Technical measures

Turbot is mainly taken by beam trawlers in a mixed fishery directed at sole and plaice in the southern and central part of the North Sea. Technical measures (EC Council Regulation 1543/2000) applicable to the mixed flatfish fishery affect the catching of turbot. The minimum mesh size of 80 mm in the beam trawl fishery selects sole at the minimum landing size (24 cm); however, this mesh size is likely to catch immature turbot (age 1 and 2 fish). Mesh enlargement would reduce the catch of smaller turbot, while at the same time potentially increasing the yield per recruit, but would also result in loss of marketable sole catches.

A closed area has been in operation since 1989 (the plaice box), and since 1995 this area has been closed in all quarters. The closed area applies to vessels using towed gears, but vessels smaller than 300 HP are exempted from the regulation. An additional technical measure concerning the fishing gear is the restriction of the aggregated beam length of beam trawlers to no more than 24 m. In the 12 nautical mile zone and in the plaice box, the maximum aggregated beam-length is 9 m.

21.7.3 Combined TAC

At present the EU provides a combined TAC for turbot and brill in the North Sea. This TAC seems largely ineffective at reducing F: increases in the stock at similar TACs lead to increased discarding. In addition, it is unclear how the quantitative single species advice for turbot and the qualitative single species advice for brill can/will be used to formulate a combined TAC for these two stocks. In this situation, improving the brill assessment may be necessary in order to ensure efficient management of both of these stocks. Ideally, a combined TAC should not be used.

21.8 Industry Survey turbot and brill

The available scientific surveys used for the assessment of turbot in 27.4 generally have a weak internal consistency, especially for older ages, leading to a poor ability to track cohorts over time. Because of this, the assessment is strongly influenced by the Dutch LPUE index. A scientific survey with higher catch rates for turbot and a better internal consistency would be preferable. In this context, the Dutch producer organization VisNed and Wageningen Marine Research initiated an industry-based survey to monitor large flatfish such as brill and turbot in the North Sea. The survey started in 2018, and the set up and first results were presented during the 2019 WGNSSK. The group considered the survey valuable, but provided recommendations to make the survey more adequate for future use in the assessment; therefore, the first year of the survey (2018) is seen as a pilot year. An annual update of the survey was provided since WGNSSK 2020.

In 2021, the survey took place in quarter 3 and 3 traditional beam trawl vessels were selected. The survey area is based on LPUE data over a 6-year period (2007–2009 (before pulse) and 2012–2014 (first years with pulse fisheries)). By defining the positions were 60% of the LPUE is realized, the survey area covers the main high LPUE areas but also some areas around these. Inaccessible areas such as wind parks, Natura 2000 closures, etc were removed from the survey area following discussions with the participating fishermen. A 5x5 km grid was overlaid onto the survey area.

Each grid cell in the survey area is a potential survey station. Each year 60 grid cells are to be randomly selected using an R-script. Because the cutting out of unfishable areas resulted in some cells having irregular shapes and smaller surface areas than regular 5x5 km grid cells, the probability of being randomly selected as survey station was made proportional to their surface areas. The selected survey stations are then equally distributed over the three participating vessels (~20 survey stations each) on the basis of their normal fishing grounds. Survey hauls are carried out similar to commercial hauls, taking approximately 100 to 120 minutes. Hauls may start anywhere in a designated grid cell, may then follow any route, and may exit the grid cell during the haul. Data collected include fishing conditions (e.g. haul list, gear description), and for each haul: counts of all turbot and brill; length, weight, and sex of all turbot and brill; a specified number of otoliths per length class (Schram *et al.,* 2021).

In 2020, due to COVID-19 restrictions, it was not possible for researchers to board the participating vessels. An alternative method was used, whereby, the survey fish were sorted from the catches and then labelled per station and stored by the vessel's crews. At the end of the survey week all collected survey fish was handed over to a team of researchers for processing in the fish auction. This method proved to be practically feasible and there were no indications of (noticeable) irregularities in sample collection. In 2021, the survey was carried out as usual, i.e. with onboard observers.

The procedure for the random selection of survey stations and their assignment to the vessels remained unchanged from 2019 except for the number of selected stations. Instead of selecting the required 60 stations, a total of 75 stations were selected (Figure 21.8.1). Sixty stations were manually assigned to the vessels (20 each) and the remaining 15 stations were kept as 'spares', undisclosed to the skippers in case some of the stations were deemed unsuitable.

In total, 54 hauls were sampled in the 2021 survey, catching 339 brill and 1354 turbot. Numbers are lower compared to 2019 and 2020. The numbers of turbot caught during this survey were much higher than caught during the BTS-ISIS survey (98). Length measurements ranged from 17 cm to 68 cm for turbot and 21 cm to 54 cm for brill over the three years of the survey (2019-2021) (Figure 21.8.2). Ageing was done over 1 cm-classes for 135 brill and 177 turbot, showing that most of the fish caught are within ages 1 to 3 (Figure 21.8.3.). Further analysis of the survey data is needed to update the new information and align these with existing commercial sampling and independent fisheries survey data.

The aim of the survey is to become an additional index, strengthening the fisheries independent surveys for turbot. Once a period of 5 years is covered, the index of this new survey is a potential candidate to include in the turbot as well as brill assessments. In this context, it is import to develop the age-structured index in advance and make a trial assessment including the "new" index into the assessment.

21.9 Issues for future benchmarks

21.9.1 Data

The available scientific surveys (SNS and BTS-ISIS Q3) have weak internal consistency, especially for older ages, leading to a poor ability to track cohorts over time. Because of this, the assessment is strongly influenced by the Dutch LPUE index. A scientific survey with higher catch rates for turbot and a better internal consistency would be preferable (See Section 21.9).

The assessment is strongly influenced by the Dutch LPUE index. More work should be done on getting LPUE data from other Member States. In future, the use of these data may be possible after standardization or weighting of the original values to account for the difference in gear and location. Obtaining standardised Belgian, UK and Danish LPUE data for use in the assessment model should be investigated.

Estimates of discards are available (e.g. Dutch discards are available for 1999-present); however, age-length information is very limited. Age-information is based on a few fish sampled in the discards of some of the Danish and Belgian fleets (at-sea sampling). As a result, estimates of discards are highly uncertain, and not included in the current assessment. Future sampling effort needs to ensure a proper sampling coverage over the main fleets and countries for both landings and discards. Sampling should include age information for discards from all countries.

Currently, estimates of mean weights-at-age from the fishery and for the stock (from surveys) cannot be used directly in assessments without first smoothing these estimates, because of data gaps and poor sample sizes (the latter leading to highly variable and inconsistent estimates, particularly at the older ages). The smoothing techniques currently used add to any retrospective patterns present, because they re-estimate the entire time-series of smoothed weights whenever new data are added. It is therefore recommended that methods that produce more stable estimates of mean weights be investigated and their performance be compared to current methods, or sampling be improved to allow raw weights to be used directly in assessments, or to appropriately deal with smoothing of raw weights within the stock assessment model.

A delta GAM index combining different BTS surveys was tested. Currently, such an index could not improve the assessment. However, age information in DATRAS was not available for the whole time-series, and errors seem to have occurred during the upload of additional data. Once the whole time-series of age information is available, a detailed analysis of delta GAM indices with various settings should be carried out.

The procedure to create an age-structured index series from the BTS-ISIS needs to be checked. Currently, the procedure first links the individual fish from which otoliths are taken to the length sample. This allows direct ageing of the fish in the index. Those fish for which no direct age sample is available are then assigned to ages using the age–length key based on all fish in the period 1991–present. This method may be flawed as combining an ALK over many years, so that the same ALK is used each year may smear any cohort signals in the data.

21.9.2 Assessment

The Dutch LPUE data series receives a high weight in the assessment (higher than any other data source, and much higher than the survey indices of abundance); this weighting is, arguably, unrealistically high. The Dutch LPUE data are standardised by applying a statistical model that includes interactions in space, time and gear, and it may be possible to extract CVs associated with the estimates from this model. It is recommended that the use of such CVs in the SAM assessment be investigated to better deal with the weighting of the LPUE data series.

The Dutch LPUE data series (an aggregated biomass index) is associated with 60–70% of the total catch for turbot, but the current SAM assessment uses the selectivity estimated for the total catch to build an exploitable biomass estimate used to fit the Dutch LPUE data. This is not entirely representative and likely introduces some model misspecification. There is a fleet-based version of SAM that, given fleet-based data, could be used to deal with this problem. It is therefore recommended that the use of such fleet-based data and a fleet-based SAM version be investigated to provide a more appropriate fit to the Dutch LPUE data.

21.9.3 Short term forecast

The forecast is performed using future landings. Catch advice is derived by dividing the estimated landings with one minus the average discard rate.

21.10 References

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Table 21.2.1. Turbot in Area 4. Observed landings in numbers (units: thousands) SOP corrected.

Year	Age							
	1	2	3	4	5	6	7	8+
1981	0	281.417	710.601	500.715	431.067	164.709	63.06	100.708
1982	0	149.008	922.262	235.415	147.244	257.457	86.407	136.664
1983	0	356.201	596.327	424.429	97.468	100.126	159.493	179.873
1984	0	1183.479	1116.817	283.998	143.369	54.791	52.051	178.07
1985	0	616.117	1871.601	506.843	138.723	84.474	20.150	123.998
1986	0	319.968	1267.797	601.126	157.828	57.784	25.011	106.943
1987	12.614	628.753	529.783	655.921	153.307	50.455	18.436	67.921
1988	32.296	972.455	804.697	159.683	157.889	80.739	25.119	69.077
1989	0	670.885	1171.225	355.772	156.992	82.449	31.624	68.896
1990	44.795	996.958	1075.09	317.735	166.681	76.048	102.092	114.593
1991–1997				NO DATA				
1998	0	408.485	875.974	360.072	73.376	29.729	8.548	14.380
1999–2002				NO DATA				
2003	210.228	1912.523	461.399	297.626	70.863	32.991	20.708	20.550
2004	434.845	1979.308	792.077	138.215	82.397	9.657	7.531	6.069
2005	343.024	1977.307	719.985	229.782	24.746	21.800	2.592	19.149
2006	885.213	1645.741	807.818	119.166	35.123	7.903	16.181	18.138
2007	78.840	2791.458	618.679	286.152	40.456	29.207	8.289	15.975
2008	178.103	1355.321	824.390	221.060	195.962	47.301	12.935	10.261
2009	120.479	1108.945	1035.771	447.288	94.817	26.693	11.749	19.747
2010	276.908	1395.066	383.556	307.546	170.729	87.586	30.404	19.435
2011	212.310	1954.495	606.601	111.436	138.569	77.521	32.462	23.750
2012	0	1909.907	777.298	266.839	42.473	63.930	73.042	24.729
2013	173.064	1584.8	1084.468	326.283	91.221	26.054	42.121	25.958
2014	65.483	372.385	618.32	649.968	130.741	115.895	36.145	99.907
2015	39.463	1219.451	466.374	327.477	317.411	110.116	43.326	80.005
2016	0	1042.742	996.77	334.442	359.274	187.888	45.263	70.804
2017	6.946	331.84	1670.805	603.248	139.579	63.007	98.668	61.047
2018	183.056	716.549	483.507	927.520	257.585	69.546	46.239	72.987
2019	177.248	1093.111	907.494	270.405	369.323	125.781	23.556	65.771
2020	221.483	1639.610	869.970	408.220	149.262	151.225	43.944	43.062
2021	0	654.085	938.768	483.673	182.677	60.662	61.454	55.361

Table 21.2.1b. ICES estimated landings (tonnes) SOP corrected and discards of turbot in Area 4.

Year	Landings	Landing SOP	Discards	Year	Landings	Landing SOP	Discards
1981	4755	1		2020	3104	1	199
1982	4453	1		2021	2659	1	129
1983	4575	1					
1984	5297	1					
1985	6188	1					
1986	5263	1					
1987	4271	1					
1988	4041	1					
1989	4927	1					
1990	5750	1					
1991	6340	-0.007					
1992	5933	-0.007					
1993	5546	-0.008					
1994	5244	-0.008					
1995	4671	-0.009					
1996	3644	-0.011					
1997	3382	-0.012					
1998	3086	1					
1999	3187	-0.012					
2000	4025	-0.009					
2001	4100	-0.009					
2002	3749	-0.010					
2003	3374	1					
2004	3317	1					
2005	3195	1					
2006	2976	1					
2007	3509	1					
2008	3005	1					
2009	3089	1					
2010	2692	1					
2011	2771	1					
2012	2914	1					
2013	2982	1	97				
2014	2834	1	158				
2015	2922	1	112				
2016	3493	1	666				
2017	3441	1	496				
2018	3140	1	486				
2019	3046	1	230				

Table 21.2.2a. Turbot in Area 4. Raw weights at age in the landings (units: kg).

Year	Age							
	1	2	3	4	5	6	7	8+
1981	0	0.90	1.00	1.70	2.60	3.60	4.40	6.90
1982	0	0.90	1.10	1.80	2.60	3.20	4.50	5.50
1983	0	0.90	1.20	2.00	2.80	3.60	4.00	5.53
1984	0	0.80	1.30	2.20	3.20	3.80	4.50	6.17
1985	0	0.70	1.10	2.00	3.20	4.20	5.00	6.33
1986	0	1.00	1.30	2.10	3.00	3.70	6.30	5.87
1987	0.70	1.10	1.60	2.10	3.80	4.60	6.10	7.83
1988	0.70	1.00	1.60	2.80	3.10	4.60	6.00	6.90
1989	0	1.00	1.50	2.70	3.90	4.70	6.90	8.00
1990	0.90	1.00	1.60	2.70	3.40	5.40	5.60	7.30
1991–1997				NO DATA				
1998	0	0.830	1.26	2.12	3.34	4.92	5.38	6.78
1999–2002				NO DATA				
2003	0.50	0.62	1.15	1.78	2.24	2.74	2.59	3.72
2004	0.43	0.69	1.20	2.12	3.17	3.76	5.15	7.71
2005	0.44	0.62	1.13	1.89	2.89	3.47	4.60	5.87
2006	0.41	0.66	1.31	1.92	3.37	5.09	2.70	3.31
2007	0.34	0.70	1.25	1.75	3.27	3.72	4.17	2.92
2008	0.37	0.68	1.27	1.78	1.79	2.76	4.91	5.69
2009	0.41	0.62	1.25	1.76	2.95	4.83	5.47	5.06
2010	0.35	0.61	1.07	1.62	2.19	2.67	2.65	5.19
2011	0.48	0.55	1.06	1.79	1.97	3.25	4.48	4.64
2012	0	0.60	0.91	1.46	2.58	3.01	3.47	5.28
2013	0.61	0.61	1.00	1.64	2.23	3.41	2.27	5.19
2014	0.41	0.59	1.07	1.42	1.67	1.85	3.03	3.40
2015	0.41	0.59	1.10	1.30	1.67	2.12	2.78	3.23
2016	0	0.66	0.93	1.33	1.22	1.94	2.93	4.01
2017	0.54	0.98	1.18	1.74	2.15	2.37	3.07	3.68
2018	0.34	0.59	0.98	1.36	1.41	1.90	2.86	3.18
2019	0.44	0.58	0.94	1.50	1.77	2.11	3.63	2.46
2020	0.44	0.63	0.96	1.29	1.48	2.01	2.87	3.18
2021	0	0.57	0.97	1.38	1.53	1.59	2.65	2.36

Table 21.2.2b. Turbot in Area 4. Modelled weights at age in the catch (units: kg).

Year	Age							
	1	2	3	4	5	6	7	8+
1981	0.352	0.758	1.308	1.974	2.722	3.519	4.340	5.930
1982	0.365	0.787	1.358	2.049	2.825	3.653	4.504	6.260
1983	0.378	0.814	1.405	2.120	2.922	3.779	4.660	6.346
1984	0.389	0.839	1.449	2.186	3.013	3.897	4.805	6.570
1985	0.400	0.862	1.489	2.246	3.097	4.005	4.938	6.973
1986	0.410	0.883	1.525	2.301	3.172	4.102	5.058	7.480
1987	0.418	0.902	1.557	2.349	3.238	4.187	5.163	7.812
1988	0.426	0.917	1.584	2.390	3.295	4.260	5.253	6.991
1989	0.432	0.930	1.606	2.423	3.341	4.320	5.327	7.413
1990	0.436	0.940	1.623	2.449	3.376	4.366	5.383	7.210
1991	0.439	0.947	1.634	2.466	3.400	4.396	5.421	7.435
1992	0.441	0.950	1.640	2.475	3.412	4.412	5.441	7.462
1993	0.441	0.950	1.641	2.475	3.413	4.413	5.442	7.463
1994	0.440	0.947	1.635	2.467	3.401	4.398	5.423	7.438
1995	0.437	0.941	1.624	2.450	3.378	4.368	5.387	7.387
1996	0.432	0.931	1.607	2.425	3.343	4.323	5.331	7.311
1997	0.426	0.918	1.585	2.392	3.297	4.264	5.257	7.210
1998	0.419	0.902	1.558	2.350	3.240	4.190	5.166	6.977
1999	0.410	0.883	1.525	2.301	3.173	4.103	5.059	6.938
2000	0.400	0.862	1.489	2.246	3.097	4.005	4.939	6.773
2001	0.390	0.839	1.449	2.187	3.015	3.899	4.807	6.593
2002	0.378	0.815	1.408	2.124	2.928	3.786	4.669	6.403
2003	0.367	0.790	1.364	2.058	2.838	3.670	4.525	6.218
2004	0.355	0.765	1.320	1.992	2.746	3.551	4.379	5.727
2005	0.343	0.739	1.276	1.925	2.654	3.432	4.232	5.404
2006	0.331	0.714	1.232	1.859	2.563	3.315	4.087	5.989
2007	0.320	0.689	1.190	1.795	2.475	3.200	3.946	5.268
2008	0.309	0.665	1.149	1.733	2.389	3.090	3.810	5.321
2009	0.298	0.643	1.109	1.674	2.308	2.984	3.680	5.110
2010	0.288	0.621	1.072	1.618	2.231	2.885	3.557	4.883
2011	0.279	0.601	1.038	1.566	2.159	2.792	3.443	4.427
2012	0.270	0.583	1.006	1.518	2.093	2.707	3.338	4.362
2013	0.263	0.566	0.977	1.475	2.033	2.629	3.242	4.143
2014	0.256	0.551	0.952	1.436	1.980	2.560	3.157	4.208
2015	0.250	0.538	0.929	1.402	1.933	2.500	3.083	4.255
2016	0.245	0.527	0.911	1.374	1.894	2.449	3.020	4.218
2017	0.241	0.519	0.895	1.351	1.862	2.408	2.969	4.128
2018	0.238	0.512	0.884	1.333	1.838	2.377	2.931	3.990
2019	0.236	0.508	0.876	1.322	1.823	2.357	2.907	3.929

Year	Age 1	2	3	4	5	6	7	8+
2020	0.235	0.506	0.873	1.317	1.816	2.349	2.896	3.992
2021	0.352	0.758	1.308	1.974	2.722	3.519	4.340	5.930

Table 21.2.3a. Turbot in Area 4. Raw weights at age in the stock estimated as the catch weights in Q2 (units: kg).

Year	Age 1	2	3	4	5	6	7	8+
1981	0	0.9	0.8	1.48	2.59	3.23	5.66	6.52
1982	0	0.59	1.01	1.8	2.53	3.33	4.88	6.19
1983	0	0.61	1.13	1.99	2.77	3.38	3.97	4.88
1984	0	0.66	1.04	2.07	2.87	4.25	4.93	6.34
1985	0	0.59	1.02	1.83	2.95	4.46	5.99	6.04
1986	0	0.91	1.12	1.98	3.08	3.48	7.02	6.10
1987	0.7	0.72	1.25	1.87	3.6	3.24	5.36	8.19
1988	0.7	1.16	1.65	2.65	3.31	5.78	7.24	7.38
1989	0	0.81	1.48	2.96	5.3	5.77	8.26	8.31
1990	0.9	0.84	1.79	3.09	3.02	5.34	3.47	8.65
1991–1997								NO DATA
1998	0	0.8	1.03	1.67	3.08	5.06	2.57	7.49
1999–2002								NO DATA
2003	0	0.5	1.14	1.99	2.45	2.82	4.14	2.54
2004	0	0.52	1.1	1.9	2.47	2.91	5.35	6.41
2005–2006								NO DATA
2007	0	0.59	1.1	1.57	2.58	2.71	1.72	4.87
2008	0	0.65	1.14	1.44	2.1	5.16	6.01	7.12
2009	0	0.44	0.80	1.51	1.65	3.55	4.70	4.78
2010	0	0.45	1.04	1.62	2.3	2.38	2.71	5.37
2011	0	0.39	0.95	1.88	2.01	4.00	4.42	5.16
2012	0	0.51	0.85	1.42	2.2	2.67	2.58	3.73
2013	0	0.59	0.95	1.60	2.18	3.30	2.51	3.95
2014	0.38	0.57	0.95	1.24	1.50	1.72	1.84	2.82
2015	0.41	0.49	0.89	0.93	1.46	1.4	1.37	4.45
2016	0.41	0.58	0.78	1.3	0.8	1.49	4.78	2.71
2017	0.39	0.38	0.92	1.6	2.04	2.31	2.87	3.21
2018	0.27	0.45	1.03	1.46	1.64	2.72	2.37	4.19
2019	0.44	0.39	0.86	1.37	2.04	2.25	4.25	3.07
2020	0.44	0.56	1.16	1.39	2.39	2.31	3.21	2.80
2021	0	0.41	0.89	1.49	1.71	1.82	2.85	2.44

Table 21.2.3b. Turbot in Area 4. Modelled weights at age in the stock (units: kg).

Year	Age							
	1	2	3	4	5	6	7	8+
1981	0.352	0.758	1.308	1.974	2.722	3.519	4.340	5.930
1982	0.365	0.787	1.358	2.049	2.825	3.653	4.504	6.260
1983	0.378	0.814	1.405	2.120	2.922	3.779	4.660	6.346
1984	0.389	0.839	1.449	2.186	3.013	3.897	4.805	6.570
1985	0.400	0.862	1.489	2.246	3.097	4.005	4.938	6.973
1986	0.410	0.883	1.525	2.301	3.172	4.102	5.058	7.480
1987	0.418	0.902	1.557	2.349	3.238	4.187	5.163	7.812
1988	0.426	0.917	1.584	2.390	3.295	4.260	5.253	6.991
1989	0.432	0.930	1.606	2.423	3.341	4.320	5.327	7.413
1990	0.436	0.940	1.623	2.449	3.376	4.366	5.383	7.210
1991	0.439	0.947	1.634	2.466	3.400	4.396	5.421	7.435
1992	0.441	0.950	1.640	2.475	3.412	4.412	5.441	7.462
1993	0.441	0.950	1.641	2.475	3.413	4.413	5.442	7.463
1994	0.440	0.947	1.635	2.467	3.401	4.398	5.423	7.438
1995	0.437	0.941	1.624	2.450	3.378	4.368	5.387	7.387
1996	0.432	0.931	1.607	2.425	3.343	4.323	5.331	7.311
1997	0.426	0.918	1.585	2.392	3.297	4.264	5.257	7.210
1998	0.419	0.902	1.558	2.350	3.240	4.190	5.166	6.977
1999	0.410	0.883	1.525	2.301	3.173	4.103	5.059	6.938
2000	0.400	0.862	1.489	2.246	3.097	4.005	4.939	6.773
2001	0.390	0.839	1.449	2.187	3.015	3.899	4.807	6.593
2002	0.378	0.815	1.408	2.124	2.928	3.786	4.669	6.403
2003	0.367	0.790	1.364	2.058	2.838	3.670	4.525	6.218
2004	0.355	0.765	1.320	1.992	2.746	3.551	4.379	5.727
2005	0.343	0.739	1.276	1.925	2.654	3.432	4.232	5.404
2006	0.331	0.714	1.232	1.859	2.563	3.315	4.087	5.989
2007	0.320	0.689	1.190	1.795	2.475	3.200	3.946	5.268
2008	0.309	0.665	1.149	1.733	2.389	3.090	3.810	5.321
2009	0.298	0.643	1.109	1.674	2.308	2.984	3.680	5.110
2010	0.288	0.621	1.072	1.618	2.231	2.885	3.557	4.883
2011	0.279	0.601	1.038	1.566	2.159	2.792	3.443	4.427
2012	0.270	0.583	1.006	1.518	2.093	2.707	3.338	4.362
2013	0.263	0.566	0.977	1.475	2.033	2.629	3.242	4.143
2014	0.256	0.551	0.952	1.436	1.980	2.560	3.157	4.208
2015	0.250	0.538	0.929	1.402	1.933	2.500	3.083	4.255
2016	0.245	0.527	0.911	1.374	1.894	2.449	3.020	4.218
2017	0.241	0.519	0.895	1.351	1.862	2.408	2.969	4.128
2018	0.238	0.512	0.884	1.333	1.838	2.377	2.931	3.990
2019	0.236	0.508	0.876	1.322	1.823	2.357	2.907	3.929
2020	0.235	0.506	0.873	1.317	1.816	2.349	2.896	3.992
2021	0.235	0.507	0.875	1.319	1.819	2.352	2.901	3.889

Table 21.2.4. Turbot in Area 4. Natural mortality at age and maturity at age.

Age	1	2	3	4	5	6	7	8+
natural mortality	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
maturity	0	0.04	0.47	0.95	1	1	1	1

Table 21.2.5. Turbot in Area 4. Fraction of harvest before spawning and fraction of natural mortality before spawning.

Age	1	2	3	4	5	6	7	8+
Harvest	0	0	0	0	0	0	0	0
Natural mortality	0	0	0	0	0	0	0	0

Table 21.3.1. Turbot in Area 4. SNS survey index

	Age							Age					
Year	**1**	**2**	**3**	**4**	**5**	**6**	**Year**	**1**	**2**	**3**	**4**	**5**	**6**
2004	186.52	27.029	18.76	4.09	3.00	3.42	2020	85.59	65.38	57.96	5.55	2.14	5.00
2005	75.39	155.55	23.66	0.00	0.00	0.00	2021	23.21	28.86	12.68	7.35	0.00	0.00
2006	196.15	97.47	14.87	3.61	1.09	0.00							
2007	89.74	55.60	33.78	11.84	1.32	0.00							
2008	52.09	99.74	40.83	11.87	10.92	1.20							
2009	26.27	20.31	5.65	14.47	5.09	0.00							
2010	96.02	35.81	9.27	5.37	3.70	6.76							
2011	116.69	36.89	0.00	0.00	0.00	1.69							
2012	39.86	33.51	9.46	1.23	0.00	0.00							
2013	110.16	16.12	15.64	0.44	0.00	0.00							
2014	102.71	18.31	9.45	6.16	4.74	1.20							
2015	273.79	45.87	2.00	2.00	0.00	0.00							
2016	52.83	115.69	26.71	2.00	1.31	0.50							
2017	271.90	54.70	60.34	0.50	0.00	0.50							
2018	118.21	84.25	16.84	21.94	8.64	3.18							
2019	148.66	81.43	17.07	1.53	4.37	0.83							

Table 21.3.2. Turbot in Area 4. BTS survey index

	Age						
Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**
1991	1.227	1.665	0.217	0.024	0.014	0.000	0.012
1992	1.361	1.178	0.320	0.034	0.015	0.011	0.003
1993	1.680	1.406	0.185	0.052	0.045	0.002	0.001
1994	1.830	1.580	0.102	0.031	0.006	0.003	0.003
1995	1.833	0.607	0.101	0.012	0.009	0.003	0.000
1996	0.615	1.901	0.113	0.075	0.040	0.000	0.009
1997	0.669	1.308	0.378	0.026	0.038	0.013	0.012
1998	1.915	0.916	0.233	0.152	0.005	0.000	0.001
1999	1.243	1.181	0.195	0.095	0.017	0.003	0.001
2000	4.214	0.847	0.386	0.164	0.054	0.055	0.000
2001	1.044	1.410	0.129	0.152	0.000	0.000	0.040
2002	2.814	0.493	0.146	0.046	0.032	0.022	0.001
2003	1.543	0.875	0.101	0.054	0.000	0.012	0.011
2004	2.166	0.640	0.359	0.000	0.069	0.017	0.000
2005	1.143	1.538	0.526	0.116	0.036	0.006	0.012
2006	1.705	0.799	0.273	0.114	0.005	0.000	0.000
2007	1.342	0.902	0.563	0.280	0.090	0.060	0.000
2008	1.196	1.125	0.431	0.143	0.076	0.017	0.080
2009	0.972	0.420	0.346	0.281	0.152	0.050	0.005
2010	1.691	0.348	0.099	0.070	0.089	0.015	0.015
2011	1.840	0.892	0.163	0.063	0.065	0.017	0.000
2012	0.977	0.930	0.240	0.236	0.021	0.045	0.084
2013	0.668	0.585	0.456	0.158	0.018	0.037	0.041
2014	2.270	0.176	0.225	0.321	0.120	0.050	0.014
2015	4.279	1.163	0.192	0.088	0.099	0.000	0.012
2016	0.774	1.909	0.451	0.056	0.035	0.037	0.024
2017	2.654	0.460	0.843	0.058	0.013	0.014	0.039
2018	1.622	1.190	0.281	0.309	0.176	0.033	0.000
2019	2.899	1.116	0.386	0.036	0.110	0.016	0.000
2020	1.836	1.241	0.392	0.128	0.032	0.055	0.041
2021	0.533	0.733	0.436	0.180	0.062	0.021	0.000

Table 21.3.3. Turbot in Area 4. Dutch_BT2_LPUE survey index (biomass)

Year	Index
1995	0.0432
1996	0.0384
1997	0.0381
1998	0.0353
1999	0.0354
2000	0.0446
2001	0.0467
2002	0.0460
2003	0.0477
2004	0.0490
2005	0.0491
2006	0.0496
2007	0.0664
2008	0.0697
2009	0.0688
2010	0.0596
2011	0.0632
2012	0.0763
2013	0.0789
2014	0.0766
2015	0.0874
2016	0.0982
2017	0.0948
2018	0.0849
2019	0.0874
2020	0.0908
2021	0.0786

Table 21.4.1a. Fbar (Ages 2–6) of turbot in Area 4.

Year	Fbar	Low	High	Year	Fbar	Low	High
1981	0.389	0.316	0.478	2020	0.350	0.288	0.425
1982	0.378	0.311	0.459	2021	0.349	0.283	0.430
1983	0.413	0.342	0.498				
1984	0.456	0.379	0.549				
1985	0.496	0.412	0.598				
1986	0.477	0.393	0.578				
1987	0.486	0.400	0.591				
1988	0.473	0.385	0.582				
1989	0.586	0.485	0.709				
1990	0.706	0.570	0.873				
1991	0.752	0.602	0.940				
1992	0.785	0.627	0.983				
1993	0.815	0.655	1.015				
1994	0.826	0.668	1.021				
1995	0.811	0.660	0.997				
1996	0.745	0.616	0.901				
1997	0.682	0.552	0.843				
1998	0.651	0.531	0.799				
1999	0.621	0.507	0.760				
2000	0.643	0.527	0.785				
2001	0.699	0.579	0.846				
2002	0.764	0.620	0.941				
2003	0.725	0.611	0.861				
2004	0.647	0.544	0.768				
2005	0.573	0.480	0.684				
2006	0.447	0.368	0.544				
2007	0.414	0.341	0.502				
2008	0.381	0.315	0.460				
2009	0.426	0.352	0.515				
2010	0.407	0.337	0.491				
2011	0.366	0.300	0.446				
2012	0.346	0.285	0.420				
2013	0.327	0.269	0.397				
2014	0.323	0.270	0.387				
2015	0.321	0.267	0.387				
2016	0.346	0.286	0.420				
2017	0.347	0.288	0.417				
2018	0.354	0.294	0.427				
2019	0.358	0.296	0.433				

Table 21.4.1b. Total and Spawning stock Biomass of turbot in Area 4 (tonnes).

Year	TSB	Low	High	SSB	Low	High
1981	19683	16098	24067	15445	12074	19756
1982	18379	14970	22564	13770	10610	17869
1983	18501	15229	22474	12353	9440	16165
1984	19484	16324	23254	11351	8715	14783
1985	18797	15919	22195	11467	9065	14505
1986	16325	13714	19433	10964	8686	13840
1987	14794	12347	17727	9750	7583	12536
1988	13920	11694	16569	8058	6176	10512
1989	14252	11966	16974	8008	6175	10385
1990	14163	11510	17427	6951	5247	9209
1991	14006	10722	18296	5784	4148	8064
1992	13268	10105	17419	5420	3933	7470
1993	12025	9323	15509	4914	3641	6632
1994	10726	8537	13475	4108	3085	5469
1995	9930	8242	11962	3718	2958	4673
1996	9222	7783	10926	3252	2602	4066
1997	8795	7532	10270	3497	2912	4199
1998	8704	7469	10142	3748	3200	4389
1999	8812	7231	10739	3610	2850	4574
2000	9773	8092	11805	3974	3180	4968
2001	9484	7940	11329	3780	3066	4659
2002	9262	7897	10863	3623	3042	4314
2003	8770	7748	9928	3017	2596	3507
2004	8460	7519	9518	2825	2410	3310
2005	8204	7256	9275	2867	2426	3388
2006	8604	7609	9729	3120	2602	3740
2007	9945	8895	11118	3917	3305	4643
2008	9974	8875	11209	4798	4043	5694
2009	10002	8812	11353	5943	5019	7037
2010	9688	8445	11114	5679	4673	6901
2011	10451	9023	12105	5325	4299	6596
2012	11234	9706	13002	5839	4743	7188
2013	11282	9737	13072	6850	5642	8317
2014	12220	10576	14120	8126	6751	9781
2015	14143	12153	16458	8122	6573	10035
2016	14755	12772	17046	8396	6823	10332
2017	14212	12325	16387	9294	7748	11147
2018	13604	11667	15863	9333	7674	11350
2019	13710	11732	16021	8620	6957	10680
2020	13375	11329	15790	8577	6838	10758
2021	12120	10037	14635	8756	6927	11067

Table 21.4.1c. Recruitment (Age 1) of turbot in Area 4 (units: thousands).

Year	Value	Low	High	Year	Value	Low	High
1981	2538.36	1855.02	3473.42	2018	6050.86	4667.04	7844.99
1982	4215.15	3140.51	5657.52	2019	6605.08	5021.16	8688.66
1983	6492.61	4810.08	8763.66	2020	4013.92	2875.00	5604.01
1984	5084.44	3708.49	6970.93	2021	2197.17	1264.24	3818.54
1985	2440.50	1779.75	3346.54				
1986	3407.38	2537.10	4576.18				
1987	3986.18	2956.93	5373.69				
1988	3752.96	2749.23	5123.13				
1989	4535.18	2975.58	6912.20				
1990	5893.62	3664.26	9479.34				
1991	5050.24	3253.40	7839.47				
1992	4369.22	2817.39	6775.81				
1993	4930.56	3289.82	7389.60				
1994	3784.07	2526.35	5667.94				
1995	4838.54	3447.38	6791.09				
1996	3332.89	2431.51	4568.42				
1997	2837.86	2038.31	3951.04				
1998	4080.91	2891.55	5759.48				
1999	3376.05	2316.47	4920.29				
2000	5452.59	3894.78	7633.48				
2001	3519.60	2398.35	5165.04				
2002	5949.89	4427.44	7995.84				
2003	4801.80	3622.82	6364.46				
2004	5861.21	4512.01	7613.85				
2005	4394.02	3397.49	5682.84				
2006	6375.34	4947.23	8215.72				
2007	5289.35	4088.61	6842.73				
2008	3190.66	2380.83	4275.93				
2009	3956.83	3018.05	5187.62				
2010	5419.34	4213.23	6970.71				
2011	6895.15	5204.82	9134.44				
2012	4155.35	3145.41	5489.58				
2013	3309.27	2525.26	4336.68				
2014	6958.99	5320.94	9101.31				
2015	9597.78	7238.49	12726.05				
2016	3158.91	2390.17	4174.89				
2017	5291.10	4067.78	6882.32				

Table 21.4.2. Turbot in Area 4. Estimated fishing mortality.

Year	Age							
	1	2	3	4	5	6	7	8+
1981	0.002	0.119	0.615	0.532	0.359	0.317	0.227	0.227
1982	0.002	0.113	0.576	0.514	0.360	0.326	0.242	0.242
1983	0.002	0.135	0.607	0.559	0.402	0.361	0.279	0.279
1984	0.004	0.177	0.671	0.610	0.441	0.384	0.288	0.288
1985	0.004	0.205	0.726	0.667	0.481	0.402	0.288	0.288
1986	0.005	0.210	0.685	0.632	0.468	0.390	0.276	0.276
1987	0.006	0.242	0.722	0.626	0.463	0.380	0.270	0.270
1988	0.007	0.257	0.722	0.571	0.443	0.375	0.279	0.279
1989	0.009	0.327	0.904	0.707	0.549	0.446	0.360	0.360
1990	0.012	0.383	1.044	0.842	0.688	0.572	0.546	0.546
1991	0.014	0.410	1.096	0.901	0.742	0.612	0.610	0.610
1992	0.016	0.441	1.136	0.936	0.774	0.640	0.672	0.672
1993	0.020	0.484	1.181	0.965	0.792	0.653	0.716	0.716
1994	0.022	0.509	1.208	0.972	0.792	0.648	0.726	0.726
1995	0.023	0.505	1.176	0.959	0.780	0.637	0.734	0.734
1996	0.018	0.405	1.036	0.891	0.760	0.635	0.773	0.773
1997	0.014	0.323	0.886	0.816	0.741	0.646	0.845	0.845
1998	0.013	0.303	0.821	0.767	0.721	0.644	0.902	0.902
1999	0.015	0.320	0.778	0.728	0.674	0.605	0.867	0.867
2000	0.026	0.443	0.845	0.746	0.646	0.535	0.685	0.685
2001	0.041	0.587	0.932	0.806	0.661	0.513	0.605	0.605
2002	0.069	0.819	1.010	0.852	0.663	0.476	0.508	0.508
2003	0.075	0.834	0.945	0.800	0.616	0.432	0.429	0.429
2004	0.077	0.802	0.874	0.710	0.506	0.341	0.281	0.281
2005	0.063	0.670	0.795	0.626	0.450	0.322	0.280	0.280
2006	0.045	0.519	0.607	0.465	0.357	0.289	0.281	0.281
2007	0.040	0.506	0.544	0.421	0.326	0.272	0.254	0.254
2008	0.035	0.449	0.495	0.386	0.311	0.263	0.229	0.229
2009	0.050	0.590	0.571	0.413	0.306	0.250	0.212	0.212
2010	0.044	0.546	0.544	0.396	0.298	0.252	0.215	0.215
2011	0.034	0.467	0.488	0.365	0.274	0.235	0.198	0.198
2012	0.028	0.407	0.458	0.367	0.269	0.230	0.187	0.187
2013	0.024	0.367	0.420	0.358	0.265	0.225	0.172	0.172
2014	0.015	0.289	0.397	0.373	0.296	0.261	0.215	0.215
2015	0.011	0.263	0.385	0.380	0.314	0.266	0.205	0.205
2016	0.011	0.249	0.405	0.430	0.359	0.288	0.210	0.210
2017	0.010	0.234	0.408	0.439	0.364	0.288	0.203	0.203
2018	0.015	0.265	0.421	0.437	0.363	0.286	0.188	0.188
2019	0.022	0.311	0.435	0.428	0.348	0.268	0.159	0.159
2020	0.027	0.338	0.424	0.408	0.328	0.250	0.137	0.137
2021	0.026	0.330	0.424	0.411	0.331	0.251	0.132	0.132

Table 21.4.3. Turbot in Area 4. Estimated population abundance (units: thousands).

Year	Age							
	1	2	3	4	5	6	7	8+
1981	2538.36	3100.01	1602.12	1315.40	1761.28	713.33	362.53	602.34
1982	4215.15	2015.80	2283.60	672.41	626.98	1019.77	428.57	639.53
1983	6492.61	3458.91	1478.64	1057.10	327.55	361.16	610.82	694.42
1984	5084.44	5507.27	2516.04	683.85	485.74	178.68	207.84	803.42
1985	2440.50	4262.96	3756.20	1080.55	317.38	254.01	98.69	617.67
1986	3407.38	1873.68	2975.24	1405.38	442.88	163.44	136.61	443.55
1987	3986.18	2804.46	1172.69	1370.50	579.58	220.33	90.38	360.17
1988	3752.96	3307.97	1792.16	459.06	596.03	290.74	122.78	286.03
1989	4535.18	2993.92	2049.28	744.26	239.15	318.37	159.69	255.82
1990	5893.62	3663.63	1759.31	636.49	305.04	120.23	174.03	242.28
1991	5050.24	4905.15	2052.11	493.23	220.48	124.86	56.17	197.56
1992	4369.22	4162.76	2684.85	558.62	162.63	84.69	55.17	112.93
1993	4930.56	3481.35	2216.36	698.07	180.82	60.79	35.89	70.38
1994	3784.07	4035.44	1674.95	565.16	217.03	66.62	26.05	42.59
1995	4838.54	2867.46	1954.12	400.38	180.11	81.31	28.59	27.26
1996	3332.89	3965.87	1335.57	493.47	125.74	69.86	35.90	22.01
1997	2837.86	2756.46	2146.41	373.91	165.42	47.41	31.36	22.08
1998	4080.91	2278.53	1651.23	738.97	134.03	64.15	19.81	19.34
1999	3376.05	3320.61	1384.70	581.85	287.55	52.69	27.25	12.97
2000	5452.59	2605.27	2033.50	547.75	231.53	126.45	23.59	13.85
2001	3519.60	4316.51	1277.36	700.51	217.76	98.52	62.60	15.48
2002	5949.89	2640.60	1983.60	396.97	253.06	95.14	48.10	35.38
2003	4801.80	4599.76	893.98	593.66	132.42	104.42	49.36	42.30
2004	5861.21	3565.02	1587.78	282.46	217.52	54.20	54.08	47.12
2005	4394.02	4366.58	1289.02	520.50	106.31	104.23	29.41	64.80
2006	6375.34	3391.70	1844.95	410.95	215.25	53.48	62.21	59.44
2007	5289.35	5134.87	1704.22	878.30	213.54	128.34	33.27	74.73
2008	3190.66	4344.59	2513.69	798.80	466.08	129.44	81.19	67.37
2009	3956.83	2418.42	2407.60	1384.55	466.48	257.93	79.02	97.51
2010	5419.34	3240.06	1002.86	1078.53	745.84	291.51	160.99	114.59
2011	6895.15	4233.79	1648.45	438.53	603.73	450.91	181.62	173.51
2012	4155.35	5736.74	2222.09	895.93	254.16	384.71	301.76	226.78
2013	3309.27	3358.61	3491.51	1164.06	519.10	167.85	260.58	347.97
2014	6958.99	2430.54	2018.73	2156.46	688.57	348.12	117.31	449.59
2015	9597.78	5734.78	1605.71	1183.45	1314.91	435.88	223.65	396.61
2016	3158.91	8046.64	3464.95	962.34	693.97	782.69	269.83	412.51
2017	5291.10	2387.10	5290.84	1792.13	502.94	379.50	474.36	433.62
2018	6050.86	4221.74	1546.52	2804.91	931.33	286.53	235.67	576.11
2019	6605.08	4922.00	2715.19	844.46	1512.67	531.13	175.66	541.52
2020	4013.92	5290.14	2953.91	1387.11	465.85	875.61	335.75	488.93
2021	2197.17	3066.23	2963.08	1560.09	739.29	274.35	553.94	574.70

Table 21.5.1a. Turbot in Area 4. Predicted catch numbers at age (units: thousands).

Year	Age 1	2	3	4	5	6	7	8+
1981	4.81	316.82	673.79	496.32	484.59	176.60	66.95	111.24
1982	7.42	196.20	915.12	246.91	172.94	258.24	83.95	125.28
1983	14.60	396.59	615.87	414.31	98.97	99.73	135.24	153.74
1984	16.75	811.07	1126.69	285.79	158.06	51.97	47.37	183.10
1985	9.91	717.88	1778.90	481.81	110.76	76.75	22.49	140.78
1986	14.29	322.30	1352.40	602.74	151.27	48.16	30.02	97.45
1987	20.43	548.13	553.01	583.69	196.02	63.52	19.47	77.59
1988	22.25	682.23	845.19	182.71	194.72	82.85	27.23	63.44
1989	38.22	760.58	1121.93	345.78	92.40	104.51	44.02	70.51
1990	62.86	1063.21	1051.00	332.79	139.12	47.92	66.96	93.21
1991	62.75	1505.42	1260.62	269.44	105.98	52.31	23.49	82.61
1992	63.68	1354.90	1682.62	312.48	80.46	36.66	24.73	50.62
1993	86.67	1220.90	1418.72	397.76	90.85	26.71	16.83	32.99
1994	75.64	1471.10	1085.27	323.57	109.02	29.10	12.33	20.16
1995	100.87	1039.57	1248.27	227.28	89.52	35.07	13.63	13.00
1996	53.86	1204.67	794.27	267.61	61.45	30.07	17.75	10.88
1997	35.35	693.28	1159.72	191.58	79.43	20.67	16.43	11.57
1998	49.11	542.19	849.26	363.42	63.18	27.91	10.83	10.57
1999	46.68	829.13	687.52	275.95	129.28	21.89	14.53	6.91
2000	125.98	851.01	1066.42	264.30	100.91	47.91	10.72	6.29
2001	128.35	1753.76	712.44	355.89	96.46	36.13	26.00	6.43
2002	360.98	1355.95	1161.80	209.28	112.39	32.94	17.50	12.87
2003	316.13	2390.87	502.96	300.22	55.76	33.41	15.72	13.47
2004	394.38	1806.44	850.73	131.66	78.97	14.27	12.06	10.51
2005	244.90	1954.14	649.03	221.78	35.19	26.16	6.54	14.42
2006	256.01	1255.62	768.49	139.61	58.89	12.23	13.89	13.27
2007	189.61	1862.70	654.08	275.32	54.12	27.83	6.78	15.23
2008	100.64	1435.89	896.21	233.16	113.42	27.21	15.11	12.54
2009	173.43	987.05	958.70	427.90	111.91	51.87	13.74	16.95
2010	213.59	1247.20	384.67	321.58	174.89	59.10	28.38	20.20
2011	211.11	1443.04	581.72	122.33	131.55	85.86	29.62	28.30
2012	103.48	1750.85	745.20	251.19	54.52	71.84	46.86	35.21
2013	70.10	941.63	1092.21	319.63	109.83	30.76	37.37	49.91
2014	91.13	556.28	603.20	612.31	160.82	72.82	20.60	78.95
2015	98.95	1206.26	467.81	340.94	322.92	92.73	37.71	66.87
2016	30.32	1611.74	1053.09	306.77	190.92	178.52	46.58	71.20
2017	46.84	452.83	1616.89	581.02	140.08	86.54	79.32	72.50
2018	81.43	894.49	484.97	906.13	258.47	64.96	36.79	89.94
2019	127.96	1197.27	873.77	268.55	405.12	113.77	23.52	72.49
2020	97.29	1383.65	932.43	424.36	118.87	176.14	38.95	56.72
2021	52.10	785.36	934.82	479.88	189.72	55.35	62.38	64.72

Table 21.5.1b. Turbot in Area 4. Catch at age residuals.

Year	Age							
	1	2	3	4	5	6	7	8+
1981	0.000	-2.239	0.415	2.469	0.332	0.853	2.314	0.002
1982	0.000	0.014	0.439	-0.991	-0.678	-1.254	-1.728	0.030
1983	0.000	1.316	0.008	0.969	0.380	-0.089	0.132	-0.042
1984	0.000	2.150	-0.011	0.597	-0.065	-0.093	-0.273	-0.906
1985	0.000	-0.432	-0.316	0.577	0.985	-0.176	-0.783	-0.896
1986	0.000	-1.057	-0.459	-1.027	-0.071	0.188	-0.723	-0.173
1987	0.339	0.768	-1.825	1.363	-1.054	-1.165	-0.058	-0.694
1988	0.715	0.912	-0.747	-1.491	-0.041	-0.071	0.089	0.076
1989	0.000	-0.458	0.188	0.843	2.611	-0.326	-0.337	-0.023
1990	0.578	0.314	-0.182	-1.401	0.767	1.900	2.008	0.286
1991–1997	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1998	0.000	-0.101	-0.203	0.458	0.595	0.047	-0.499	0.977
1999–2002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2003	1.262	0.497	-2.529	-0.452	-0.638	-1.247	0.172	0.989
2004	0.874	0.183	-1.227	-0.401	-0.501	-2.471	-2.271	-1.871
2005	0.150	-0.519	0.431	-0.743	-1.599	-0.518	-2.396	1.577
2006	1.325	0.588	-0.771	-3.074	-1.730	-0.891	1.276	0.963
2007	-1.241	1.185	-0.945	0.920	-0.423	0.951	0.610	-0.490
2008	0.031	-0.118	-0.837	-0.471	1.592	1.590	-0.663	-0.885
2009	-0.037	0.348	1.130	1.071	-0.522	-2.388	-0.491	0.395
2010	0.685	1.037	-1.358	-0.685	-0.045	1.553	0.046	-0.254
2011	-0.125	0.543	0.928	-1.258	0.075	-0.338	0.078	-0.775
2012	0.000	-0.063	0.130	1.592	-0.716	-0.114	1.163	-1.622
2013	0.079	0.542	0.643	0.497	-0.287	0.054	0.274	-2.183
2014	-0.715	-2.340	0.513	1.915	0.124	2.116	1.933	0.565
2015	-0.915	0.427	0.854	0.458	0.700	0.537	-0.144	0.257
2016	0.000	-1.585	-0.324	1.959	2.322	0.053	-0.557	-0.162
2017	-1.314	-0.934	1.179	-0.089	-0.051	-1.046	0.434	-0.674
2018	1.705	-0.741	-0.083	-0.307	-0.012	0.335	0.311	-1.090
2019	1.036	0.147	0.154	-0.181	-0.213	0.156	-0.609	-0.749
2020	0.663	0.197	-0.926	-0.832	0.723	-0.504	-0.031	-1.167
2021	0.000	-1.289	-0.420	0.066	-0.127	0.392	-0.125	-0.520

Table 21.5.2a. Turbot in Area 4. Predicted index at age SNS.

Year	Age 1	2	3	4	5	6
2004	99.023	36.117	9.750	0.972	0.864	0.242
2005	74.953	48.563	8.370	1.900	0.439	0.471
2006	110.148	41.957	13.677	1.681	0.950	0.248
2007	91.705	64.127	13.206	3.706	0.963	0.601
2008	55.511	56.456	20.171	3.455	2.125	0.611
2009	68.159	28.450	18.302	5.872	2.135	1.228
2010	93.687	39.322	7.773	4.632	3.432	1.385
2011	120.051	54.333	13.288	1.924	2.826	2.169
2012	72.681	76.796	18.302	3.925	1.194	1.857
2013	58.054	46.239	29.536	5.133	2.445	0.813
2014	122.865	35.353	17.355	9.411	3.172	1.644
2015	169.827	84.997	13.922	5.141	5.981	2.051
2016	55.926	120.460	29.615	4.035	3.058	3.626
2017	93.730	36.109	45.134	7.467	2.208	1.758
2018	106.801	62.476	13.071	11.703	4.093	1.329
2019	116.039	70.530	22.728	3.544	6.719	2.495
2020	70.244	74.344	24.906	5.904	2.098	4.168
2021	38.467	43.342	24.988	6.628	3.324	1.305

Table 21.5.2b. Turbot in Area 4. Index at age residuals SNS

Year	Age 1	2	3	4	5	6
2004	0.435	-1.468	1.236	0.952	1.065	1.638
2005	-0.598	2.098	0.448	0.000	0.000	0.000
2006	1.074	1.194	-0.282	0.818	-0.285	0.000
2007	0.080	-0.061	1.901	0.635	-0.167	0.000
2008	-0.614	1.712	0.500	0.742	0.913	-0.174
2009	-1.241	-0.499	-1.179	2.003	0.594	0.000
2010	0.619	0.013	0.041	0.071	-0.002	1.615
2011	0.389	-0.616	0.000	0.000	0.000	-0.206
2012	-1.196	-0.128	-0.221	-0.745	0.000	0.000
2013	0.529	-1.833	0.449	-2.248	0.000	0.000
2014	1.047	-1.410	-0.263	0.335	0.659	-0.584
2015	1.689	-1.324	-2.146	0.438	0.000	0.000
2016	-1.426	0.918	-0.319	-0.723	-0.564	-1.619
2017	2.236	-0.720	0.048	-3.186	0.000	-0.542
2018	-0.218	0.433	0.120	0.489	0.452	0.508
2019	0.184	0.060	-0.497	-0.595	0.057	-0.966

Year	Age 1	2	3	4	5	6
2020	-0.896	-0.273	1.588	-0.707	0.100	0.211
2021	-1.824	-0.410	-0.543	0.625	0.000	0.000

Table 21.5.3a. Turbot in Area 4. Predicted index at age BTS-ISIS

Year	Age 1	2	3	4	5	6	7
1991	1.669	1.226	0.192	0.053	0.019	0.012	0.005
1992	1.441	1.018	0.244	0.058	0.014	0.008	0.005
1993	1.623	0.826	0.195	0.072	0.015	0.006	0.003
1994	1.243	0.941	0.145	0.058	0.018	0.006	0.002
1995	1.588	0.670	0.173	0.041	0.015	0.008	0.002
1996	1.098	0.995	0.130	0.053	0.011	0.007	0.003
1997	0.938	0.733	0.233	0.043	0.014	0.004	0.003
1998	1.349	0.614	0.187	0.087	0.012	0.006	0.002
1999	1.114	0.884	0.162	0.071	0.026	0.005	0.002
2000	1.787	0.636	0.227	0.066	0.021	0.013	0.002
2001	1.141	0.952	0.134	0.080	0.020	0.010	0.006
2002	1.891	0.495	0.197	0.044	0.023	0.010	0.005
2003	1.520	0.853	0.093	0.068	0.013	0.011	0.005
2004	1.853	0.676	0.174	0.035	0.022	0.006	0.006
2005	1.402	0.909	0.149	0.068	0.011	0.012	0.004
2006	2.061	0.785	0.243	0.060	0.024	0.006	0.007
2007	1.716	1.200	0.235	0.132	0.025	0.015	0.004
2008	1.038	1.056	0.359	0.123	0.055	0.016	0.010
2009	1.275	0.532	0.326	0.209	0.055	0.032	0.010
2010	1.753	0.736	0.138	0.165	0.088	0.036	0.020
2011	2.246	1.016	0.237	0.069	0.073	0.056	0.023
2012	1.360	1.437	0.326	0.140	0.031	0.048	0.039
2013	1.086	0.865	0.526	0.183	0.063	0.021	0.034
2014	2.299	0.661	0.309	0.336	0.082	0.042	0.015
2015	3.177	1.590	0.248	0.183	0.154	0.053	0.028
2016	1.046	2.254	0.527	0.144	0.079	0.093	0.034
2017	1.753	0.676	0.803	0.266	0.057	0.045	0.060
2018	1.998	1.169	0.233	0.417	0.105	0.034	0.030
2019	2.171	1.319	0.405	0.126	0.173	0.064	0.023
2020	1.314	1.391	0.443	0.211	0.054	0.107	0.045
2021	0.720	0.811	0.445	0.236	0.086	0.034	0.074

Table 21.5.3b. Turbot in Area 4. Index at age residuals BTS-ISIS.

Year	Age						
	1	2	3	4	5	6	7
1991	-0.591	0.708	-1.042	-2.242	-0.976	0.000	0.205
1992	-0.075	0.519	0.190	-1.304	-0.414	-0.312	-1.040
1993	0.248	0.806	-0.459	-0.792	0.883	-1.623	-1.754
1994	0.163	0.781	-1.562	-0.681	-0.957	-0.419	0.642
1995	0.015	-1.106	-0.999	-1.201	0.232	-0.227	0.000
1996	-1.500	1.864	-0.199	1.223	1.844	0.000	1.401
1997	-0.457	1.789	1.445	-0.462	1.274	1.194	1.718
1998	1.366	0.798	0.767	1.027	-1.006	0.000	-0.335
1999	-0.188	0.404	0.201	0.622	-0.202	-0.498	-0.599
2000	1.734	-0.657	0.800	1.279	1.132	1.946	0.000
2001	-1.352	-0.193	-1.624	0.371	0.000	0.000	2.378
2002	1.074	-1.663	-1.809	-0.667	0.009	0.843	-1.467
2003	-0.560	-0.343	0.081	-0.568	0.000	-0.043	0.972
2004	-0.257	-0.269	1.497	0.000	1.047	0.763	0.000
2005	-0.666	0.574	2.493	0.556	1.115	-0.796	1.158
2006	-0.389	0.024	0.941	1.215	-1.661	0.000	0.000
2007	-0.262	-0.125	2.795	1.398	1.614	1.561	0.000
2008	0.051	0.361	0.606	0.194	0.168	0.025	2.297
2009	0.100	-1.020	0.263	0.611	1.302	0.483	-0.799
2010	0.429	-1.114	-0.765	-1.151	0.052	-1.017	-0.447
2011	-0.051	0.115	-0.304	-0.003	-0.069	-1.303	0.000
2012	-0.529	0.155	-0.094	1.025	-0.220	0.025	0.778
2013	-1.798	0.182	0.704	0.121	-1.181	0.792	0.202
2014	1.039	-2.394	-0.012	0.262	0.517	0.181	0.014
2015	0.871	-0.161	0.112	-0.773	-0.356	0.000	-0.858
2016	-1.518	0.153	-0.433	-1.420	-0.941	-0.979	-0.361
2017	0.611	-1.441	-0.186	-2.357	-1.653	-1.286	-0.548
2018	-0.697	-0.141	0.350	-0.483	0.527	-0.075	0.000
2019	0.211	-0.598	-0.098	-1.648	-0.373	-1.450	0.000
2020	-0.477	-0.515	-0.236	-0.688	-0.483	-0.672	-0.064
2021	-1.208	-0.549	-0.236	-0.494	-0.407	-0.546	0.000

Table 21.5.4. Turbot in Area 4. Predicted index and residuals of the Dutch LPUE.

year	Index	Residuals
1995	0.0429	0.334
1996	0.0386	-0.874
1997	0.0387	-1.601
1998	0.0355	-0.304
1999	0.0363	-0.321
2000	0.0444	0.005
2001	0.0475	-0.294
2002	0.0456	0.007
2003	0.0468	0.844
2004	0.0485	-0.917
2005	0.0508	-2.751
2006	0.0514	-0.766
2007	0.0657	0.933
2008	0.0707	-0.068
2009	0.0675	0.216
2010	0.0589	1.363
2011	0.0641	0.421
2012	0.0769	1.728
2013	0.0798	2.120
2014	0.0766	2.466
2015	0.0824	2.715
2016	0.0945	1.233
2017	0.0950	-0.601
2018	0.0870	-0.723
2019	0.0859	1.029
2020	0.0878	0.708
2021	0.0797	-0.724

Table 21.5.5. Turbot in Area 4. Fit parameters.

Name	value	std.dev
logFpar	-3.885	0.130
logFpar	-4.336	0.188
logFpar	-5.030	0.240
logFpar	-7.864	0.071
logFpar	-8.364	0.085
logFpar	-8.690	0.157
logFpar	-9.731	0.084
logSdLogFsta	-0.780	0.415
logSdLogFsta	-1.429	0.232
logSdLogFsta	-2.005	0.211
logSdLogFsta	-1.944	0.272
logSdLogFsta	-1.500	0.269
logSdLogN	-0.809	0.152
logSdLogN	-2.250	0.335
logSdLogObs	-0.134	0.228
logSdLogObs	-1.172	0.264
logSdLogObs	-2.250	0.332
logSdLogObs	-1.141	0.135
logSdLogObs	-1.089	0.156
logSdLogObs	-0.524	0.141
logSdLogObs	-0.229	0.166
logSdLogObs	0.084	0.120
logSdLogObs	-0.909	0.089
logSdLogObs	-0.383	0.143
logSdLogObs	-0.085	0.086
logSdLogObs	-3.225	0.631
transfIRARdist	-0.050	0.298
itrans_rho	0.949	0.191

Table 21.5.6. Turbot in Area 4. Negative Log-Likelihood.

422.456

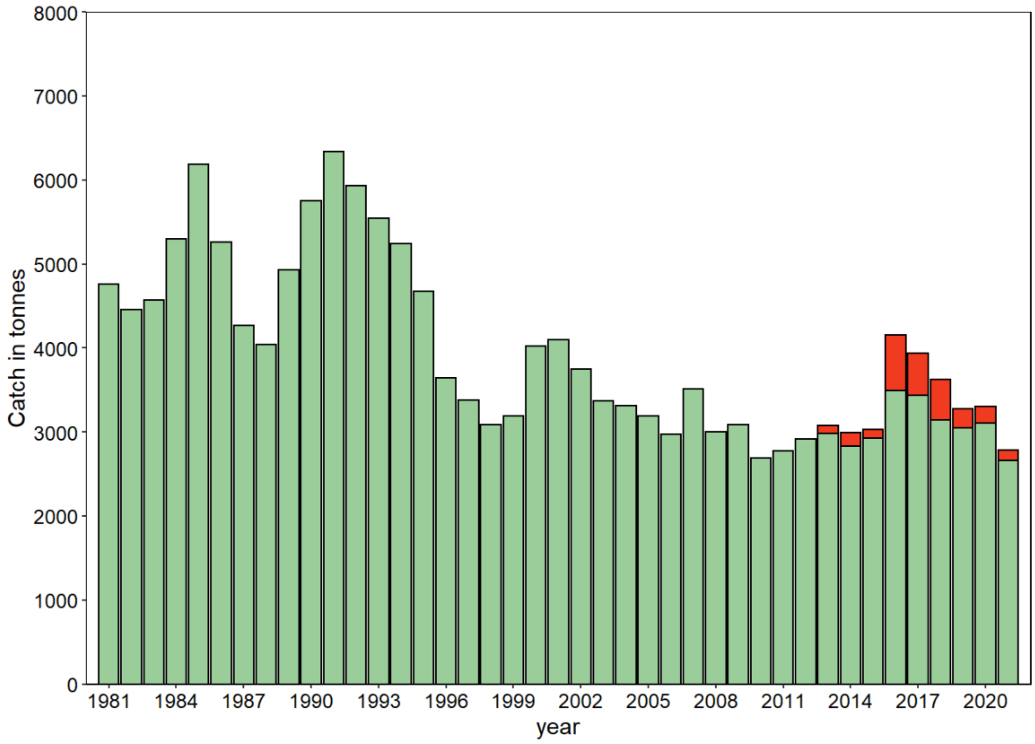


Figure 21.2.1. Turbot in Area 4. Total catches 1981–2021. ICES estimated landings (green) and discards (red).

Figure 21.2.2. Turbot in Area 4. Landings at age for the years with available data between 1975–2021. Data for 1991–1997 and 1999–2002 are missing.

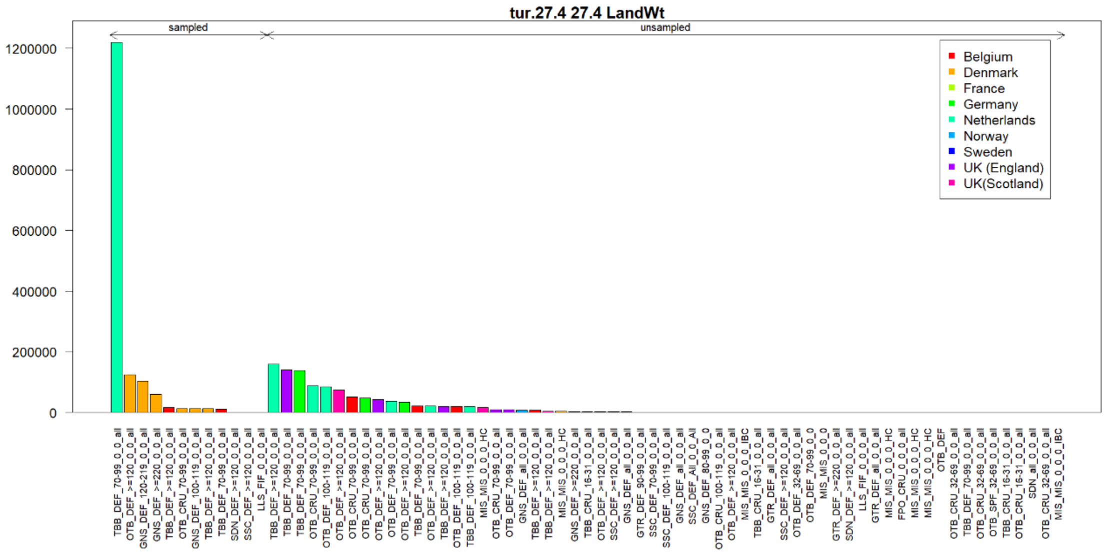


Figure 21.2.3. Turbot in Area 4: Total landings by métier in 2021 sorted by sampled/unsampled for numbers at age in InterCatch.

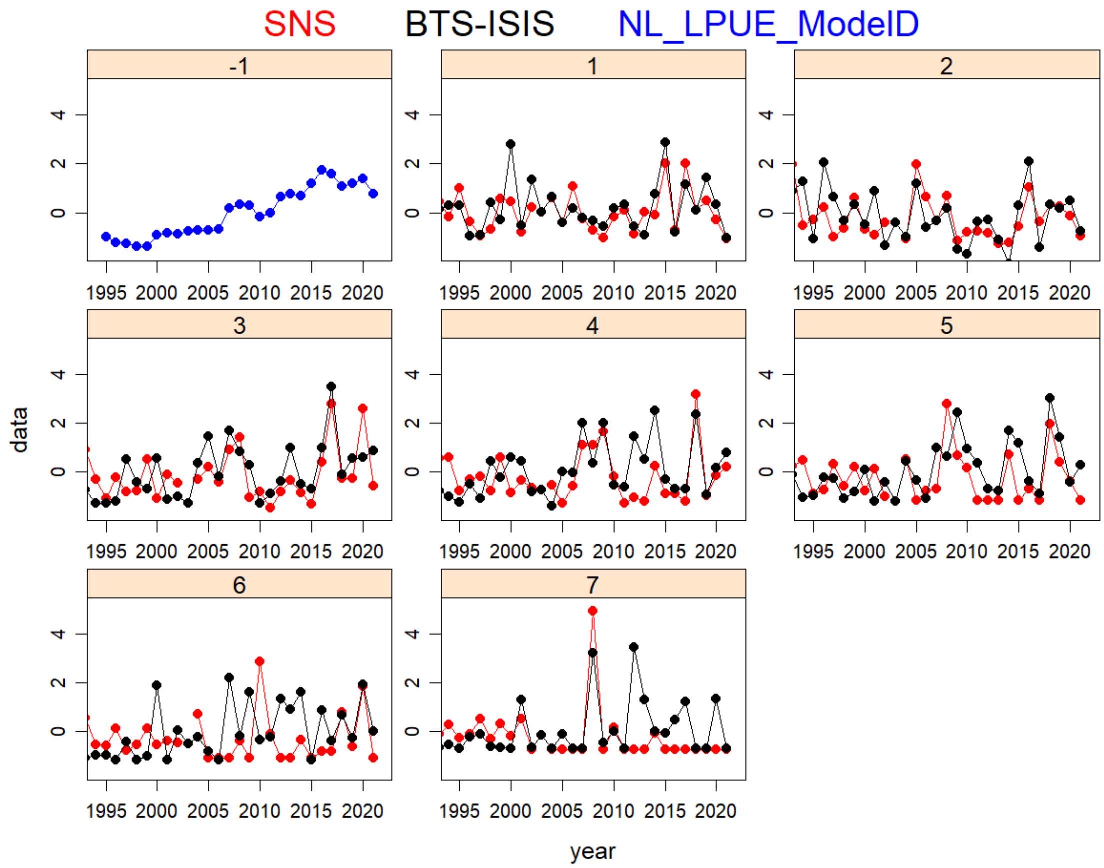
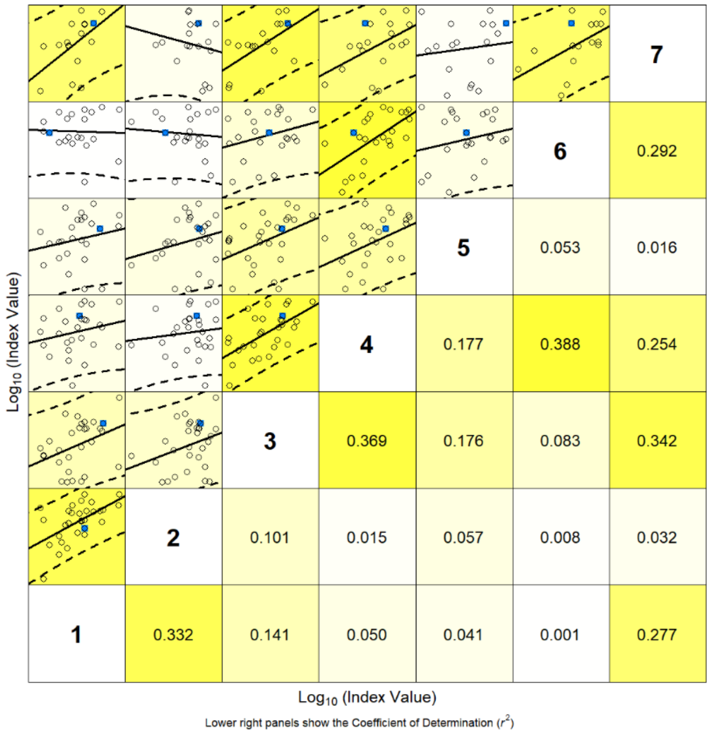


Figure 21.2.4. Turbot in Area 4. Time series of the standardized indices for ages 1 to 7 from the three tuning fleets available for the assessment: BTS-ISIS (black), SNS (red) and NL beam trawl LPUE (shown in the "-1" panel).



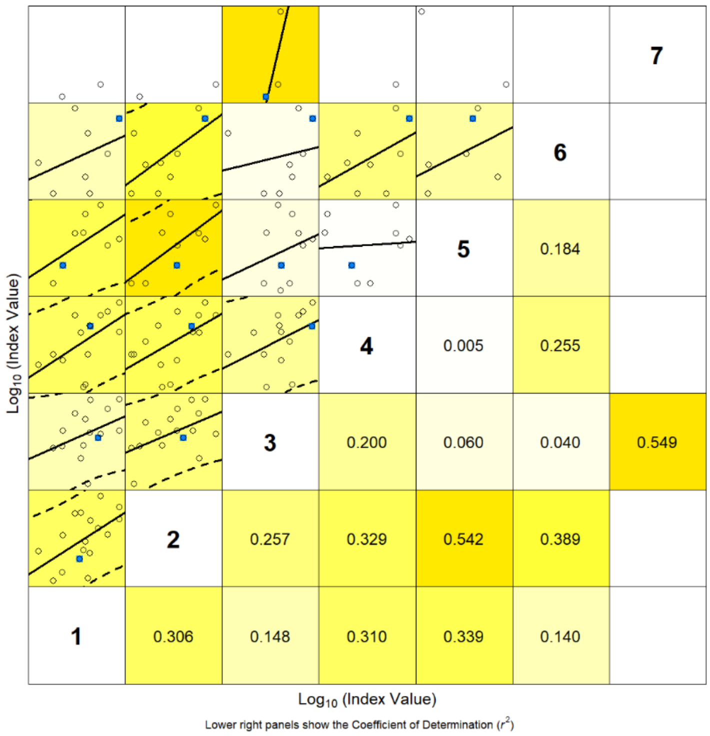


Figure 21.2.5. Turbot in Area 4. Internal consistency of the two tuning indices available for the assessment: BTS-ISIS from 1991–2021 (top), and SNS 2004–2021 (bottom).

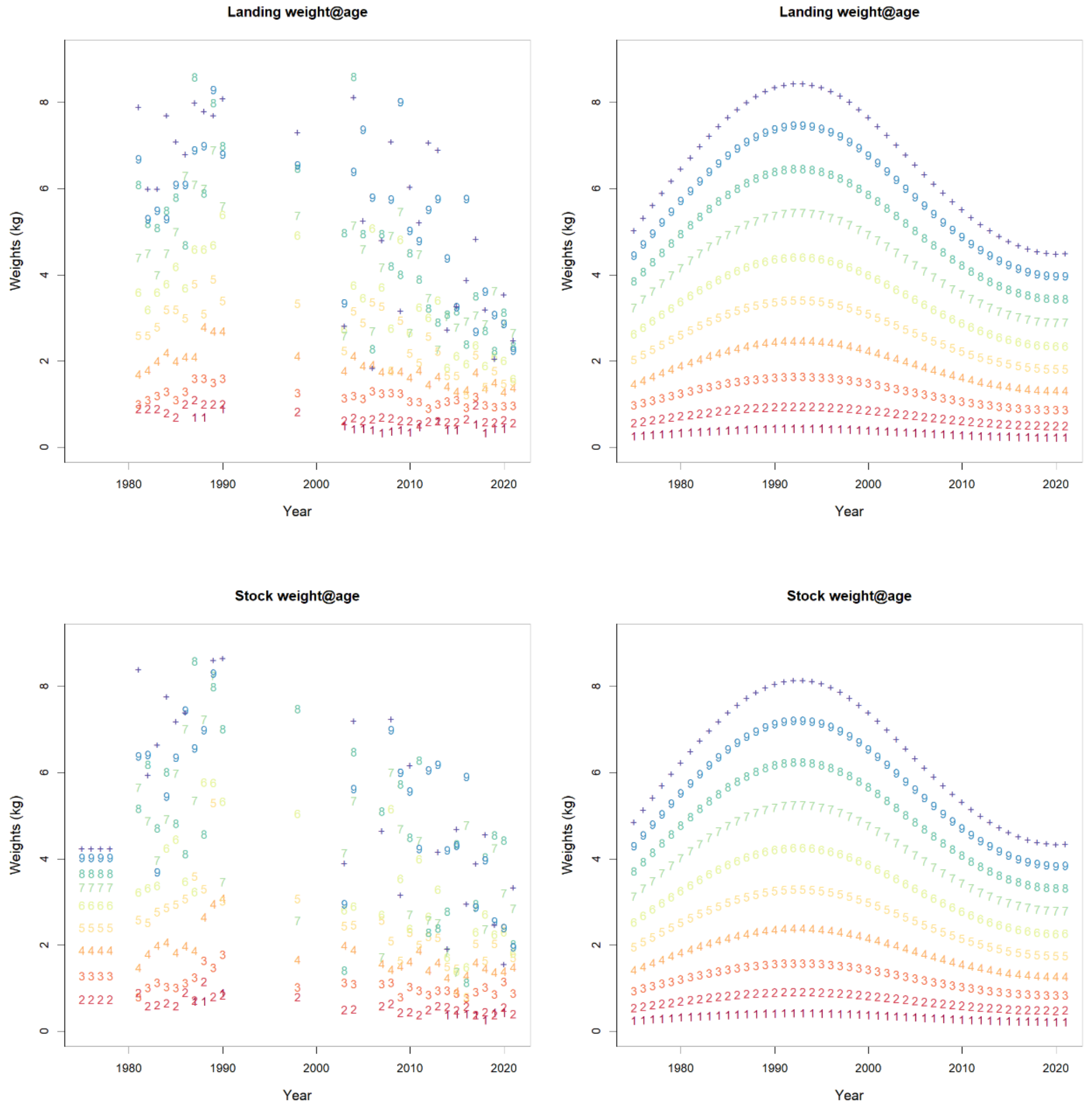


Figure 21.2.6. Turbot in Area 4. Raw landings (top-left), modelled landings (top right) and raw stock (bottom left) and modelled (bottom right) weight at age.

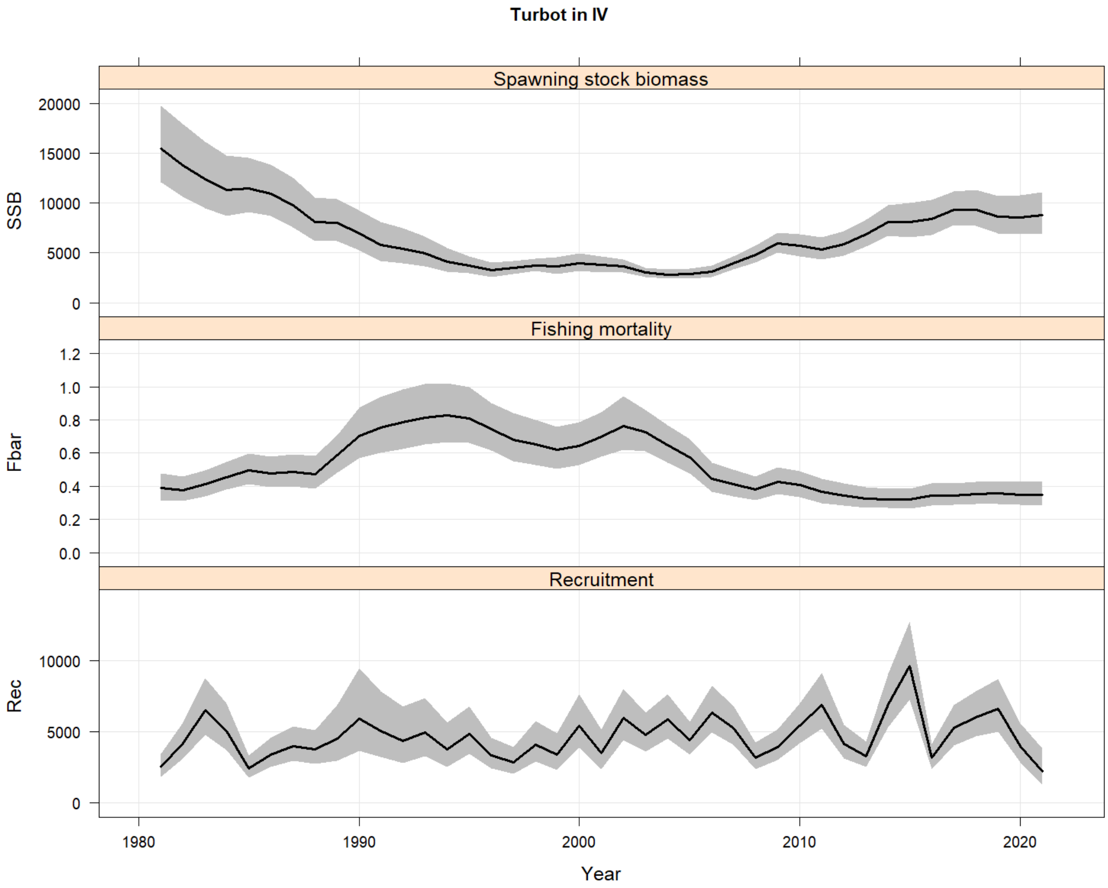


Figure 21.4.1. Turbot in Area 4. Summary plot of SSB, F and Recruitment, including the uncertainty bounds.

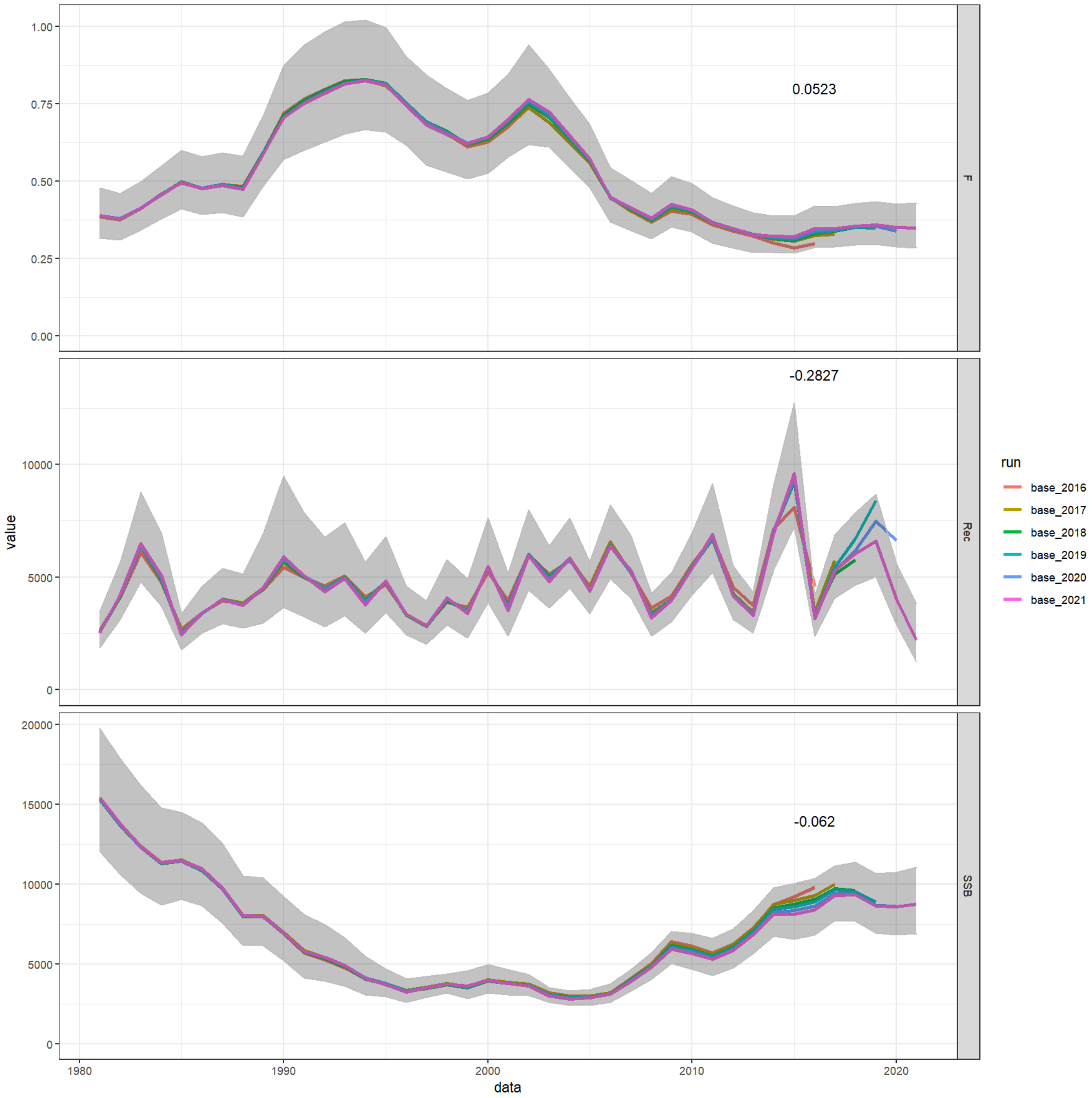


Figure 21.4.2. Turbot in Area 4. Retrospective analysis plot on SSB, F and R including confidence band last year assessment and Mohn's rho values.

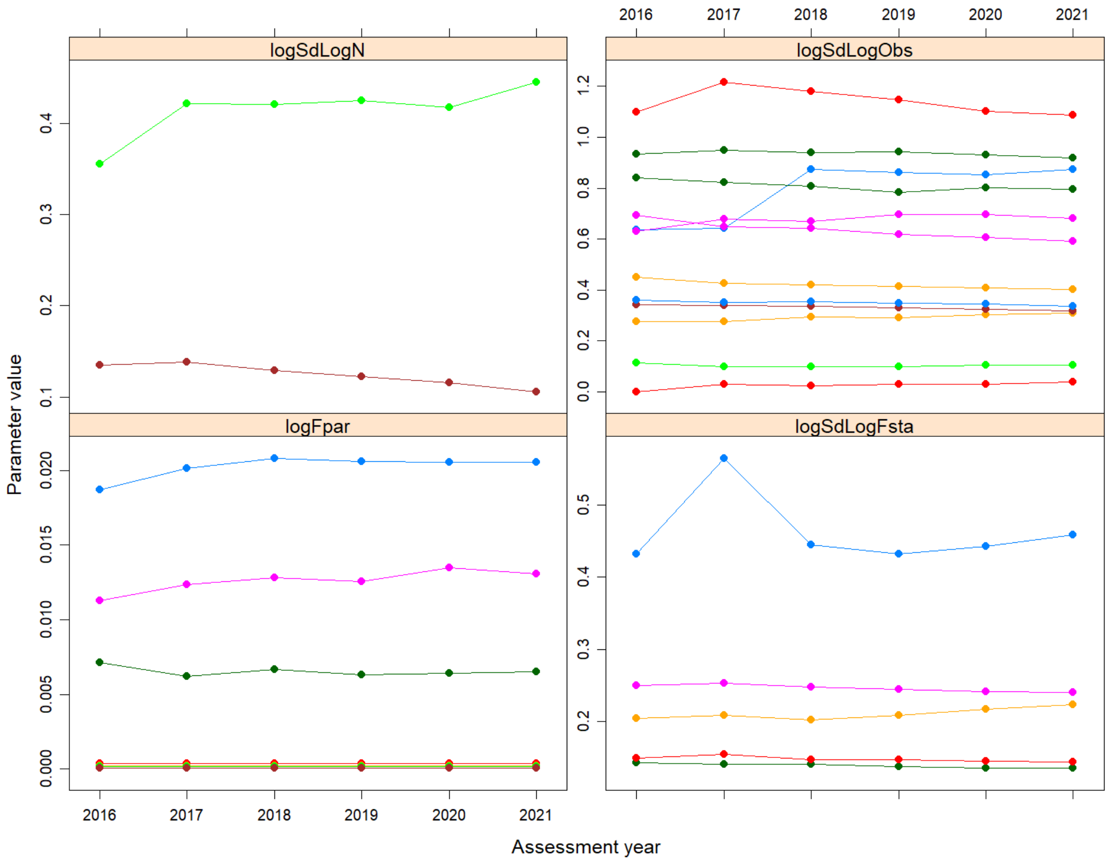


Figure 21.4.3. Turbot in Area 4. Retrospective analysis plot on the value of the estimated parameters, ideally, all show a flat line indicating that with reducing the model with a year's worth of data does not affect the parameters to be estimated: logSdLogN = the random walk in N, logSdLogObs is the observation variance in the surveys and catch, logFpar are the catchability parameters and logSdLogFsta are the sd's of the random walks in F.

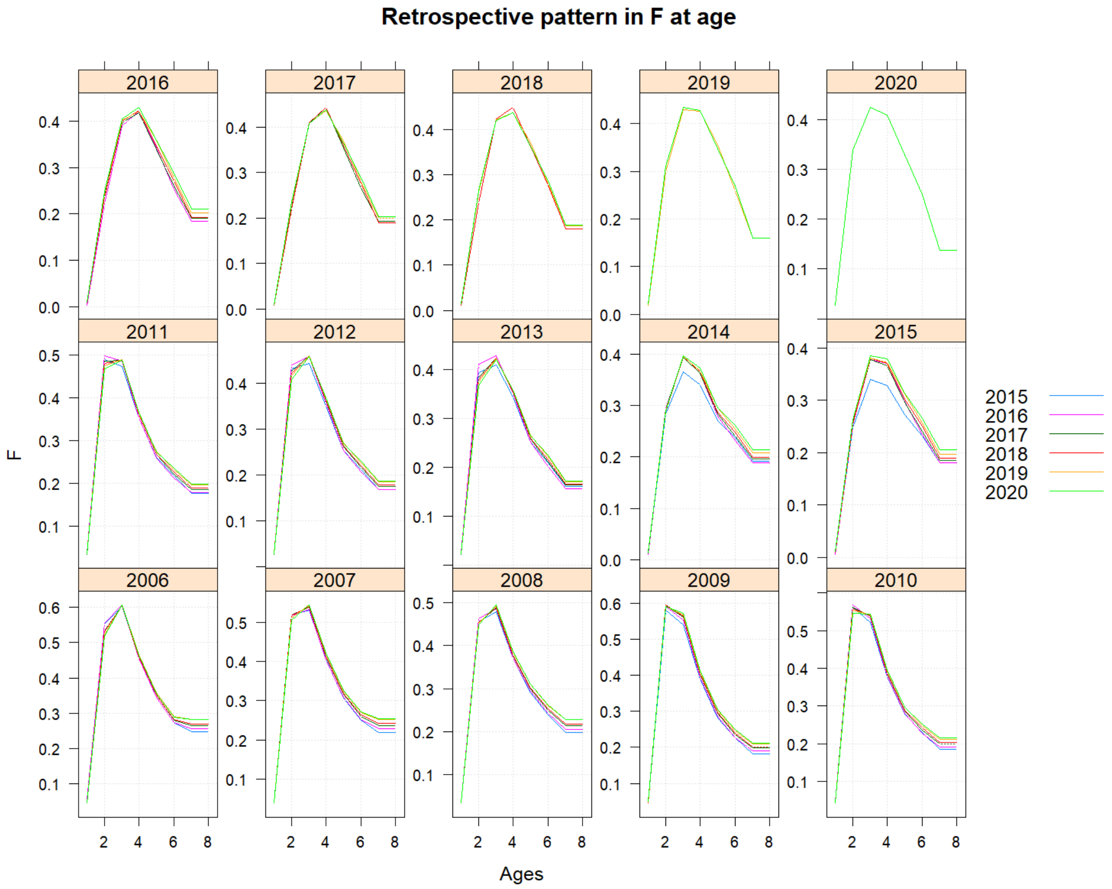


Figure 21.4.4. Turbot in Area 4. Retrospective analysis plot of selectivity pattern.

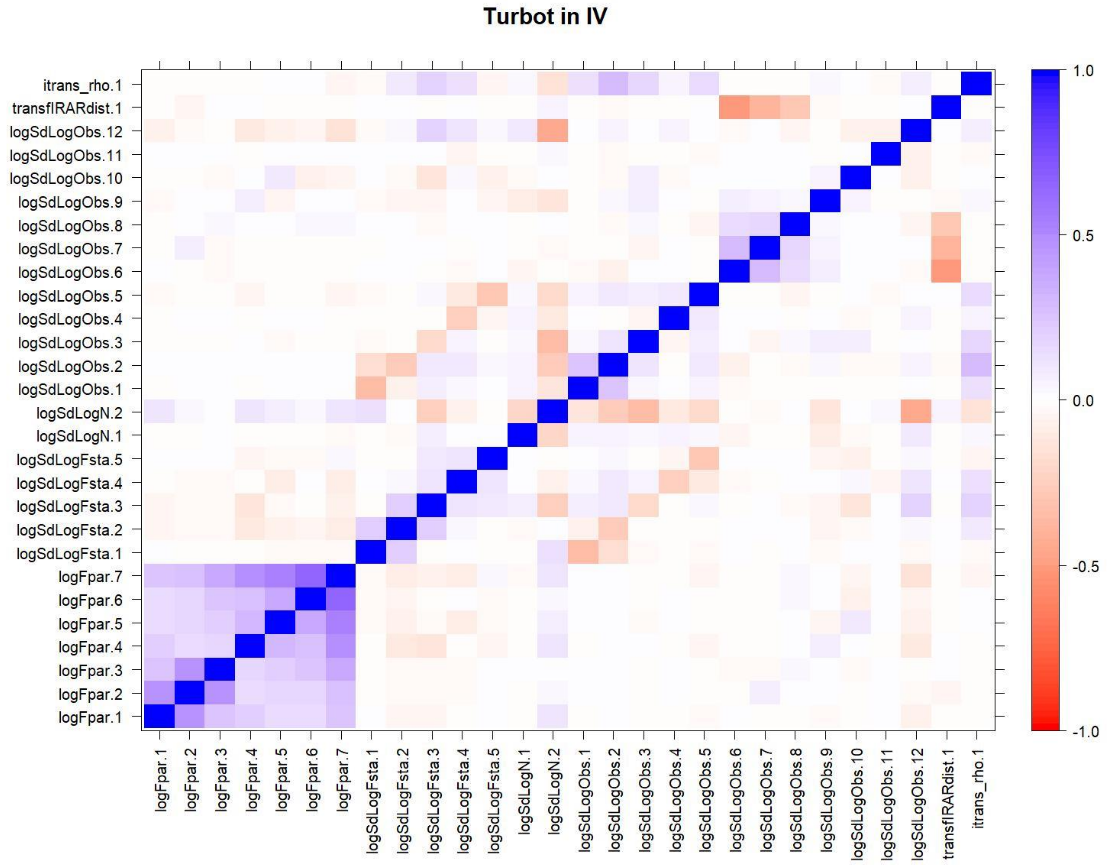


Figure 21.5.1. Turbot in Area 4. Parameter-correlation plot. It shows the correlation among all parameters that are estimated in the model. Fpar parameters refer to catchabilities, Fstates to the random walk in F, logN to the random walk in N, logObs to the observation variances, fRARdist to the auto-correlation in the surveys and trans_rho to the correlation in the F-random walks.

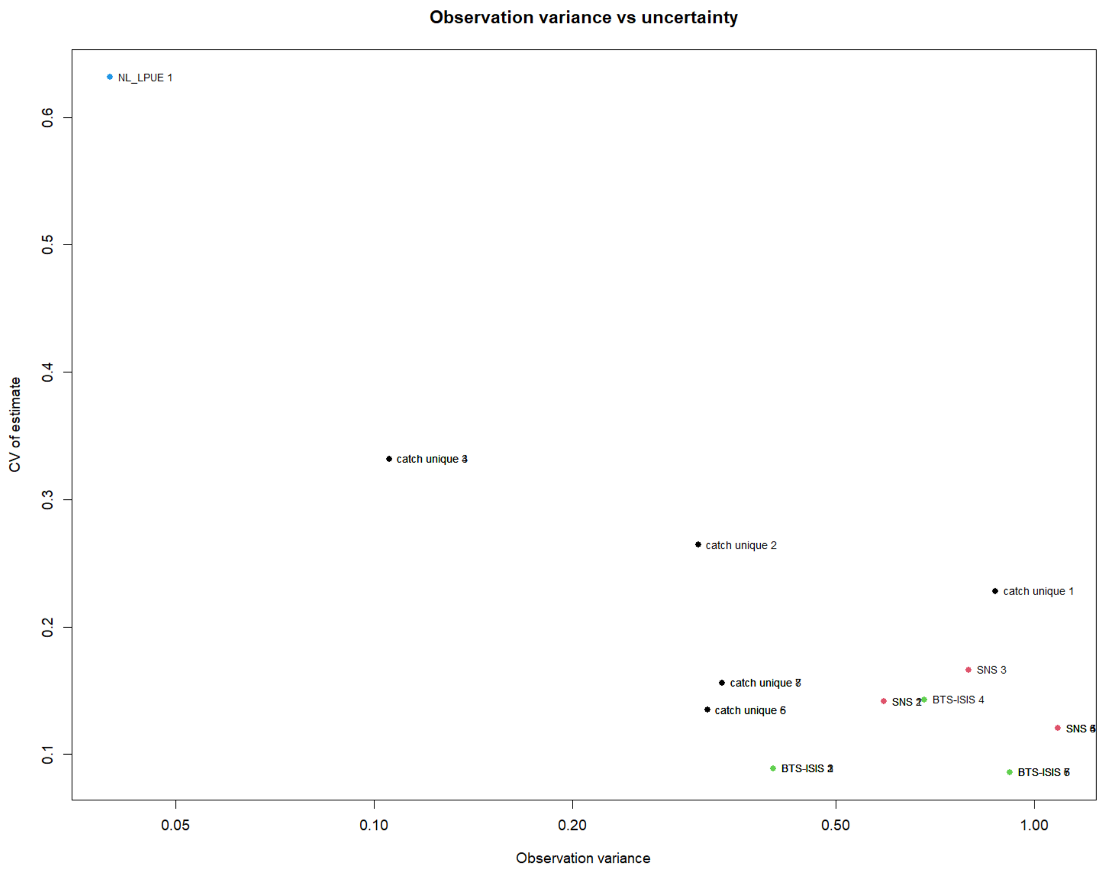


Figure 21.5.2. Turbot in Area 4. Plot showing the observation variance vs the CV of that estimate.

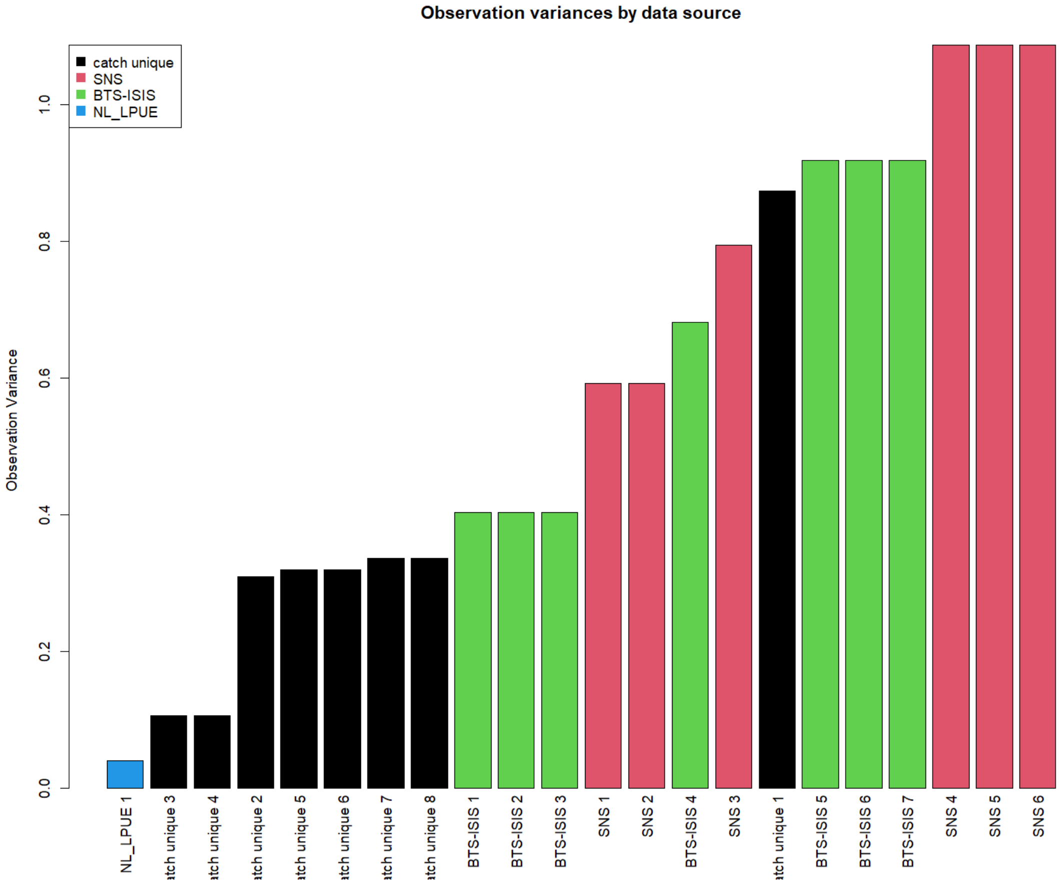


Figure 21.5.3. Turbot in Area 4. Estimated observation variances (scaling factor for each of the surveys), ordered from the best to the worst survey fit and has colour coding to show which bars belong to one dataset.

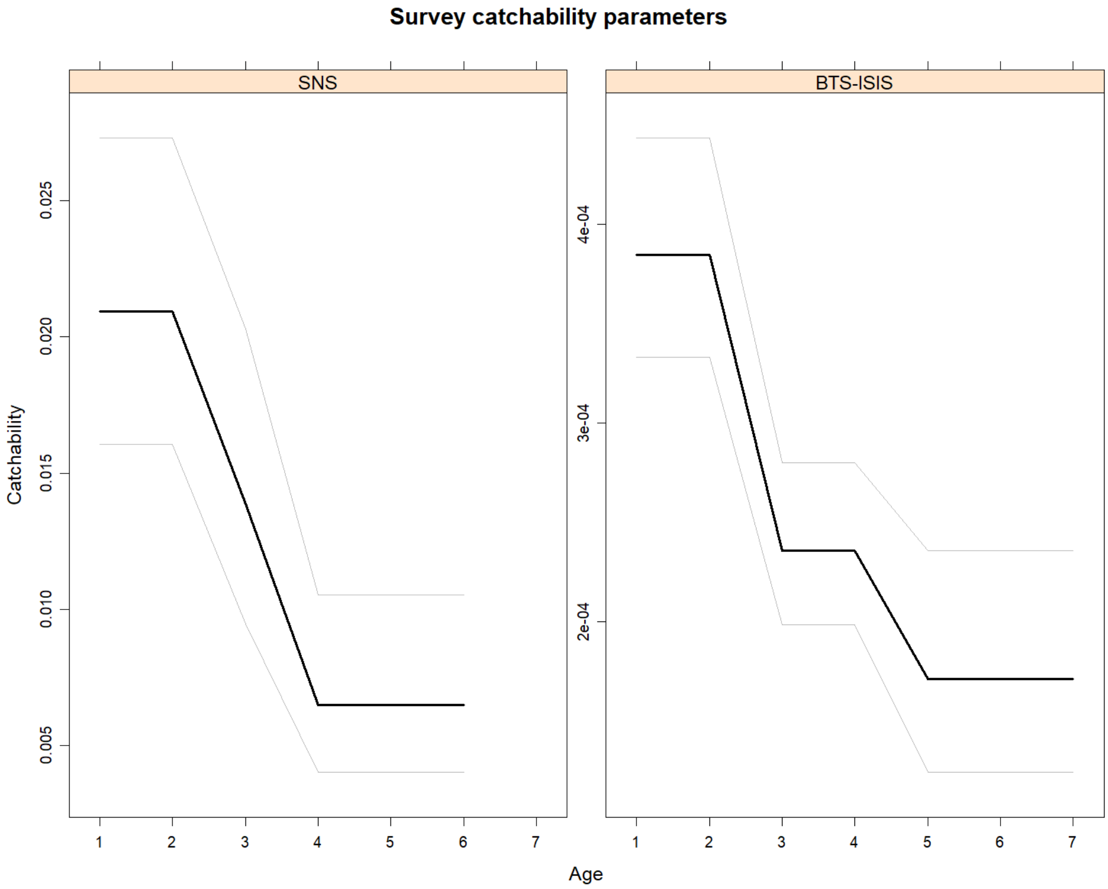


Figure 21.5.4. Turbot in Area 4. Catchabilities of the surveys for all surveys with more than 1 age-group.

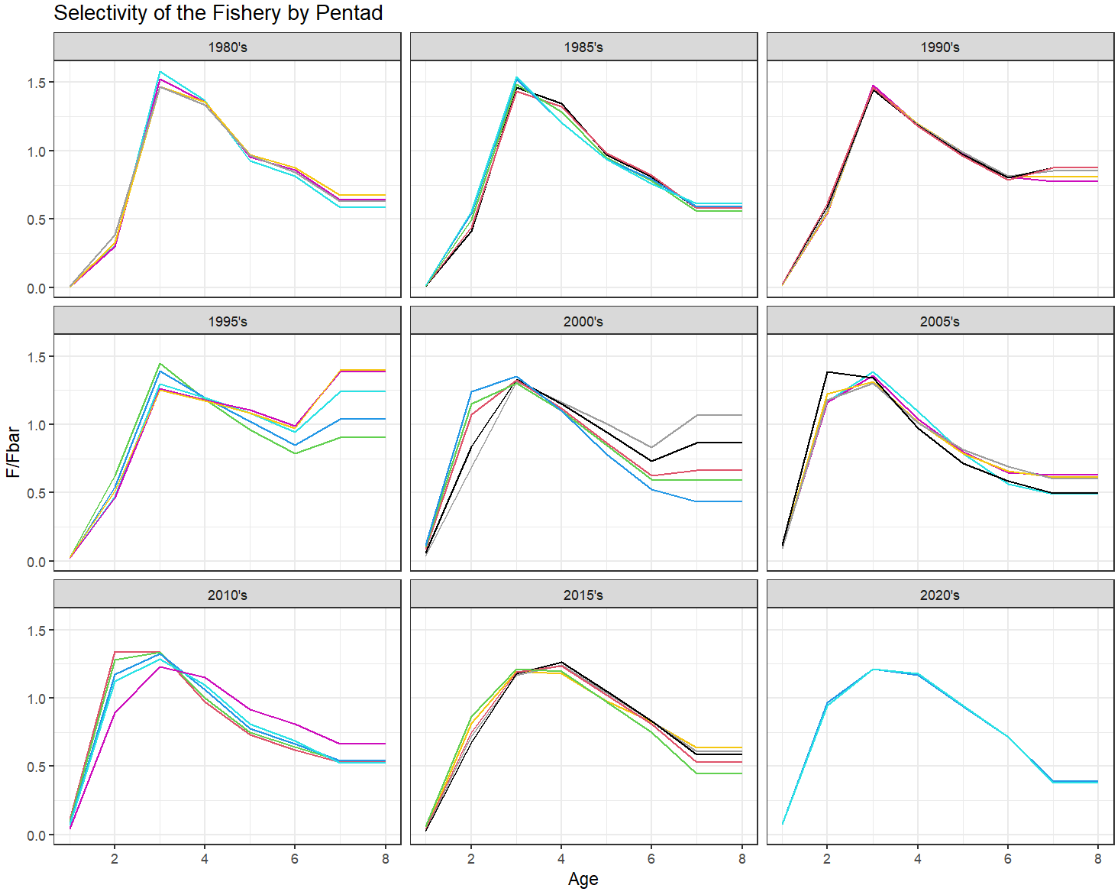


Figure 21.5.5. Turbot in Area 4. Estimated selectivity from 1981 to 2021, grouped by a 5-year period. Note the 1980s are 1981 up to 1984, 2015s is 2015 up to 2019. Values represent actual F-at-age.

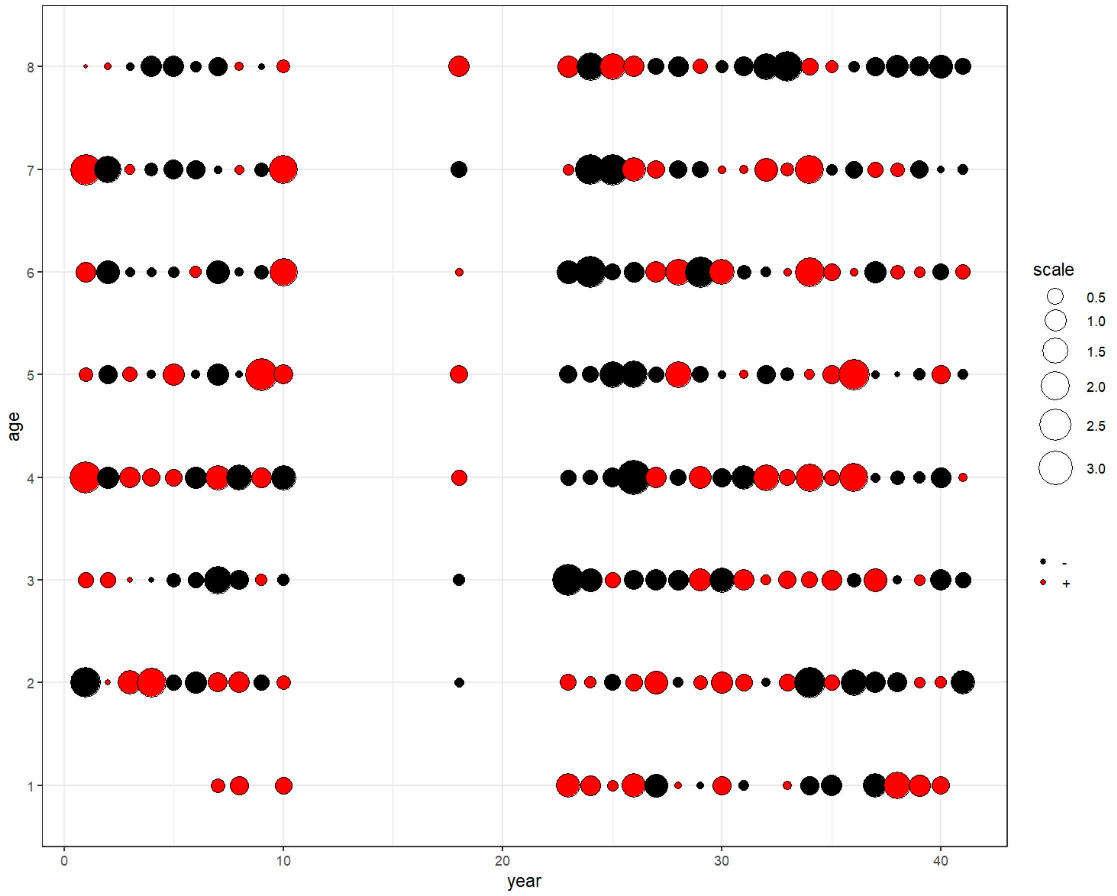


Figure 21.5.6. Turbot in Area 4. Residual bubble plot of landings.

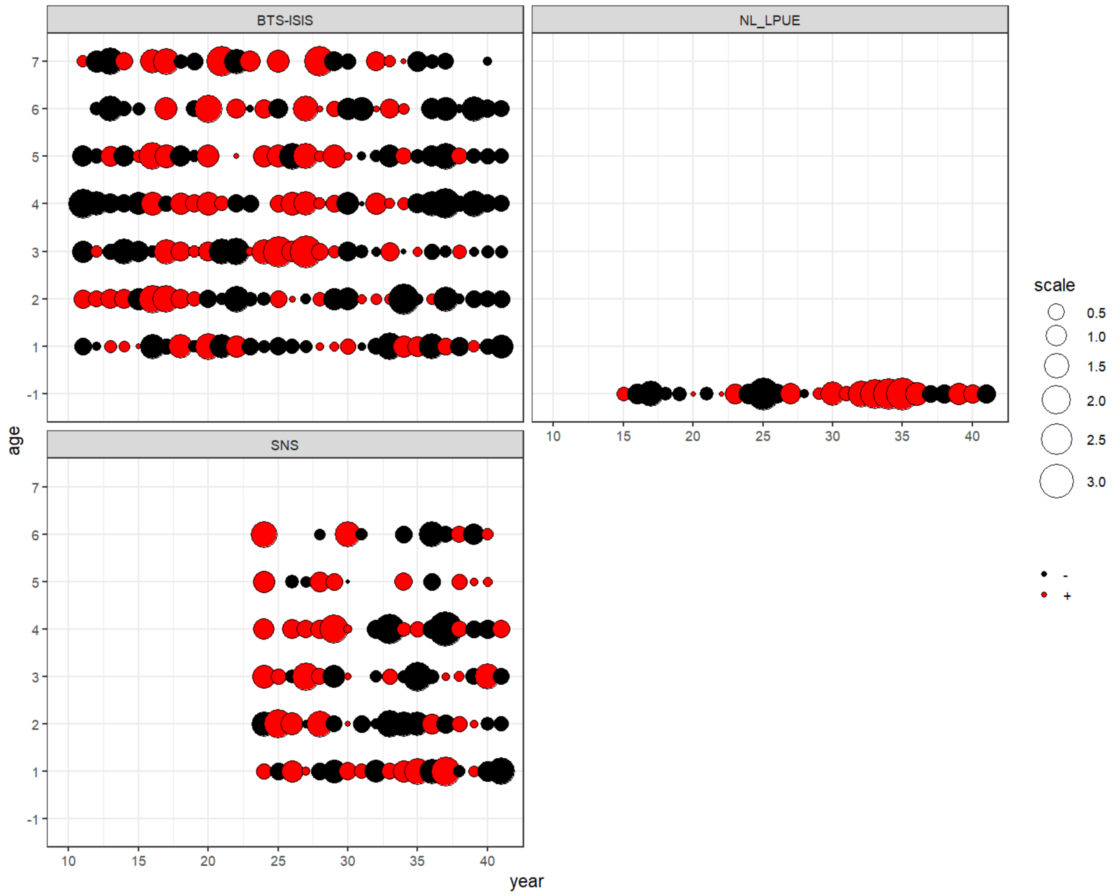


Figure 21.5.7. Turbot in Area 4. Residual bubble plot of SNS, BTS-ISIS survey and the Dutch LPUE index.

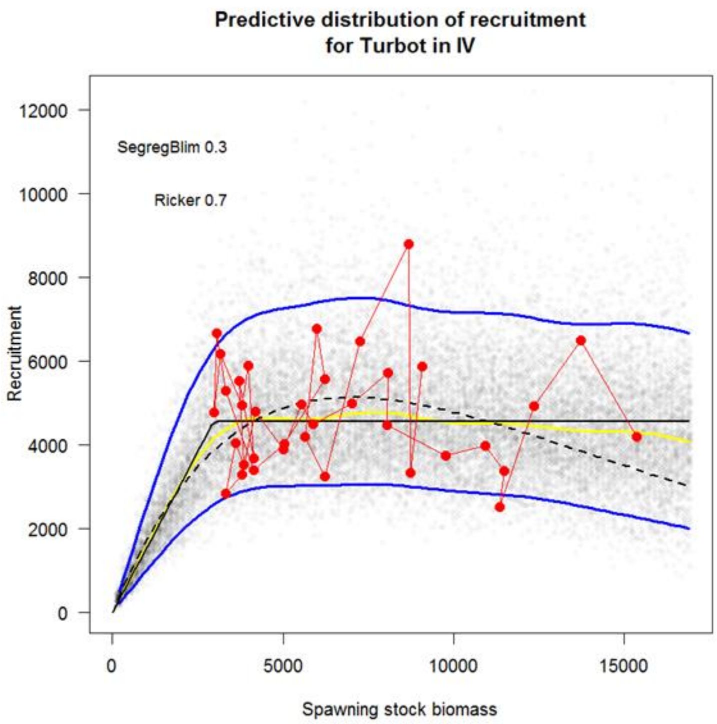


Figure 21.6.1. Turbot in Area 4. Stock recruitment pairs over time which has been used to calculate the reference points.

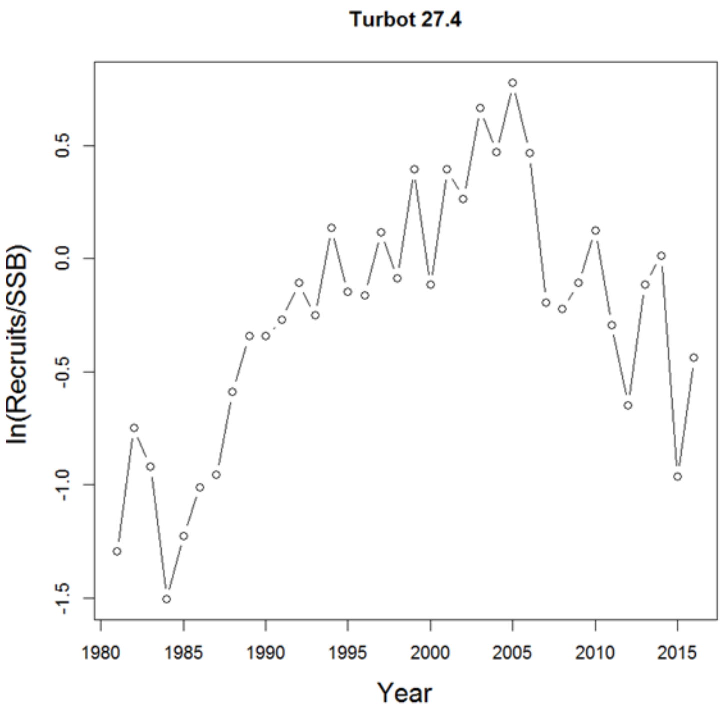


Figure 21.6.2 Turbot in Area 4. Productivity over time

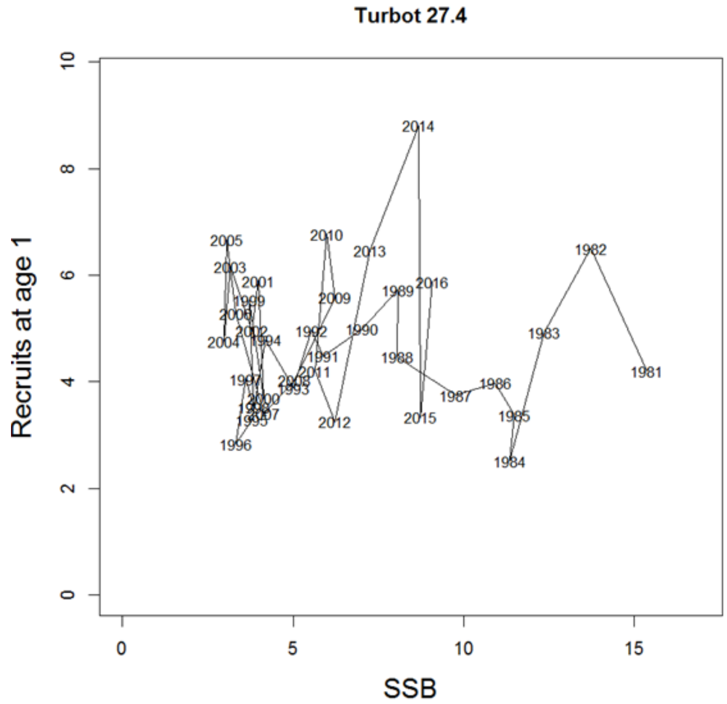


Figure 21.6.3. Turbot in Area 4. Stock recruitment pairs over time.

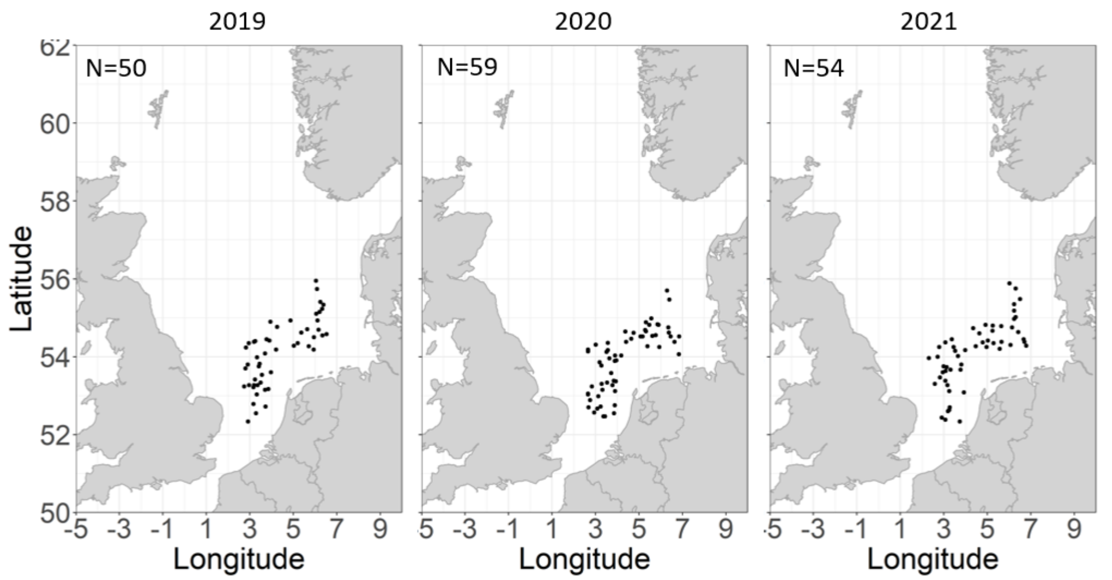


Figure 21.8.1. Turbot in Area 4. Maps showing the area survey stations monitored during the new Dutch industry-based survey in the period 2019 to 2021.

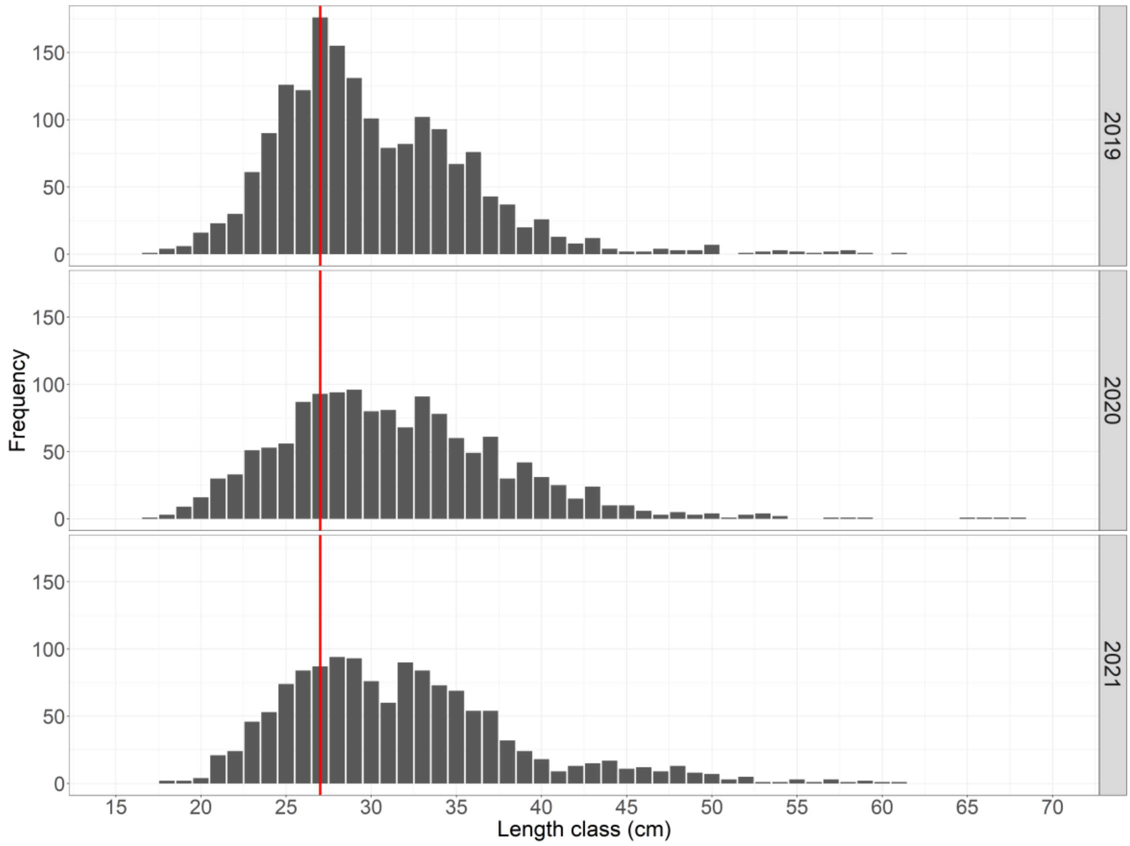


Figure 21.8.2. Turbot in Area 4. Length composition (1cm-classes) of individuals of turbot sampled within the Dutch industry in 2019 (top), 2020 (middle) and 2021 (bottom). The red line indicates the 27cm minimum landing size implemented by the Dutch POs.

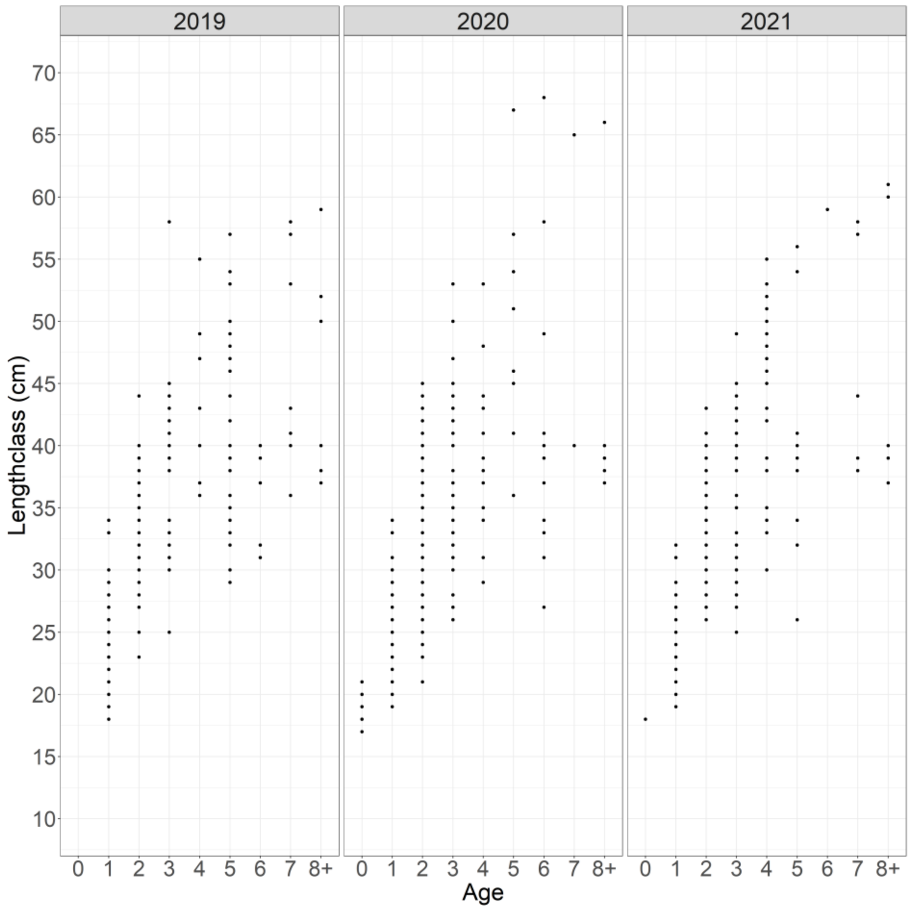


Figure 21.8.3. Turbot in Area 4. Age-length distribution of turbot (left) and brill (right) sampled in the 2019, 2020 and 2021 industry survey.

22 Whiting (*Merlangius merlangus*) in Division 3.a (Skagerrak and Kattegat)

22.1 General

22.1.1 Stock definition

There is a paucity of information on the population structure of whiting in Division 3.a (the Skagerrak-Kattegat area). No genetic or otolith-based surveys have been conducted. Tagging of whiting has previously been undertaken, but these data need to be re-examined. Results from previously modelled survey data (SURBAR) were inconclusive regarding independent population dynamics in Division 3.a in comparison with the North Sea (ICES, 2016), presumably due to the need of age readings in 3.a (age information used in SURBAR was borrowed from Subarea 4). The drop in landings in the beginning of the 1990s gives, however, an indication of local stock structure as this reduction was not paralleled by any similar event in the North Sea. There are also findings of locally spawned whiting eggs in Kattegat 3.aS (Börjesson *et al.*, 2013).

22.1.2 Ecosystem aspect

No new information was presented at the Working Group. A summary of available information on ecosystem aspects is presented in the Stock Annex last updated at ICES WKDEM (ICES, 2020).

22.1.3 Fisheries

Whiting landings in Division 3.a have declined in recent decades from over 20 000 tonnes in the 1980s to 179 tonnes in 2019, 520 tonnes in 2020 and 199 tonnes in 2021. Denmark is catching most of the whiting in the area; Sweden and Norway follow with considerably less amounts. The Danish industrial fleet (main target species: sprat) is landing 40–80% of whiting in the area. Information was uploaded to InterCatch by Sweden, Denmark, Norway, Germany and the Netherlands. Discard estimates are available since 2002. A summary of available information on fisheries and information on derivation of discards is presented in the Stock Annex (last updated during the WKDEM 2020 benchmark (ICES, 2020).

22.2 Data available

22.2.1 Catch

The estimation of discards is done using InterCatch data. In 2020 and 2021, ICES estimated catch was equal to 1830 and 1212 tonnes, respectively. They correspond to landings and discards (imported or raised) as shown in Table 22.1.

The raising of discards for unsampled strata was done assuming a discard rate equal to a weighted mean of reported discard rates, with weights equal to the total landings in tonnes. The raising is done by grouping all fleets by area. The industrial fleet, responsible for a substantial part of the landings (87% in 2020 and 43% in 2021), does not have any discards. The landings and estimated discards are shown in Table 22.2.

22.2.2 Survey index

A combined survey index was derived using four bottom trawl surveys that operate in the area, namely the two international bottom trawl surveys (NS-IBTS (Q1 and Q3) and BITS (Q1 and Q4)) and two Danish national bottom trawl surveys targeting cod and sole both conducted in Q4.

The survey index calculation is described in the stock annex, here a short description is given. Predictions of a Tweedie Generalised Additive model on a fine grid are used to estimate the biomass index. The model is described by the following equation

$$\log(\mu i) = Gear(i) + f_1(lon_i, lat_i) + f_2(timeOfYear_i, lon_i, lat_i) + f_3(time_i, lon_i, lat_i) + f_4(depth_i) + U(i)_{ship:gear} + \log(HaulDur_i),$$

which includes a time-invariant spatial effect (f_1), a seasonal repeating pattern (f_2), a space-time interaction effect (f_3) that can capture smooth changes over longer time scales, a smooth function of depth (f_4), a fixed gear effect and random effects for the interaction between ship and gear. Finally, the model includes an offset term of the logarithm of haul duration that corresponds to the assumption that catch is proportional to haul duration.

The prediction of the biomass index in Q1 is used for giving advice and is shown in Figure 22.1. Quarter 1 is used as it covers the early part of the spawning period of whiting in the greater North Sea (González-Irusta and Wright, 2017).

22.3 Data analyses

22.3.1 Exploratory assessments

Previously, an exploratory SURBAR analysis has been performed and showed that internal consistency was virtually absent, impeding cohort analysis for the stock (ICES, 2016). The main conclusion from the SURBAR analysis was that the lack of internal consistency in the available survey indices (Figure 12.1.6 in ICES 2016) prevents an analytical assessment. This internal inconsistency could be related to a) age reading problems, and/or b) a mixture of several stock components leading to unaccounted migrations.

During the WKDEM 2020 benchmark (ICES, 2020) there was an attempt to do an assessment using the surplus production model in continuous time (SPiCT). The estimated uncertainty was very high, therefore none of the scenarios deemed adequate to be used to provide advice for the stock. During WGNSSK 2022, an exploratory SPiCT assessment had similar issues and was not put forward to provide catch advice.

22.3.2 Advice

In the last benchmark of whiting in Division 3.a. in 2020 (ICES WKDEM, 2020) the stock was raised from category 5 to category 3 (ICES, 2018). The advice, starting from 2020, was based on the trends of new combined survey index, which was first introduced in the benchmark, using the “2-over-3 rule”. According to the rule, the advice for the next 2 years will be equal to the last given advice multiplied by the ratio of the average index in the last 2 years to the average index during the 3 years prior. For the first application of the rule, an average observed catch should be used instead of the last advice. An uncertainty cap should be used; this means that the next advice cannot increase or decrease by more than 20% compared to the last advice. Finally, a precautionary buffer of 20% should be applied if it was not applied in the last 2 years and there is no indication of the stock status.

For the first application of the “2-over-3” rule in 2020, the average catch of the last 10 years ($C_{2010–2019}$=1203 tonnes) is used. Additionally, the precautionary buffer is applied in 2020 as it was last applied in 2017. In 2022, ICES moves away from the “2-over-3” rule as it is shown in large scale Management Strategy Evaluations to be not precautionary. A set of empirical rules are used instead, summarised in the WKLIFE-X report (ICES, 2020).

Whiting in Division 3.a lacks representative length distributions from the catch, as very few samples from the industrial fishery are collected. The industrial fleet is responsible for a considerable part of the landings and uses gear with small mesh sizes, thus, catching smaller whiting compared to the other fleets. The consequence is that the only applicable empirical rule is the “*rb-rule*”. This consists of a multiplier “*r*” that captures the survey index trends, a biomass safeguard *b* that is below one if the stock biomass index is lower than a trigger reference point $I_{trigger}$, defined as 1.4 I_{loss}, where I_{loss} is the lowest observed index over the entire index time series. Finally, a multiplier m = 0.5 is used to ensure that the rule is precautionary. The calculations are summarised in Table 22.3

For whiting in Division 3.a, ICES advises that when the precautionary approach is applied, catches in each of the years 2023 and 2024 should be no more than 676 tonnes. This corresponds to projected landings corresponding to the advice equal to 188 tonnes.

The history of ICES advice, advice basis and agreed TAC is shown in Table 22.4.

22.3.3 Issues for future benchmarks

During the last benchmark of whiting in Division 3.a (ICES, 2020) there was an attempt to assess the stock using the surplus production model in continuous time (SPiCT) and several scenarios of data input were considered. The conclusion was that there was no model that could be used to provide advice. Future research is needed to improve the assessment model. More specifically, SPiCT cannot deal at the moment with biomass indices that combine multiple surveys from different quarters of the year and an extension to the model is needed to allow for such autocorrelated time series.

In the routine surveys, IBTS quarter 1 and quarter 3 in Division 3.a, biological data are collected for this species, in particular otoliths for aging and maturation information. These can be used in a future benchmark to understand growth and maturity patterns of the population in this area.

22.4 References

González-Irusta, J. M., & Wright, P. J. (2017). Spawning grounds of whiting (Merlangius merlangus). Fisheries Research, 195(June), 141–151. https://doi.org/10.1016/j.fishres.2017.07.005

ICES. 2018. Advice basis. *In* Report of the ICES Advisory Committee, 2018. ICES Advice 2018, Book 1, Section 1.2. https://doi.org/10.17895/ices.pub.4503.

ICES. 2020. Benchmark Workshop for Demersal Species (WKDEM). ICES Scientific Reports. 2:31. 136 pp. http://doi.org/10.17895/ices.pub.5548

Table 22.1. Whiting in Division 3.a (Skagerrak and Kattegat): Landings and discards split be raised and imported. All weights are in tonnes.

	Catch category	Imported or Raised	Catch (tonnes)	Percent
2020	Landings	Imported	520	
	Discards	Imported	990	76 %
	Discards	Raised	320	24 %
	Logbook registered discard	Imported	0	
	BMS landing	Imported	0	
	Catch category	**Imported or Raised**	**Catch (tonnes)**	**Percent**
2021	Landings	Imported	199	
	Discards	Imported	902	89 %
	Discards	Raised	111	11 %
	Logbook registered discard	Imported	0	
	BMS landing	Imported	0	

Table 22.2. Whiting in Division 3.a (Skagerrak and Kattegat): Nominal landings (t) as supplied by the Study Group on Division 3.a Demersal Stocks (ICES, 1992b) and updated by the WGNSSK in 2007. The estimates of discards for 2002–2018 were updated in WKDEM2020 (ICES, 2020).

Year	Denmark (1)			Norway	Sweden	Others	Total	WG estimate of Discards
1975	19,018			57	611	4	19,690	
1976	17,870			48	1,002	48	18,968	
1977	18,116			46	975	41	19,178	
1978	48,102			58	899	32	49,091	
1979	16,971			63	1,033	16	18,083	
1980	21,070			65	1,516	3	22,654	
	Total consumption	**Total industrial**	**Total**					
1981	1,027	23,915	24,942	70	1,054	7	26,073	
1982	1,183	39,758	40,941	40	670	13	41,664	
1983	1,311	23,505	24,816	48	1,061	8	25,933	
1984	1,036	12,102	13,138	51	1,168	60	14,417	
1985	557	11,967	12,524	45	654	2	13,225	
1986	484	11,979	12,463	64	477	1	13,005	
1987	443	15,880	16,323	29	262	43	16,657	
1988	391	10,872	11,263	42	435	24	11,764	
1989	917	11,662	12,579	29	675	-	13,283	
1990	1,016	17,829	18,845	49	456	73	19,423	
1991	871	12,463	13,334	56	527	97	14,041	
1992	555	3,340	3,895	66	959	1	4,921	
1993	261	1,987	2,248	42	756	1	3,047	
1994	174	1,900	2,074	21	440	1	2,536	
1995	85	2,549	2,634	24	431	1	3,090	

Year	Denmark (1)			Norway	Sweden	Others	Total	WG estimate of Discards
1996	55	1,235	1,290	21	182	-	1,493	
1997	38	264	302	18	94	-	414	
1998	35	354	389	16	81	-	486	
1999	37	695	732	15	111	-	858	
2000	59	777	836	17	138	1	992	
2001	61	970	1,031	27	126	+	1,184	
2002	164	1347	1510	23	134	1	1669	2373
2003	104	641	745	20	72	2	839	1837
2004	252	954	1206	17	74	1	1298	2782
2005	110	853	962	13	73	0	1048	1625
2006	71	410	481	11	86	0	578	1497
2007	57	275	332	14	82	1	429	1524
2008	54	286	340	14	52	0	407	795
2009	73	172	245	10	34	0	289	778
2010	49	158	207	10	30	1	248	803
2011	40	44	85	8	20	0	114	937
2012	30	7	37	16	10	1	63	377
2013	29	130	159	8	15	1	183	687
2014	49	346	395	5	37	2	439	649
2015	75	570	645	6	56	5	712	820
2016	129	334	463	13	62	5	543	1307
2017	189	193	382	8	33	7	431	1185
2018	175	156	332	5	34	2	372	1357
2019	78	75	153	5	20	1	179	627
2020	64	437	501	4	14	< 0.5	520	1310
2021	100	85	185	2	12	1	199	1014

[1] Values from 1992 updated by WGNSSK (2007), WGNSSK (2011).

Table 22.3. Whiting in Division 3.a. Definitions and values of the components of the *rb*-rule.

Component	Definition	Description	Value
A_y	Advice for years 2020 and 2021	Last advice (using the "2-over-3" rule	929 tonnes
I_{loss}	Minimum observed index		0.39
$I_{trigger}$	1.4 I_{loss}	Biomass safeguard trigger	0.54
r	$\frac{\bar{I}(2020,2021)}{\bar{I}(2017,2018,2019)}$	Biomass index trend	1.45
b	$\min\left(1, \frac{I_{2021}}{I_{trigger}}\right)$	Biomass safeguard	1
m		Multiplier that ensures probability of B falling below B_{lim} to no more than 5%	0.5
Advice for 2023, 2024	A_y * r * b * m	"rb-rule"	676 tonnes

Table 22.4. Whiting in Division 3.a. ICES advice, agreed total allowable catch (TAC) and ICES estimated landings and discards. All weights are in tonnes.

Year	ICES advice/single-stock exploitation boundaries	Catch corresponding to advice	Landings corresponding to advice	Agreed TAC	ICES landings*	ICES catches*^
1987	Precautionary TAC	-		17000	16657	
1988	Precautionary TAC	-		17000	11764	
1989	Precautionary TAC	-		17000	13283	
1990	Precautionary TAC	-		17000	19423	
1991	TAC	-		17000	14041	
1992	No advice	-		17000	4921	
1993	Precautionary TAC	-		17000	3047	
1994	If required, precautionary TAC	-		17000	2536	
1995	If required, precautionary TAC	-		15200	3090	
1996	If required, precautionary TAC	-		15200	1493	
1997	If required, TAC equal to recent catches	-		15200	414	
1998	No advice			15200	486	
1999	TAC, average period 1993–1996	6000		8000	858	
2000	TAC, average period 1996–1998	1500		4000	992	
2001	TAC, average period 1996–1998	1500		2500	1184	
2002	TAC, average period 1996–1998	1500		2000	1669	4042
2003	TAC, average period 1996–1998	1500		1500	839	2676
2004	TAC, average period 1996–1998	1500		1500	1298	4080
2005	Average period 1996–1998	1500		1500	1048	2673
2006	Average period 1996–1998	1500		1500	578	2075
2007	Average period 1996–1998	1500		1500	429	1953
2008	Recent average catches	1050		1050	407	1201
2009	Same advice as last year	1050		1050	289	1067
2010	Same advice as last year	1050		1050	248	1050

Year	ICES advice/single-stock exploitation boundaries	Catch corresponding to advice	Landings corresponding to advice	Agreed TAC	ICES landings*	ICES catches*^
2011	No advice	-		1050	114	1050
2012	Reduce catch	-		1050	63	440
2013	20% Reduction in catches (average of the last 3 years)	< 500		1050	183	870
2014	No new advice, same as for 2013	< 500		1050	439	1088
2015	No new advice, same as for 2014	< 500	< 212	1050	712	1531
2016	Precautionary approach (same advised catch value as given for 2015)	≤ 500		1050	543	1850
2017	Precautionary approach (same advised catch value as given for 2015)	≤ 500		1050	431	1615
2018	Precautionary approach	≤ 400		1050	372	1729
2019	Precautionary approach	≤ 400		1660	179	806
2020	Precautionary approach	≤ 400		1660	520	1830
2021	Precautionary approach	≤ 929		929	199	1212
2022	Precautionary approach	≤ 929		929		
2023	Precautionary approach	≤ 676				
2024	Precautionary approach	≤ 676				

*** Includes bycatch in small-mesh industrial fishery.**

^ Since 2018, discards include BMS landings

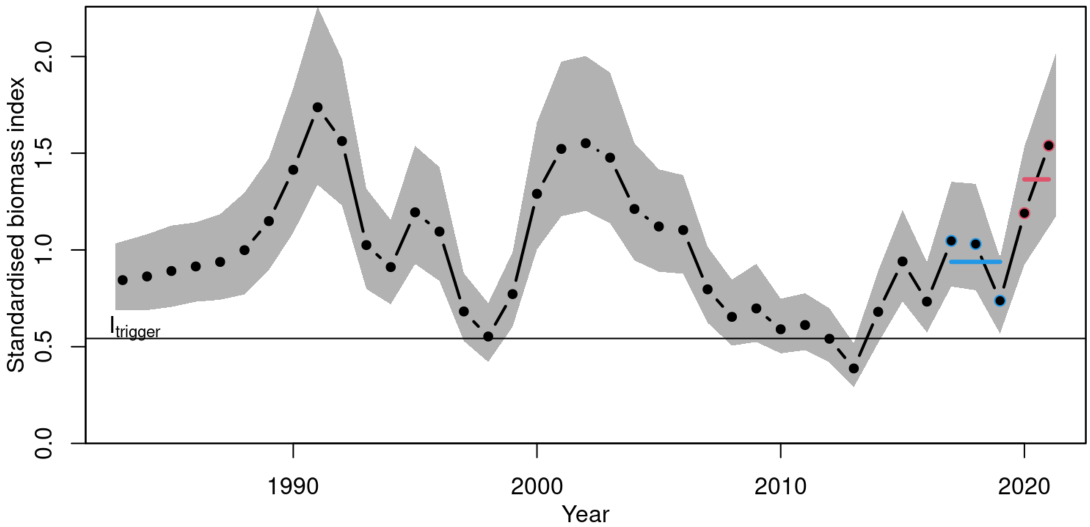


Figure 22.1. Whiting in Division 3.a (Skagerrak and Kattegat): Combined biomass index (Q1) using survey data from the two international bottom trawl surveys and two Danish national surveys. The average of the last two years (red line) and the average of the three years before that (blue line) are used to calculate the *r* multiplier of the "rb-rule". The horizontal line shows the $I_{trigger}$ reference point which is 1.4 times the minimum observed index value (I_{loss}). The shaded grey area shows the 95% confidence interval.

23 Whiting (*Merlangius merlangus*) in Subarea 4 (North Sea), Division 7.d (Eastern English Channel)

This Section contains the assessment and forecast relating to whiting in the North Sea (ICES Subarea 4) and eastern Channel (ICES Division 7.d). The current assessment is formally classified as an update assessment. The most recent benchmark for this stock was conducted in January 2018 (ICES, 2018a). The benchmark concluded with a SAM assessment with new input data and updated reference points. An interbenchmark was carried out in 2021 to assess the impact of new natural mortality estimates on the assessment, and the reference points were updated as a result (ICES, 2021a). For the 2022 assessment, the SAM model was updated with a plus group at age 6 (previously age 8) and F averaged across age 2 to 5 (previously 2 to 6). This was done in order to address retrospective patterns caused by a drop in the abundance of age 7 and 8 individuals which resulted in a much higher F, and lower SSB, compared to previous assessments. As the assessment model was updated, reference points were updated. Both the model changes and the reference points update were subject to a review. Since 2020, survey indices are recalculated using a new automated substitution procedure to fill ALK key in areas with low sample size. This new automated method is seen as an improvement to data quality and transparency of the procedure. For the 2022 assessment of whiting in 27.4 and 7.d, the historical time series of DATRAS survey indices obtained with the new automated substitution procedure are used, as in the 2021 assessment.

23.1 General

23.1.1 Stock definition

A summary of available information on stock definition can be found in the Stock Annex and in the WKNSEA 2018 benchmark report working documents (ICES, 2018a). A complex population structure for whiting in the North Sea has been proposed, based on studies about whiting movements, life-history traits, genetic data, identification of spawning aggregation, as well as on population temporal asynchrony observed in SSB, recruitment and egg abundance between areas. The benchmark concluded that literature and provided data did not suffice to revise management units for this stock. As before, the new assessment was run for the combined North Sea and Eastern Channel (27.4 and 27.7d). Exploratory SURBAR assessments were run for individual components (northern and southern component) and compared to the combined stock.

23.1.2 Ecosystem aspects

No new information was presented at the WG. A summary of available information on ecosystem aspects is presented in the Stock Annex prepared by ICES WKROUND (2013).

23.2 Fisheries

Information on the fishery (and its historical development) is contained in the Stock Annex prepared by ICES WKNSEA (2018a).

23.3 ICES advice

ICES advice for 2020

In May 2019, ICES concluded as follows:

ICES advises that when the MSY approach is applied, catches in 2020 should be no more than 22 082 tonnes. If discard and industrial bycatch rates do not change from the average of the last 3 years (2016–2018), this implies landings of no more than 12 737 tonnes and human consumption catch of no more than 19 354 tonnes.

ICES advice for 2021

In April 2020, ICES concluded as follows:

ICES advises that when the MSY approach is applied, catches in 2021 should be no more than 26 304 tonnes. If discard and industrial bycatch rates do not change from the average of the last 3 years (2017–2019), this implies landings of no more than 14 487 tonnes and human consumption catch of no more than 24 071 tonnes.

ICES advice for 2022

In April 2021, ICES concluded as follows:

ICES advises that when the MSY approach is applied, catches in 2022 should be no more than 88 426 tonnes. If discard and industrial bycatch rates do not change from the average of the last 3 years (2018–2020), this implies landings of no more than 51 276 tonnes and human consumption catch of no more than 85 460 tonnes.

23.4 Management

Management of whiting is implemented by TAC and technical measures. The TACs for this stock are split between two areas: (i) Subarea 4 and Division 2.a (EU waters), and (ii) Divisions 7b–k. Since 1996 the North Sea and eastern Channel whiting assessments have been combined into one.

The TAC in Subarea 4 for 2016 was set as a Roll-over TAC at 13 678 tonnes and for 2017 the TAC was increased to 16 003 tonnes of landings for human consumption. Since 2018, with introduction of the landing obligation the TAC accounts for total human consumption catch in Subarea 4, including discards and landings below minimum landings size (BMS) but excluding industrial bycatch (IBC). The TAC in Subarea 4 for 2020 was set to 17 158 tonnes, for 2021 it was 21 306 tonnes and for 2022 it was 26 636 tonnes. There is no separate TAC for Division 7.d; landings from this Division are counted against the TAC for Divisions 7.b–k combined (22 778 tonnes in 2016, 27 500 tonnes in 2017, 22 213 tonnes in 2018, 19 184 tonnes in 2019, 10 863 in 2020, 10 259 in 2021, and 8 352 in 2022. There are no means to control how much of the Division 7.b–k TAC is taken from Division 7.d. By comparison, a specific TAC for Division 7.d was established for cod in 2009, and the same procedure for whiting may be appropriate.

Since 2006, the landings data have been collated separately for each area. In previous years, the human consumption landings in Subarea 4 and Division 7.d were calculated as about 80% and 20% of the combined area totals, respectively. In 2021, 79% of the total landings originated from Subarea 4.

The minimum landing size for whiting in Subarea 4 and Division 7.d is 27 cm. The minimum mesh size for targeting whiting in Subarea 4 is 120 mm and in Division 7.d is 80 mm.

Whiting are a by-catch in some *Nephrops* fisheries that use a mesh size of 80 mm, although landings are restricted through bycatch regulations. They are also caught in flatfish fisheries that use a smaller mesh size. Industrial fishing with small-meshed gear is permitted, subject to by-catch limits of protected species. Regulations also apply to the area of the Norway pout box, preventing industrial fishing with small meshes in an area where the by-catch limits are likely to be exceeded. Industrial bycatch occurred mainly in Subarea 4 by Danish industrial fisheries. In

2016–2018, some very minor catches in the Norwegian fishery have been reported as BMS may be considered industrial bycatch but were not reported as such.

Conservation credit scheme

Since 2008, real time closures (RTCs) have been implemented under the Scottish Conservation Credits Scheme (CCS). The CCS has two central themes aimed at reducing the capture of cod through (i) avoiding areas with elevated abundances of cod through the use of Real Time Closures (RTCs) and (ii) the use of more species selective gears. Within the scheme, efforts are also being made to reduce discards generally. In 2009, 144 RTCs were implemented, and the CCS was adopted by 439 Scottish and around 30 English and Welsh vessels. In 2010, there were 165 closures, and from July 2010, the area of each closure increased (from 50 square nautical miles to 225 square nautical miles). In more recent years, the following numbers of closures were implemented: 185 (2011), 173 (2012), 166 (2013), 94 (2014), 97 (2015) and 114 (2016). Although the scheme is intended to reduce mortality on cod, it undoubtedly has an effect on the mortality of associated species such as whiting. However, the scheme was suspended 20 November 2016 and there are no plans for its reintroduction.

In 2016, 14 Scottish demersal whitefish vessels participated in a trial Fully Documented Fishery (FDF) scheme, following similar schemes during 2010–2015. The uptake of the scheme declined due to concerns about monitoring of discards under the EU Landing Obligation. The cod-specific FDF scheme terminated at the end of 2016, due to the suspension of most aspects of the EU Cod Recovery plan which removed the opportunity for countries to provide additional quota for participants. However, a new Scottish FDF scheme has commenced, which is being run along similar lines and which is intended to monitor discarding of saithe and monkfish. Since 2017 there were no data submissions to InterCatch on discard rates from the FDF fleets for whiting.

23.5 Data available

23.5.1 Catch

Since 2009, international data on landings and discards have been collated through the InterCatch system. As additional categories logbook registered discards and BMS landings can be uploaded. In 2021 data, no logbook registered discards are submitted. Minor whiting landings have been reported as BMS landings into InterCatch since 2016. In 2021 data, these mostly originated from Scotland OTB_DEF métiers (13 t). Generally, BMS was treated as discards as in previous years.

2019 Swedish landing data in area 4 were missing from the submission to InterCatch in 2020 and the Swedish catches (6 tonnes) were added manually in the assessment. In 2021, Swedish catch data for 2019 was submitted to InterCatch. InterCatch data was therefore raised for both 2019 and 2020. In 2022, Belgium submitted age distribution data for 2020 and 2021. In addition, an error was found in the 2020 Scottish data which was resubmitted. InterCatch was therefore raised for both 2020 and 2021. In 2021 data, 46% of the landings (here total landings include industrial bycatch) had associated discard data imported to InterCatch. The landings of métiers for which discard data was provided in 2021 are illustrated in Figure 23.1. Discards were raised from discard ratios from Subarea 4 and Division 7.d combined. Data are stratified by gear type (TR1 and TR2) and quarter to raise discards for fleets without imported discards, while for other gear types discards are raised using discard rates from all available fleets. The raised discards amounted to 48% of total discards (Table 23.3b). Industrial bycatch landings were excluded from the discard raising, as no discards occur in that fleet. Throughout this report minor BMS landings were grouped together with discards for age allocations as well as estimation of mean weights-at-age.

Figure 23.2a shows métier specific landings in percent of the total landings in 2021 for whiting in Subarea 4 and Division 7.d, for fleets sampled for age compositions in landings and unsampled fleets. The Figure also shows the cumulative landings when sampled and unsampled fleets are ordered by landings yield. Sampled fleets comprise around 67% of the overall landings, and are available for 11 métiers (Table 23.3.c).

However, although the unsampled fleets provide considerable landings overall (33%), most métiers provide less than 5% of the overall landings each. A métier summarized as miscellaneous landings of industrial bycatch (MIS_MIS_0_0_0_IBC) provides 6% of the total landings, all of which occurred in the Danish fishery and were not sampled.

For raising discard rates from sampled to unsampled fleets all samples were used with splitting of fleets on the basis of gear type. Discard rates for unsampled whiting fleet components were obtained from discards reported by France, UK (England, Scotland), Netherlands, Denmark, Belgium and Germany.

Of the total discards, 52% were imported into InterCatch. 53% of the discards were sampled for age distributions (Table 23.3c). The 12 métiers providing discard samples and unsampled métiers are listed in Figure 23.2b.

Official reported landings by country, WG estimates of total catch and catch component yields, as well as TACs covering the respective areas are given in Table 23.1 for the North Sea (Subarea 4) and in Table 23.2 for the Eastern Channel (Division 7.d).

ICES estimates of numbers and weights at age for the defined catch components (total catch, landings, discards and industrial bycatch) are given in tables 23.4–23.11. In 2021, discards represented 44% of the total catches (Table 23.12). Figure 23.3 plots the trends in the commercial catch for each component in Subarea 4 and Division 7.d combined. Recent years have seen these time series stabilize to a certain extent. There has been an increase in discards and bycatch in recent years. There continued to be high discard of whiting up to age 2 (Figure 23.4).

23.5.2 Age compositions

Age compositions in the landings and discards were based on samples provided by France, UK (England, Scotland), Denmark and Belgium. Age compositions are applied to landings with splitting of fleets on the basis of quarter (1,2 vs 3,4) and gear type (TR1 and TR2), while discards age compositions are allocated using all discard samples with splitting of fleets on the basis of gear type (TR1) and quarter (1,2 vs 3,4). For the remaining gear types age compositions were allocated using all available samples.

Limited sampling of the industrial bycatch component resulted in the 2006 data appearing as an outlier and the 2007 to 2010 data were deemed unreliable. This applies to both the age compositions and the estimates of mean weights at age. Thus, the data for 2006 to 2010 were replaced with estimates derived from the years 1990 to 2005 (as described in the Stock Annex). For the industrial bycatch in 2011 and 2012, age compositions were inferred in InterCatch from corresponding age samples taken from small-mesh fisheries of France and the UK. In recent years, age compositions for industrial bycatch are estimated from all samples (landings and discards) without splitting of fleets. Minor BMS landings (below minimum landing size) were not sampled. BMS was treated the same as discards, and age compositions are inferred from discard samples only. BMS and discards were combined as discards.

Total international catch numbers at age (Subarea 4 and Division 7.d combined) as estimated by ICES are presented in Table 23.4. Numbers for human consumption landings, discards, and industrial bycatch are given in tables 23.5 to 23.7. Total catches, and catch components, as estimated by ICES are listed in Table 23.12.

23.5.3 Weight at age

Mean weights at age (Subarea 4 and Division 7.d combined) in the catch are presented in Table 23.8. Mean weights at age (both areas combined) in human consumption landings are presented in Table 23.9, and for the discards and industrial by-catch in the North Sea in tables 23.10 and 23.11, respectively. Weights-at-age are depicted graphically in Figure 23.5, which indicates an increasing trend (with annual fluctuations) in mean weight-at-age in the landings, discards and total catch for ages > 2 since the early 2000s. In recent years, mean weights at age have stabilized on the higher level. Mean weights at age in landings have decreased for age 0 since the late 2000s.

Unrepresentative sampling of industrial bycatch in 2006 to 2010 resulted in poor estimates of the mean weights at age and these have been replaced by the mean weight at age for the period 1995 to 2005 (zero weights are taken as missing values). From 2009 onwards, the weights at ages of total catches were used for weights at ages of industrial bycatch.

Stock mean weights at age are estimated from commercial catch weights at age scaled to the level of weights at age estimated in IBTS Q1 (ICES WKNSEA 2018, Figure 23.6).

Unsmoothed values of weights at age are used in the assessment (Table 23.13).

23.5.4 Maturity and natural mortality

Values for proportion mature at age are estimated using IBTS Q1, in Table 23.14 and Figure 23.7. The estimation procedure is discussed in the Stock Annex. Values prior 1991 are assumed constant using values of 1991, due to data quality issues and high variability in results in the earlier time period. The same maturation proportion was assumed for individuals 6 years and older.

Estimates of natural mortality (M) are taken from the 2020 update key run from of the SMS multispecies model (ICES WGSAM, 2021b) (Table 23.15 and Figure 23.8). At the 2021 interbenchmark (ICES, 2021a), the most recent estimates of natural mortality values were smoothed and included in the assessment. The new natural mortality values for 2021 are assumed to be the same as in 2020 (Figure 23.8). The same natural mortality was assumed for individuals 6 years and older.

23.5.5 Research vessel data

Up until 2019, the historical time series of survey indices has been calculated using a manual substitution procedure. The data obtained with this manual procedure is only available until Q3 2019. Since 2020, survey indices are recalculated using a new automated substitution procedure to fill ALK key in areas with low sample size. This new automated method is seen as an improvement to data quality and transparency of the procedure. A comparison of the historical survey indices obtained with the old manual method and the historical survey indices recalculated with the new automated method show that the new method revealed that assessment outputs obtained with the new methods result in lower Mohn's rho values for SSB, F and recruitment. The new data series therefore appear to lead to more consistent assessment results (see Annex 9). As a result, for the 2021 assessment on whiting in 27.4 and 7d it was decided to use the historical time series of survey indices obtained with the new automated substitution procedure. These indices were also used for the 2022 assessment.

Survey tuning indices are presented in Table 23.16a and b. The indices used in the assessment are ages 1–5 from the IBTS–Q1 and ages 0–5 from IBTS–Q3 surveys, from 1983–2022 and 1991–2021, respectively. The report of the 2001 meeting of WGNSSK (ICES WGNSSK, 2002), and the ICES advice for 2002 (ICES ACFM, 2001) provide arguments for the exclusion of commercial CPUE tuning series from calibration of the catch-at-age analysis. Such arguments remain valid and only survey data have been considered for tuning purposes. All available tuning series are presented in the Stock Annex.

In Figure 23.9, survey distribution maps based on the IBTS–Q1 survey in the North Sea, for ages 1–3+ of the first quarter (Q1) 2018–2022, are presented. Figure 23.10, the third quarter is represented (Q3) for ages 0–3+ for the years 2018–2021 For ages 2–3+ CPUE is higher along the UK east coast. Whiting at age 0 are found in the Northern North Sea and Scottish east coast as well as in the German Bight. CPUE at age 0 in Q3 is low in 2018, but is higher from 2019 onwards.

23.6 Benchmark

The ICES Benchmark Workshop on North Sea Stocks 2018 (WKNSEA) was held at ICES in Copenhagen in early 2018. Analyses focused on a number of key issues (maturity, natural mortality, stock-weights at age, stock identity, assessment model) details can be found in WKNSEA report (ICES, 2018a) and stock annex.

No changes were made to the use of survey indices. Catch data was updated in Intercatch following a data call for 2009–2016. A new stratification design to allocate discard ratios and age distributions was introduced, details of the allocation scheme can be found in the Stock Annex and in Section 23.5. The assessment model was updated from XSA to SAM and new reference points were estimated.

As before, Area 27.4 represents the management unit with TAC advice to be given. WGNSSK and WKNSEA recommended, that the stock identity issue should be reviewed in the future when firm evidences become available. Until then it is recommended to monitor area-specific stock development based on survey data when it is available (see Section 23.15). The feasibility of combining Division 3.a with Subarea 4 components was explored, but data showed there were biological reasons to leave the components as separate stocks.

In April 2021, an interbenchmark was carried out to assess the impact of new natural mortality estimates from WGSAM (ICES, 2021b) on the assessment, and the reference points previously defined during the 2018 benchmark were updated as a result (ICES, 2021a). In April 2022, the SAM assessment model was updated, and the reference points were updated during the WGNSSK 2022 meeting (Annex 8).

23.7 Data analyses

23.7.1 Exploratory survey-based analyses

In Figure 23.11, time-series of survey log CPUE at age (ages 1–5+) are presented, which suggest that while broad trends are captured in a consistent way by the two surveys, finer-scale details of year-class strength may not be.

Catch-curve analyses for the surveys are shown in Figure 23.12. These show consistent tracking of year classes (since catch curves are mostly smooth) and consistent selection with some exceptions in recent years. The catchability of the IBTS–Q1 seems to have changed since 2007, underestimating the size of the 2006-year class at age 1. The 2007 to 2010- and 2012-year classes also seem to have been underestimated at age 1. The IBTS–Q3 survey shows low mortality for the 2006-year class, and a potential under estimate of the 2007, 2012- and 2013-year class at age 1. However, numbers at age 2 in the 2007-year class may well be an overestimate.

The consistency within surveys is assessed using correlation plots in Figures 23.13 and 23.14. These indicate that the IBTS–Q1 and Q3 surveys both show good internal consistency across ages. The log CPUE plots by survey (Figure 23.15) support the conclusion of good internal consistency. Only in recent years, age 1 differs somewhat from overall pattern.

Figures 23.16–23.18 summarize the results of a SURBAR analysis using the available IBTS surveys. These show a well-specified analysis in which the data agree broadly with the separability assumptions in the model and uncertainty bounds are fairly tight. Mortality has been on a relatively lower level since the early 2000s. Recruitment (age 1) in 2020 and 2021 is estimated to have been much higher than in recent years and on par with historical high values, while SSB and TSB, although at an intermediate level compared to the historical time series, are increasing. The log survey residuals (Figure 23.17) suggest in most recent years some negative residuals in Q1 and positive residuals in Q3 that should be investigated if trends continue in the coming year.

23.7.2 Exploratory catch-at-age-based analyses

Catch curves for the catch data are plotted in Figure 23.19 and show numbers-at-age on the log scale linked by cohort. This shows partial recruitment to the fishery up to age 2 for some cohorts. Also evident is the persistence of the 1999- to 2001-year classes in past catches and the recent low catches of the 2002–2011 year classes.

The negative gradients of log catches per cohort, averaged over ages 2–6 are given in Figure 23.20. The gradients appear to have been decreasing since 1990 and are fluctuating around a mean level for more recent cohorts that is lower than the mean level prior to 1990, suggesting a fishing mortality likely to be lower than in the past for the cohorts 2000 to 2010. For the 2000 cohort the negative gradient of commercial catch data was lowest in the series (similar to 2010 cohort). Slopes for the catch curves were less steep for this cohort, indicating relatively higher CPUE at higher ages. However, for the last 3 cohorts (2011, 2012 and 2013), a strong and continuous increase in the gradient can be observed which suggests an increase in fishing mortality in recent years.

Within cohort correlations between ages are presented in Figure 23.21. In general, catch numbers correlate well between cohorts with the relationship breaking down as cohorts are compared across increasing age gaps. Correlation were negative comparing age groups up to age 4 to ages 6+. This is due to the increased catches of older fish over the years and decreasing trends for younger age groups (Figure 23.19).

23.7.3 Conclusions drawn from exploratory analyses

Catch curve analysis and correlation plots show that in general both surveys and catch data track cohorts well and are internally consistent (Figures 23.12–14, 23.19–21). However, beginning with the 2006-year class, the IBTS Q1 appears to be underestimating the abundance of age 1 whiting in some years (Figure 23.12). In previous assessments, this had implications for the estimation of recruitment and can result in a considerable retrospective bias in recruitment.

23.7.4 Final assessment

The final assessment used SAM (stockassessment.org) fitted to the combined landings, discards and industrial bycatch data for the period and two survey tuning indices. The used time range for input data for SAM was agreed at WKNSEA and is detailed in the stock annex (ICES, 2018a). During WGNSSK 2022, it was agreed to update the model with a plus group at age 6 and F averaged over ages 2 to 5 in order to address retrospective patterns (Annex 8).The assessment model, including input data, results and diagnostics can be found on www.stockassessment.org as “NSwhiting_2022_6plusgroup_v2_F25”.

The settings as given by the configuration file updated during WGNSSK 2022 are provided below (further details can be found in the Stock Annex).

```
Catch-at-age data                              1978-2019      ages 0-6+
Survey: IBTS Q1                                1983-2020      ages 1-5
Survey: IBTS Q3                                1991-2019      ages 0-5

$minAge
# The minimium age class in the assessment
```

```
 0

$maxAge
# The maximum age class in the assessment
 6

$maxAgePlusGroup
# Is last age group considered a plus group (1 yes, or 0 no).
 1

$keyLogFsta
# Coupling of the fishing mortality states (nomally only first row is used).
   0   1   2   3   4   5   5
  -1  -1  -1  -1  -1  -1  -1
  -1  -1  -1  -1  -1  -1  -1

$corFlag
# Correlation of fishing mortality across ages (0 independent, 1 compound symmetry, or 2 AR(1)
 2

$keyLogFpar
# Coupling of the survey catchability parameters (nomally first row is not used, as that is covered
by fishing mortality).
  -1  -1  -1  -1  -1  -1  -1
  -1   0   1   2   3   3  -1
   4   5   6   7   8   8  -1

$keyQpow
# Density dependent catchability power parameters (if any).
  -1  -1  -1  -1  -1  -1  -1
  -1  -1  -1  -1  -1  -1  -1
  -1  -1  -1  -1  -1  -1  -1

$keyVarF
# Coupling of process variance parameters for log(F)-process (nomally only first row is used)
   0   0   0   0   0   0   0
  -1  -1  -1  -1  -1  -1  -1
  -1  -1  -1  -1  -1  -1  -1

$keyVarLogN
# Coupling of process variance parameters for log(N)-process
 0 1 1 1 1 1 1

$keyVarObs
# Coupling of the variance parameters for the observations.
   0   1   1   1  1   1   4
  -1   2   2   2   2   2  -1
   3   3   3   3   3   3  -1

$obsCorStruct
# Covariance structure for each fleet ("ID" independent, "AR" AR(1), or "US" for unstructured). |
Possible values are: "ID" "AR" "US"
 "ID" "AR" "AR"

$keyCorObs
# Coupling of correlation parameters can only be specified if the AR(1) structure is chosen above.
# NA's indicate where correlation parameters can be specified (-1 where they cannot).
#0-1 1-2 2-3 3-4 4-5 5-6 6-7 7-8
  NA  NA  NA  NA  NA  NA
  -1   0   0   0   0  -1
   1   1   2   2   2  -1

$stockRecruitmentModelCode
# Stock recruitment code (0 for plain random walk, 1 for Ricker, and 2 for Beverton-Holt).
 0

$noScaledYears
# Number of years where catch scaling is applied.
 0

$keyScaledYears
# A vector of the years where catch scaling is applied.


$keyParScaledYA
# A matrix specifying the couplings of scale parameters (nrow = no scaled years, ncols = no ages).

$fbarRange
# lowest and higest age included in Fbar
 2 5

$keyBiomassTreat
# To be defined only if a biomass survey is used (0 SSB index, 1 catch index, and 2 FSB index).
 -1 -1 -1

$obsLikelihoodFlag
# Option for observational likelihood | Possible values are: "LN" "ALN"
 "LN" "LN" "LN"
```

```
$fixVarToWeight
# If weight attribute is supplied for observations this option sets the treatment (0 relative weight,
1 fix variance to weight).
 0
```

The results of the final assessment run are illustrated in Figure 23.22.

Fishing mortality estimates at age from final SAM run are presented in Table 23.17. Estimated stock numbers at age are given in Table 23.18. The assessment summaries are presented in Table 23.19 for recruitment, SSB, mean F, and TSB including upper and lower ranges. Catch biomass with lower and upper range as estimated in SAM are given in Table 23.20.

Estimated correlations are illustrated in Figure 23.23. The correlations reflect SAM settings of autocorrelations and parameter coupling, assuming independence in the catch fleet and correlation between ages in each survey fleet coupled for ages 2+.

The joint–sample residuals for the unobserved processes (stock size N and fishing mortality F) show no apparent cohort effects across ages, although in the final year the residuals (for log(N)) are quite large with some tendency for a year effect (Figure 23.24).

Standardized one-observation–ahead residuals are presented in Figure 23.25. These show that the IBTS–Q3 survey fits more closely to the model than the IBTS–Q1 survey, which demonstrate some year effects in the 2000s and towards the end of the time series. This indicates that the model is effectively paying less attention to the Q1 survey than to the Q3 survey, and this is visible in Figures 23.27 and 28 which show the comparison of predicted and observed points for each survey fleet. The single fleet SAM runs were conducted to compare trends in the catch data with using only survey data for quarter 1 or 3 separately. The leave-one-out runs show that both surveys used were in agreement. Summary plots of these runs together with the final run are presented in Figure 23.29. The population trends from each survey are consistent. The mean F estimates are consistent across the time series with only some difference in most recent year's estimates. Estimates of SSB is in some years lower and recruitment dynamics are less pronounced when using only IBTS Q1 data in the model. The run using only quarter 3 matches more closely the final SAM run with both surveys included, in particular for recruitment, because only IBTS Q3 survey delivers indices for age 0.

A retrospective analysis is shown in Figure 23.30. The retrospective patterns show that results were robust to removing up to 4 years of recent data, but when removing 5 years one of the peels ended outside the confidence intervals for SSB and recruitment. Despite some retrospective bias in recruitment and SSB, there is very low retrospective bias in catches and fishing mortality. Mohn's rho measures the retrospective bias, values are given in Table 23.21 and confirm the relatively higher retrospective bias in recruitment and SSB, although the Mohn's Rho value for SSB is below the acceptable threshold of 0.2 set by WKFORBIAS (ICES, 2020a). Retrospective peels are generally covered by the confidence interval, apart from one peel for both SSB and recruitment.

Final SAM run model parameters are given in Table 23.22.

The spawning stock recruitment relationship shows no apparent pattern, confirming that the assumed random walk in recruitment in the model is appropriate (Figure 23.31).

Finally, Figure 23.32 compares the SURBAR results with the final SAM assessment. Dynamics in SAM and SURBAR are similar with higher variability in the SSB estimates from SURBAR. The comparison of recruitment (at age 1) shows similar dynamics with more variability in SURBAR results. The mean Z (total mortality, ages 2–4) estimates from SURBAR show higher mortalities since 1990 than SAM and some increase in mortality in recent years, but the trends are similar. The relative constant mortality estimated by SAM in recent years follows the lower variability in

SSB from SAM and relatively constant catches, data which are included only in the SAM assessment.

23.8 Historical stock trends

Historical trends for catch, mean F, SSB and recruitment are presented in Figure 23.22. These show that mean F has been declining since 1990 and reached the minimum of time-series in 2021 of 0.163. The SSB was at extremely high levels before 1983 (no survey information included prior 1983). The medium level of 1990 has not been reached since, although the recent increase in SSB indicate that SSB is trending towards this level, with the 2021 SSB estimate being on par with what was observed in the mid-1990s. Recruitment is fluctuating around a recent (post 2001) lower average but is showing an increase in recent years. The levels of high recruitment which occurred between 1998 and 2001 have not been reached since. Recruitment was relatively low in 2017 and 2018, but is estimated to be relatively higher in 2019 and 2020. In the most recent year, landings, discards and industrial bycatch have also all remained at or around a recent average. The stock–recruitment plot in Figure 23.31 does not show a clear relationship between SSB and subsequent recruitment.

23.9 Biological reference points

The 2013 benchmark meeting (ICES WKROUND, 2013) attempted to calculate F_{MSY} for North Sea whiting, but concluded that this value was inestimable using standard equilibrium considerations and would need to be determined as part of a management strategy evaluation. After the considerable revisions in the 2012 assessment, caused by new estimates of natural mortality, the target F of 0.3 was no longer considered applicable. The management plan was re-evaluated in October 2013 (ICES, 2013) and ICES advised that updating the target F from 0.3 to 0.15 within the management plan. New revisions of natural mortalities were presented at WGSAM 2014. An interbenchmark was performed for whiting in the North Sea and Division 7.d in early 2016 (ICES, 2016). This included Eqsim runs and MSE. A target F of 0.15 together with a TAC constraint of 15% according to the EU–Norway Management Plan may not be sufficient to keep SSB above B_{lim}. It was concluded to use instead the MSY approach with target F of 0.15.

In the WKNSEA 2018 benchmark new data and assessment model were introduced, Eqsim was run to determine new reference points (ICES, 2018a). $F_{p.05}$ was calculated by running Eqsim to ensure that the long-term risk of SSB < B_{lim} of any F used does not exceed 5% when applying the advice rule. Accordingly, F_{MSY} had to be set to $F_{p.05}$ = 0.172.

At WGNSSK 2020, it was recommended to use new survey indices provided by DATRAS for the whiting assessment in 2020 and onwards (see Section 23.5.5). At the benchmark 2018, the reference points B_{lim} = 119 970 and F_{MSY} = 0.172 were set for North Sea whiting and are suggested to remain unchanged (ICES, 2018a). The new indices resulted in minor changes of assessment results, with the level of estimated SSB and F generally remaining the same over the time series. Retrospectives and Mohn's rho indicated that using the completely new survey indices leads to more consistent assessments with lower retro than using a survey series combining old (up to 2019) and new method (Q1 2020) (Annex 9, see ICES (2020b)).

The use of both new and old survey indices would lead to higher but similar F_{MSY} reference points if recalculated using EqSim this year. Even though new survey indices would have led to a slight increase in the reference points even when used with benchmark data, it was not recommended to change the reference points due to the issue of precautionarity. Previous management strategy evaluations indicated that the current F_{MSY} may not be precautionary (WKNSMSE 2018). A further increase in the reference point F_{MSY} by recalculating F_{MSY} with EqSim was therefore not recommended at the time (Annex 9 for more details, see ICES, 2020b).

In April 2021, an interbenchmark was carried out to include new natural mortality estimates from WGSAM (ICES, 2021b). Eqsim was run to determine new reference points, and the reference points previously defined during the 2018 benchmark were updated as a result (ICES, 2021a). The new F_{MSY} value is 0.371 and the new B_{lim} value is 103 560.

In April 2022, following the update of the SAM assessment model new reference points were estimated using EqSim. The reference points previously defined during the 2021 interbenchmark were updated as a result (Annex 8). Current reference points are listed in Table 23.23.

23.10 Short-term forecasts

A short-term forecast was carried out based on the final SAM assessment. SAM survivors from 2021 were used as input population numbers for ages 1 and older in 2022. Recruitment assumptions are detailed in Table 23.24. In the intermediate and following two years the geometric mean of recruitment from 2002–2021 is used.

The exploitation pattern is chosen as the mean exploitation pattern over the most recent three years 2019–2021. The mean exploitation pattern was scaled to the mean $F_{2\text{–}5}$ in 2021 for forecasts (Figure 23.33). Partial F at age for each catch component was estimated by splitting the forecast F at age using the mean proportion in the catch of each catch component over the years 2019–2021. The F at age used in the forecast is compared with the F at age estimates for 2019–2021 in Figure 23.33.

Mean weights at age are generally consistent over the recent period but there is variability at several ages (Figure 23.5 and 6). To avoid introducing bias, therefore, the average of estimates of 2019–2021 are used for the purposes of forecasting. The strong trend as observed between 2000 and 2010 is not apparent in the recent three years.

The inputs to the short-term forecast are given in Table 23.25, and results are presented in Table 23.26. As in previous years, the MFDP program was used to carry out the forecasts, accounting for separate fleet for industrial bycatch.

No TAC constraint was applied in the intermediate year since it is not considered that fishing will stop when the TAC is reached.

Assuming mean F_{2022} equal to mean F_{2021} (using the average selectivity over the last 3 historical years) results in human consumption catches in the intermediate year 2022 of 40 965 tonnes from a total catch of 44 160 tonnes, giving an SSB in 2022 of 283 606 tonnes (Table 23.26).

Carrying the same fishing mortality forward into 2023 (the status quo F option, F_{sq}) would result in human consumption catches of 43 174 tonnes out of total catches of 46 850 tonnes, and would result in an SSB of 291 617 tonnes in 2024 (a 0.87% decrease in SSB relative to 2023).

Since SSB in 2023 is predicted to be higher than MSY $B_{trigger}$, following the MSY approach allows for applying F_{MSY} leading to an F_{target} of 0.393.

Applying the F_{MSY} of 0.393 in 2023 would generate human consumption catches of 106 892 tonnes out of total catches of 110 172 tonnes, and result in an SSB of 244 860 tonnes in 2024 (a 16.8% decrease in SSB relative to 2023). In 2024, SSB would be above B_{lim} and MSY Bt_{rigger}. F of 0.393 would cause the TAC (relative to the TAC in 2022) to be changed by +211.4%.

23.11 MSY estimation and medium-term forecasts

No medium-term forecasts or MSY estimation were conducted during the WG meeting.

23.12 Quality of the assessment

Previous meetings of WGNSSK and the benchmark workshop (ICES WKROUND 2009; ICES WKROUND 2013) have concluded that the historical survey data and commercial catch data contain different signals concerning the stock. Analyses by Working Group members and by the ICES Study Group on Stock Identity and Management Units of Whiting (ICES SGSIMUW, 2005) indicate that data since the early to mid–1990s are sufficiently consistent to undertake a catch-at-age analysis calibrated against survey data from 1990. WKNSEA (ICES, 2018a) considered the question of time series length again and concluded that the divergence between survey-based and catch-based analysis are not sufficient to exclude pre-1990 data. Survey data was included since 1983 with standardization of survey design.

Given the spatial structure of the whiting stock and of the fleets exploiting it, it is important to have data that covers all fleets. Considering that age 1 and age 2 whiting make up a large proportion of the total stock biomass, good information of the discarding practices of the major fleets is important.

The survey information for Division 7.d were not available in a form that could be used by WGNSSK. Due to the recent changes in distribution of the stock, tuning information from this area would be extremely useful, and could improve the estimate of recruitment in the most recent year. However, previous analyses of the survey in Division 7.d showed it did not track cohorts well (ICES WKROUND, 2009).

Age distributions and mean weights at age have been estimated for the industrial bycatch from 2006 to 2010. This was due to low sampling levels of the Danish industrial bycatch fisheries. In recent years, no samples of industrial bycatch were available. Age distributions and weights at age were inferred from sampling of landings and discards from other fleets.

In 2017, French samples for quarter 1 and 2 particularly in Subdivision 7.d are sparse due a disruption in the onshore sampling scheme. Therefore, a percentage of data was simulated randomly from previous year's data. This affected about 8% of total catch weight (landings more than discards, in particular TR2 fleet in 7.d).

There have been issues with regard to the age readings of North Sea whiting as compared to other gadoids in the past (Norway as compared to Netherlands and UK (Scotland)). This applies in particular to the age readings used for the IBTS indices. An otholith workshop, WKARWHG2, took place in late 2016, to improve consistency in preparation techniques and readings (ICES, 2016b). This exercise showed an improvement in age reading compared to the same read in the 2015 exchange. A recommendation was made to investigate the quality of age readings further. The historical performance of the assessment is summarized in Figure 23.34. The difference in SSB is due to new benchmark model and input data, as well as an updated of the SAM assessment model in 2022 (Annex 8). SSB is estimated using new, scaled stock weights at age and maturity estimates. As the assessment model operates on numbers at age rather than biomass the new stock weights at age and maturities did not directly affect estimates of fishing mortality. Since 2018, recruitment is estimated at age 0 instead of age 1 such that previous assessment results are not plotted in Standard graphs. Catch data and natural mortalities were updated. Estimates of fishing mortality remained at a similar level as before.

23.13 Status of the stock

For North Sea whiting, SSB has a generally downwards trend since the start of the assessment time-series. SSB is estimated to be above B_{lim} (Figures 23.22, 23.34). The stock, at the level of the entire North Sea and Eastern Channel, was at an historical low level in the late 2000s (relative to the period since 1978), and the recent increase in SSB is in large part due to relatively improved perception of recruitment in 2007–2010, 2014–2016 and 2019-2020. All indications are that fishing mortality has been declining over most of the time-series, currently fluctuating around a low level. Since 2002, fishing mortality has been below F_{MSY} = 0.393. While landings have been relatively stable and even decreased slightly in recent years, discards and industrial bycatch increased in recent years slightly. The development of whiting biomass depends on the size of recruitment. Recruitment is varying around a recent mean, but that mean is lower relative to recruitment in the late 1990s. Recruitment in 2014–2016 was above the average of recent years, however recruitment in 2017 2018 was lower. Recruitment in 2019 and 2020 is estimated to be higher still and on par with early 2000s levels. Stock biomass estimated for 2022 increased and is now well above MSY $B_{trigger}$.

23.14 Management considerations

In 1996, 2006, 2012, 2017 and 2018, the whiting stock produced the lowest recruitments in the series (below 13 billion). In recent years an increased proportion of whiting mature already at age 1 and grow quickly at young ages; therefore, an increase in SSB is seen the year immediately after a good recruitment. Managers should consider the age structure of the population as well as the SSB since at low stock sizes short term forecasts are highly sensitive to recruitment assumptions.

Catches of whiting have been declining since 1980 (from 243 570 tonnes in 1979 to 33 186 tonnes in 2020, including discards and industrial bycatch).

Catch rates from localized fleets may not represent trends in the overall North Sea and English Channel. The localized distribution of the stock is known to be resulting in substantial differences in the quota uptake rate. This is likely to result in localized discarding problems that should be monitored carefully.

Whiting are caught in mixed demersal roundfish fisheries, fisheries targeting flatfish, the *Nephrops* fisheries, and the industrial fishery. The current minimum mesh-size in the targeted demersal roundfish fishery in the northern North Sea has resulted in reduced discards from that sector compared with the historical discard rates. Mortality may have increased on younger ages due to increased discarding in recent years as a result of recent changes in fleet dynamics of *Nephrops* fleets and small mesh fisheries in the southern North Sea. The industrial bycatch of whiting in the sprat, Norway pout and sandeel fisheries is dependent on activity in that fishery, which has recently declined after strong reductions in the fisheries. Industrial bycatches are considered low in the forecast.

Catches of whiting in the North Sea are also likely to be affected by the effort reduction seen in the targeted demersal roundfish and flatfish fisheries, although this will in part be offset by increases in the number of vessels switching to small mesh fisheries. It is important to consider both the species-specific assessments of these species for effective management, but also the broader mixed-fisheries context. This is not straight forward when stocks are managed via a series of single-species management plans that do not incorporate such mixed stocks considerations. WGMIXFISH monitors the consistency of the various single species management plans and TAC advice under current effort schemes, in order to estimate the potential risks of quota over and under shooting for the different stocks, and it was demonstrated that the current basis for whiting advice was not consistent with other single-stock management objectives. It is recommended that the ongoing discussions about the whiting management plan takes into account such mixed-fisheries considerations before implementation.

The stock dynamics of North Sea whiting are largely driven by recruitment and natural mortality. To maximize the benefit for the fishery of this stock, the most significant measure would be to improve selectivity and reduce under-sized catches in those fisheries with high rates of discarding.

BMS landings reported to ICES in 2015–2021 were low. In 2021, whiting was fully under Landings Obligation with a *de minimis* exemption for whiting caught with bottom trawls in ICES Division 4.c. Nevertheless, reported BMS was very low and discarding was still observed in the sampled fleets and are assumed to take place also in unsampled fleets. The amount of reported BMS is expected to increase in the next years as the landing obligation continues to be implemented.

ICES has developed a generic approach to evaluate whether new survey information that becomes available in autumn forms a basis to update the advice. ICES will publish new advice in November 2022 if this is the case for this year.

23.15 SURBAR Northern Southern stock component

Exploratory SURBAR assessments were run for individual components (northern and southern component) using component area-specific DATRAS survey indices provided by ICES (Figure 23.35, Tables 23.27–28) and estimated area-specific maturity ogives (Tables 23.29–30, Figure 23.37). Stock weights at age were assumed to be the same in northern, southern components and combined areas. The stock dynamics for the combined stock were more similar to the northern component and more variable in the southern one. Nevertheless, stock dynamics in northern and southern were comparable (recruitment, SSB in Figure 23.36). The SURBAR analyses indicate that the southern stock component is at a historically high level of SSB and unlikely to be negatively affected by management decisions based on the combined analyses dominated by the northern component.

23.16 Issues for future benchmarks

The stock was benchmarked in 2018, implementing a new assessment model, natural mortality estimates, maturity ogive estimation and stock weights at age estimation. The stock identity issue was revisited and decided to continue with the assessment area previously used (North Sea and Eastern Channel). The discard raising and age allocations method in InterCatch was revised to account for fleet differences (TR1/TR2, seasonal) in discard rate and age distributions. An interbenchmark was performed in 2021 to include new mortality estimates from WGSAM (ICES, 2021b), and reference points were updated accordingly (ICES, 2021a). Following updates to the SAM assessment model during WGNSSK 2022, reference points were updated (Annex 8).

23.16.1 Data and assessment

Stock weights at age are estimated each year by scaling the catch-at-weight time series by using the NS-IBTS quarter 1 weights at age (shorter time series). Even though the entire time series of stock weights at age is re-estimated each year, so far historical values did not change. If estimated stock weights at age in the historical time period differ significantly from one year to the next, the estimation should be reconsidered, i.e. only add newly estimated most recent data point (not an issue this year).

Natural mortality: When new natural mortality estimates (WGSAM) become available these data need to be included and potentially reference points may need to be revised (not an issue this year).

Stock identity: In the last benchmark, stock identity was considered for North Sea whiting distinguishing a northern and a southern stock component. Analysis (see Section 23.1.1) suggest similar dynamics in the northern and southern component with dynamics being dominated by the northern component. At this point in time, a separate assessment is not considered necessary from reviewed literature and SURBAR analyses.

Survey indices: There has been a new French data upload for the historical time series. The use of a delta GAM method to calculate indices should be explored. This would allow incorporation of survey uncertainty into the assessment.

SAM assessment: the use of unsmoothed maturity and natural mortality estimates as input for the assessment model, in order to use the new SAM method to estimate missing historical values, should be explored.

23.16.2 Reference points and Forecast

An alternative management strategy can be explored, such the ICES approach to MSY-based management for short-lived species in the form of an escapement strategy based on a stochastic forecast.

Currently a deterministic forecast continues to be done in MFDP. A SAM forecast can be considered which allows fleet separation (human consumption and industrial bycatch fleet) and stochastic forecast.

23.17 References

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Table 23.1. Whiting in Subarea 4 and Division 7.d: Whiting in Subarea 4. Nominal landings (in tonnes) as officially reported to ICES, ICES estimates of catch components, and TACs. *Before 2015, the official landings from Denmark are likely to exclude Industrial bycatch.

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
belgium.4	1040	913	1030	944	1042	880	843	391	268	529	536
denmark.4	1206	1528	1377	1418	549	368	189	103	46	58	105
faroe.4	26	0	16	7	2	21	0	6	1	1	0
france.4	4951	5188	5115	5502	4735	5963	4704	3526	1908	0	2527
germany.4	692	865	511	441	239	124	187	196	103	176	424
netherlands.4	3273	4028	5390	4799	3864	3640	3388	2539	1941	1795	1884
norway.4	55	103	232	130	79	115	66	75	65	68	33
sweden.4	16	48	22	18	10	1	1	1	0	9	4
uk.4	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
england.wales.4	2338	2676	2528	2774	2722	2477	2329	2638	2909	2268	1782
scotland.4	27486	31257	30821	31268	28974	27811	23409	22098	16696	17206	17158
total.landings.4	41083	46606	47042	47301	42216	41400	35116	31573	23937	22110	24453
unallocated.landings.4	-1097	396	1832	691	346	850	-434	633	247	-3590	173
ices.landings.4	42180	46210	45210	46610	41870	40550	35550	30940	23690	25700	24280
ices.discards.4	52270	30840	28470	41400	31840	28940	27130	16660	12480	22110	21931
ices.ibc.4	51337	39755	25045	20723	17473	27379	5116	6213	3494	5038	9160
ices.catch.4	145787	116805	98725	108733	91183	96869	67796	53813	39664	52848	55371
tac.4.2a	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	30000

Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
belgium.4	454	270	248	144	105	93	45	116	162	147	74
denmark.4	105	96	89	62	57	251	78	42	79	158	135
faroe.4	0	17	5	0	0	0	0	0	2	0	0
france.4	3455	3314	2675	1721	1261	2711	3336	3076	2305	2644	2794
germany.4	402	354	334	296	149	252	76	76	124	156	111
netherlands.4	2478	2425	1442	977	805	702	618	656	718	614	514
norway.4	44	47	38	23	16	17	11	92	73	118	28
sweden.4	6	7	10	2	0	2	1	2	4	8	6
uk.4	NA	NA	NA	NA	NA	11632	12110	10391	8853	7845	8892
england.wales.4	1301	1322	680	1209	2560	NA	NA	NA	NA	NA	NA
scotland.4	10589	7756	5734	5057	3441	NA	NA	NA	NA	NA	NA
total.landings.4	18834	15608	11255	9491	8394	15660	16275	14451	12320	11690	12554
unallocated.landings.4	-426	738	805	541	-2286	563	609	972	-124	-1111	-706
ices.landings.4	19260	14870	10450	8950	10680	15097	15666	13479	12444	12801	13260
ices.discards.4	16130	17144	26135	18142	10300	14018	5206	8356	6597	8451	7989
ices.ibc.4	940	7270	2730	1210	890	2190	1240	0	1344	1907	1035
ices.catch.4	36330	39284	39315	28302	21870	31305	22112	21835	20385	23159	22283
tac.4.2.a	29700	41000	16000	16000	28500	23800	23800	17850	15173	12897	14832

Year	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
belgium.4	45	33	46	70	65	71	71	141	211	475
denmark.4	131	124	160	2375	4727	2804	2026	2357	3606	2493
faroe.4	0	0	0	0	8	1	0	80	25	0
france.4	1925	942	1884	1131	1232	952	918	890	677	478
germany.4	25	44	31	73	111	82	99	81	246	195
netherlands.4	471	495	464	581	644	791	684	853	769	711
norway.4	94	560	918	1088	1150	993	1025	1102	1674	1099
sweden.4	4	1	2	0	6	11	8	18	27	50
uk.4	9893	11162	10290	10015	9412	9263	10689	11897	12144	11584
england.wales.4	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
scotland.4	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
total.landings.4	12588	13361	13795	15333	17355	14968	15520	17419	19399	17085
unallocated.landings.4	-356	-456	-52	2101	5113	3140	2942	1885	3421	2922
ices.landings.4	12944	13817	13847	13232	12242	11828	12578	15534	15978	14163
ices.discards.4	9307	4608	7016	12265	10413	9799	8026	7581	9749	9930
ices.ibc.4	1117	1654	1623	2097	4551	2635	1658	1864	3115	2048
ices.catch.4	23368	20079	22486	27593	27206	24262	22263	24979	28947	33186
tac.4.2.a	17056	18932	16092	13678	13678	16003	22057	17191	17158	21306

Table 23.2. Whiting in Subarea 4 and Division 7.d: Whiting in Division 7.d. Nominal landings (in tonnes) as officially reported to ICES, ICES estimates of catch components, and TACs.

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
belgium.7.d	83	83	66	74	61	68	84	98	53	48	65
france.7.d	0	0	5414	5032	6734	5202	4771	4532	4495	0	5875
netherlands.7.d	0	0	0	0	0	0	1	1	32	6	14
uk.7.d	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
england.wales.7.d	239	292	419	321	293	280	199	147	185	135	118
scotland.7.d	0	0	24	2	0	1	1	1	0	0	0
total.landings.7.d	322	375	5923	5429	7088	5551	5056	4779	4765	189	6072
unallocat.landings.7.d	-3158	-5345	183	219	468	161	106	159	165	-4241	1772
ices.landings.7.d	3480	5720	5740	5210	6620	5390	4950	4620	4600	4430	4300
ices.discards.7.d	3330	4220	4090	2970	3850	3240	3370	3000	3210	3570	4129
ices.catch.7.d	6810	9940	9830	8180	10470	8630	8320	7620	7810	8000	8429
tac.7b.k	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	22000

Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
belgium.7.d	75	58	67	46	45	73	75	68	71	88	78
france.7.d	6338	5172	6654	5006	4638	3487	3135	2875	6248	5512	4833
netherlands.7.d	67	19	175	132	128	117	118	162	112	275	282
uk.7.d	NA	NA	NA	NA	NA	72	63	87	138	258	271
england.wales.7.d	134	112	109	99	90	NA	NA	NA	NA	NA	NA
scotland..7.d	0	0	0	0	0	NA	NA	NA	NA	NA	NA
total.landings.7.d	6614	5361	7005	5283	4901	3749	3391	3192	6569	6133	5464
unalloc.landings.7.d	814	-439	1295	933	111	306	137	-1279	649	-967	315
ices.landings.7.d	5800	5800	5710	4350	4790	3443	3254	4471	5920	7100	5149
ices.discards.7.d	3109	1356	604	907	2219	2291	1763	1943	2086	4532	3183
ices.catch.7.d	8909	7156	6314	5257	7009	5734	5017	6414	8006	11632	8332
tac.7b.k	21000	31700	31700	27000	21600	19940	19940	19940	16949	14407	16568

Year	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
belgium.7.d	66	95	90	121	146	128	138	144	45	86
france.7.d	3093	3076	2126	3102	2771	2378	2720	2095	1309	1718
netherlands.7.d	437	650	663	565	556	593	484	603	330	229
uk.7.d	261	472	345	379	259	358	283	259	287	417
england.wales.7.d	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
scotland.7.d	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
total.landings.7.d	3857	4293	3224	4167	3732	3457	3625	3101	1971	2453
unalloc.landings.7.d	-556	-15	99	190	32	103	143	126	60	203
ices.landings.7.d	4413	4308	3125	3977	3700	3354	3482	2975	1911	2250
ices.discards.7.d	2389	2186	2709	4627	2313	1550	2562	2499	4046	4708
ices.catch.7.d	6802	6494	5834	8604	6013	4904	6044	5474	5957	6958
tac.7b.k	19053	24500	20668	17742	22778	27500	22213	19184	10863	10259

Table 23.3.a. Whiting in Subarea 4 and Division 7.d: Description of InterCatch raising procedure. SOP.

Catch Category	SOP
BMS landing	1.0658
Discards	1.131
Landings (incl. IBC)	0.9867
Logbook Registered Discard	NA

Table 23.3.b. Whiting in Subarea 4 and Division 7.d: Description of InterCatch raising procedure using Table 2 of CatchAndSampleData.Tables.txt. Summary of imported and raised data (uploads in weight)

Catch Category	Raised or Imported	CATON tonnes	Percent
BMS landing	Imported_Data	13.33	100
Discards	Raised_Discards	6198	60
Discards	Imported_Data	6728	40
Landings	Imported_Data	19198	100
Logbook Registered Discard	Imported_Data	0	NA

Table 23.3.c. Whiting in Subarea 4 and Division 7.d: Description of InterCatch raising procedure using Table 2 of CatchAndSampleData.Tables.txt. Summary of the imported/raised/sampled or estimated data (uploads in weight).

Catch Category	Raised or Imported	Sampled or estimated distribution	CATON tonnes	Percent
Logbook Registered Discard	Imported_Data	Estimated_Distribution	0	NA
Landings	Imported_Data	Estimated_Distribution	6400	33
Landings	Imported_Data	Sampled_Distribution	12798	67
Discards	Raised_Discards	Estimated_Distribution	6198	48
Discards	Imported_Data	Estimated_Distribution	3467	27
Discards	Imported_Data	Sampled_Distribution	3261	25
BMS landing	Imported_Data	Estimated_Distribution	13.33	100

Table 23.3d. Whiting in Subarea 4 and Division 7.d: Description of InterCatch raising procedure using Table 2 of CatchAndSampleData.Tables.txt. Summary of the imported/raised/sampled or estimated data by area (uploads in weight).

Catch Category	Raised or Imported	Sampled or Estimated distribution	Area	CATON tonnes	Percent
Logbook Registered Discard	Imported_Data	Estimated_Distribution	27.7.d	0	NA
Landings	Imported_Data	Estimated_Distribution	27.7.d	1211	50
Landings	Imported_Data	Sampled_Distribution	27.7.d	1212	50
Discards	Raised_Discards	Estimated_Distribution	27.7.d	3054	73
Discards	Imported_Data	Sampled_Distribution	27.7.d	934.9	22
Discards	Imported_Data	Estimated_Distribution	27.7.d	167.5	4
BMS landing	Imported_Data	Estimated_Distribution	27.7.d	0.071	100
Logbook Registered Discard	Imported_Data	Estimated_Distribution	27.4.c	0	NA
Landings	Imported_Data	Estimated_Distribution	27.4.c	609.7	100
Discards	Raised_Discards	Estimated_Distribution	27.4.c	1161	100
BMS landing	Imported_Data	Estimated_Distribution	27.4.c	0.78	100
Logbook Registered Discard	Imported_Data	Estimated_Distribution	27.4.b	0	NA
Landings	Imported_Data	Estimated_Distribution	27.4.b	245.1	99
Landings	Imported_Data	Sampled_Distribution	27.4.b	3.385	1
Discards	Raised_Discards	Estimated_Distribution	27.4.b	349.6	99
Discards	Imported_Data	Sampled_Distribution	27.4.b	4.535	1
BMS landing	Imported_Data	Estimated_Distribution	27.4.b	5.22	100
Logbook Registered Discard	Imported_Data	Estimated_Distribution	27.4.a	0	NA
Landings	Imported_Data	Estimated_Distribution	27.4.a	1064	100
Discards	Raised_Discards	Estimated_Distribution	27.4.a	177.5	100
BMS landing	Imported_Data	Estimated_Distribution	27.4.a	0	NA
Logbook Registered Discard	Imported_Data	Estimated_Distribution	27.4	0	NA
Landings	Imported_Data	Sampled_Distribution	27.4	11583	78
Landings	Imported_Data	Estimated_Distribution	27.4	3270	22
Discards	Imported_Data	Estimated_Distribution	27.4	3300	47
Discards	Imported_Data	Sampled_Distribution	27.4	2322	33
Discards	Raised_Discards	Estimated_Distribution	27.4	1455	21
BMS landing	Imported_Data	Estimated_Distribution	27.4	7.26	100

Table 23.4. Whiting in Subarea 4 and Division 7.d: Total catch numbers at age (thousands). Age 6 is a plus-group. Estimated by ICES, input data for SAM. Ages 0–6+ are included in the final assessment. Model input.

Age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	6+
1978	687238	418909	313391	242369	90047	7564	7564	1851	253	11	9	4	0	0	0	0	9692
1979	476383	615525	467538	218283	100976	29267	3111	1657	264	35	1	4	0	0	0	0	5072
1980	332209	265359	416009	286077	90719	52969	10752	1153	689	58	14	5	1	0	0	0	12672
1981	516869	162899	346343	266518	102295	27776	12297	3540	244	45	37	1	0	0	0	0	16164
1982	101057	192641	114443	245247	88137	26796	6909	2082	400	53	26	4	1	0	0	0	9475
1983	668604	205647	184747	118411	131507	37231	8688	1780	793	101	35	0	0	0	0	0	11397
1984	157819	323408	175965	124886	49504	59817	13860	2964	410	182	21	0	0	0	0	0	17437
1985	186723	203321	141716	82037	37847	14420	17446	3329	805	89	9	1	0	0	0	0	21679
1986	225202	576732	167078	169578	46516	13368	3487	3975	497	71	0	1	0	0	0	0	8031
1987	84863	267051	368230	122748	85240	11391	4555	928	930	98	7	0	0	0	0	0	6518
1988	416924	430344	307429	179503	39635	17902	2174	544	59	72	37	0	0	0	0	0	2886
1989	87325	331672	173676	191942	78464	14367	5051	517	291	37	6	1	0	0	0	0	5903
1990	289174	258102	501373	127967	84147	31102	1933	719	93	16	0	0	0	0	0	0	2761
1991	1057999	135797	194921	184960	36290	25554	5339	526	249	17	1	0	0	0	0	0	6132
1992	259390	230302	167479	87820	91081	11654	6634	2546	104	7	1	0	0	0	0	0	9292
1993	628301	223424	172049	125599	46181	45300	3898	1501	682	56	15	0	0	0	0	0	6152
1994	218287	191544	158369	97559	51041	18683	17905	1258	441	73	0	0	0	0	0	0	19677
1995	1597900	148169	144023	112416	35649	15061	5117	4472	314	101	54	0	0	0	0	0	10058
1996	96515	86318	118910	99644	48304	14087	4638	1282	897	166	24	6	2	0	0	0	7015
1997	19001	60946	80471	84336	41975	18303	3333	1012	305	135	16	0	0	0	0	0	4801
1998	72289	92556	50362	43424	36295	17628	6343	1417	306	66	34	0	0	0	0	0	8166
1999	76975	189162	95415	45920	33921	18271	7443	2021	565	95	12	0	0	0	0	0	10136
2000	1970	82546	129582	63706	23913	16199	8758	4309	969	244	47	3	0	0	0	0	14330
2001	18012	52567	83085	52076	20800	9256	4826	2233	896	246	124	2	0	0	0	0	8327

Age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	6+
2002	135848	51338	62462	84600	34659	8099	2048	1461	621	102	13	9	9	0	0	0	4263
2003	60744	83680	111144	55866	41841	14217	2359	473	329	50	16	1	0	0	0	0	3228
2004	34210	47966	23009	32557	30400	21755	8342	1352	198	93	12	1	4	0	0	0	10002
2005	17622	47805	34626	12204	18146	14931	8979	3041	540	83	29	1	0	0	0	0	12673
2006	15673	73908	42199	21651	8642	15077	11822	4618	1300	142	14	0	0	0	0	0	17896
2007	2490	39041	34001	24900	9906	4008	7657	5268	2560	476	82	0	0	0	0	0	16043
2008	5631	62163	28301	22741	13571	4305	1847	3954	2134	631	143	43	0	0	0	0	8752
2009	12139	57412	31004	15181	12782	7432	3380	2153	2601	1801	1967	20	1	0	0	0	11923
2010	3930	33756	33320	25516	9932	7776	6263	2136	4347	1491	1053	30	1	0	3	0	15324
2011	3563	31377	42201	28903	12537	3813	3178	2090	877	472	1293	31	1	0	0	0	7942
2012	3548	53445	32509	18882	14862	6952	2773	1558	1213	624	482	15	37	0	0	0	6702
2013	4341	20378	15548	25362	15593	10812	3343	1048	643	660	292	0	0	0	0	0	5986
2014	6225	29785	14623	17450	19683	11351	4710	2038	1018	641	431	0	0	0	0	0	8838
2015	7705	48349	53345	15714	10220	14163	5068	2086	1210	607	401	4	0	0	0	0	9376
2016	17208	27639	36165	36788	9129	7813	6046	2548	691	694	376	0	0	0	0	0	10355
2017	28724	27355	27315	24442	18432	4176	2421	2683	1349	1165	26	5	0	0	0	0	7649
2018	15656	17302	41274	26023	17040	6786	1437	1013	803	36	163	38	0	0	0	0	3490
2019	4515	29380	24143	39669	17364	7151	3087	1063	555	273	76	0	0	0	0	0	5054
2020	26813	41940	32019	29992	19892	6596	2286	640	166	35	1	1	0	0	0	0	3129
2021	35094	27281	57391	21520	12296	8836	3265	898	143	12	0	0	0	0	0	0	4318

Table 23.5. Whiting in Subarea 4 and Division 7.d: Landings numbers at age (thousands), as estimated by ICES. Age 6 is a plus-group. Data used to calculate the landing fraction in the model estimates of catches.

Age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	6+
1978	0	14793	99836	155424	76829	6693	7202	1837	253	11	9	4	0	0	0	0	9316
1979	8	8488	108548	144343	89093	26584	3011	1617	250	35	1	4	0	0	0	0	4918
1980	0	3656	62405	152570	68422	41430	9911	1135	689	58	14	5	1	0	0	0	11813
1981	6	4240	69211	104348	78253	23698	12036	3530	244	45	37	1	0	0	0	0	15893
1982	0	10890	46703	124656	59393	21376	5664	2058	400	53	26	4	1	0	0	0	8206
1983	1	10568	68640	67312	101342	31266	8330	1730	784	101	35	0	0	0	0	0	10980
1984	0	14388	62693	99204	41277	51745	12735	2813	410	182	21	0	0	0	0	0	16161
1985	1	2288	51194	57049	32340	12974	16361	3238	805	89	9	1	0	0	0	0	20503
1986	29	12879	44500	111527	37287	11285	3379	3912	485	71	0	1	0	0	0	0	7848
1987	22	11074	72372	70504	73742	10808	4506	928	899	98	7	0	0	0	0	0	6438
1988	0	7462	61360	94163	29147	16556	2158	544	56	72	37	0	0	0	0	0	2867
1989	52	8636	28406	77009	44307	9249	3888	420	208	35	6	1	0	0	0	0	4558
1990	23	6910	52533	43850	48537	16845	1341	605	91	16	0	0	0	0	0	0	2053
1991	410	11565	42525	88974	25738	21261	4581	396	249	17	1	0	0	0	0	0	5244
1992	298	9565	44697	47843	59208	9784	6099	1453	99	7	1	0	0	0	0	0	7659
1993	720	5957	28935	63383	32819	33741	2932	1339	682	56	15	0	0	0	0	0	5024
1994	77	17124	31351	45492	36289	13920	14407	914	366	73	0	0	0	0	0	0	15760
1995	277	8829	28027	58046	27775	13652	4911	4359	308	101	54	0	0	0	0	0	9733
1996	1015	12517	26611	47125	35828	11861	4396	1103	897	166	24	6	2	0	0	0	6594
1997	608	6511	23436	47717	31503	15615	2931	1010	289	135	15	0	0	0	0	0	4380
1998	1202	17071	19828	24860	24473	14579	5395	1204	219	64	16	0	0	0	0	0	6898
1999	68	16661	26669	25504	23465	14483	6554	1854	514	61	12	0	0	0	0	0	8995
2000	0	15384	31808	28283	14241	11775	6618	3758	862	244	47	3	0	0	0	0	11532
2001	150	12260	28476	27293	17491	8633	4503	2091	877	246	124	2	0	0	0	0	7843

Age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	6+
2002	0	2610	10346	30890	22353	6712	1710	1330	511	99	10	9	9	0	0	0	3678
2003	20	403	11613	13990	18974	9513	1861	443	329	50	16	0	0	0	0	0	2699
2004	0	3973	2812	9629	13302	11846	4409	747	174	84	12	1	4	0	0	0	5431
2005	74	11009	10414	5669	10926	10283	5933	2343	321	78	29	1	0	0	0	0	8705
2006	11	11055	11023	8494	5362	12259	10161	4118	1080	105	6	0	0	0	0	0	15470
2007	140	10378	14740	16491	7666	3310	6681	4227	2179	383	77	0	0	0	0	0	13547
2008	0	13234	12334	14120	9106	3564	1519	2505	1481	568	143	43	0	0	0	0	6259
2009	79	3056	17397	11259	10762	6411	3072	1994	2408	1679	1846	19	1	0	0	0	11019
2010	2	1368	8848	15426	6939	6296	3922	1922	1331	1378	979	24	1	0	0	0	9557
2011	32	4524	17621	14180	10021	2811	2303	1741	820	441	1215	30	1	0	0	0	6551
2012	0	2540	10148	11200	11692	6127	2020	1331	902	557	401	14	35	0	0	0	5260
2013	0	1724	7008	15154	11656	9344	2774	937	556	405	232	0	0	0	0	0	4904
2014	1	3211	7422	9439	12082	8031	3221	1673	806	566	329	0	0	0	0	0	6595
2015	136	3022	15736	7802	6584	9232	3800	1617	887	523	358	4	0	0	0	0	7189
2016	0	1405	9098	16279	5922	4187	4104	1747	550	573	312	0	0	0	0	0	7286
2017	0	731	6509	10287	12841	2666	1711	1640	1092	962	23	5	0	0	0	0	5433
2018	0	1264	12061	13819	11797	5389	1159	798	729	33	150	35	0	0	0	0	2904
2019	0	2387	6217	21428	13320	6133	2529	963	500	227	69	0	0	0	0	0	4288
2020	1188	4844	9771	13246	13016	4932	1868	444	129	26	1	1	0	0	0	0	2469
2021	859	3751	11333	12400	8970	6456	1636	731	28	10	0	0	0	0	0	0	2405

Table 23.6. Whiting in Subarea 4 and Division 7.d: Discards numbers at age (thousands), as estimated by ICES. Age 6 is a plus–group. Data used to calculate the discard fraction from the model estimate of catches.

Age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	6+
1978	28587	52684	114965	37682	7154	255	110	0	0	0	0	0	0	0	0	0	110
1979	4577	473830	126724	31601	7322	1263	27	7	0	0	0	0	0	0	0	0	34
1980	3144	103203	250735	88399	14135	10795	786	0	0	0	0	0	0	0	0	0	786
1981	867	50407	96509	57403	7313	1285	149	10	0	0	0	0	0	0	0	0	159
1982	18639	53753	26922	52349	18230	2972	343	22	0	0	0	0	0	0	0	0	365
1983	71016	152488	85318	33325	23442	4309	295	25	9	0	0	0	0	0	0	0	329
1984	16724	200589	82563	16814	4437	4495	1034	151	0	0	0	0	0	0	0	0	1185
1985	8497	154232	48791	15117	2985	761	801	65	0	0	0	0	0	0	0	0	866
1986	7966	404604	120492	43479	5242	627	108	63	12	0	0	0	0	0	0	0	183
1987	9978	158531	202154	34824	9776	582	49	0	31	0	0	0	0	0	0	0	80
1988	21321	65021	87197	51135	5877	846	16	0	3	0	0	0	0	0	0	0	19
1989	6898	150598	36712	61442	21267	3276	103	8	12	0	0	0	0	0	0	0	123
1990	147764	83152	241924	33084	23009	11665	246	85	0	0	0	0	0	0	0	0	331
1991	7208	81678	82053	75035	5176	1885	91	60	0	0	0	0	0	0	0	0	151
1992	7587	105838	63830	27659	23115	1231	355	1064	2	0	0	0	0	0	0	0	1421
1993	48873	128248	104844	51054	9205	10727	521	131	0	0	0	0	0	0	0	0	652
1994	8352	96890	102020	37751	9867	2885	2338	7	0	0	0	0	0	0	0	0	2345
1995	33363	53830	81783	50019	7136	1336	206	113	6	0	0	0	0	0	0	0	325
1996	4575	43126	86878	49817	11506	2205	240	179	0	0	0	0	0	0	0	0	419
1997	11525	26188	34948	32473	9398	2412	400	2	16	0	1	0	0	0	0	0	419
1998	6098	50703	24200	17053	11076	2987	936	213	87	2	18	0	0	0	0	0	1256
1999	14762	96413	56365	15228	9016	3104	862	167	51	34	0	0	0	0	0	0	1114
2000	1682	48162	81086	24082	3075	2311	1560	478	107	0	0	0	0	0	0	0	2145
2001	17352	39826	52156	23055	2795	471	283	142	19	0	0	0	0	0	0	0	444

Age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	6+
2002	1158	10597	33371	45125	10136	1182	218	131	110	3	3	0	0	0	0	0	465
2003	3584	65829	94497	39301	21654	4314	449	30	0	0	0	1	0	0	0	0	480
2004	10478	31169	15698	21879	16951	9909	3922	605	24	9	0	0	0	0	0	0	4560
2005	5499	25753	23486	6041	7192	4616	2992	688	211	5	0	0	0	0	0	0	3896
2006	15662	51961	25906	10935	2474	2595	1598	493	219	37	8	0	0	0	0	0	2355
2007	2350	22508	16283	7153	1784	572	940	1037	380	93	5	0	0	0	0	0	2455
2008	5631	48929	15967	8621	4465	741	328	1449	653	63	0	0	0	0	0	0	2493
2009	11540	51883	12179	3192	1382	653	139	52	64	32	24	0	0	0	0	0	311
2010	3701	30464	22610	8713	2444	1038	1988	99	2775	34	18	4	0	0	3	0	4921
2011	3430	25925	23211	13753	2053	862	760	272	24	13	29	0	0	0	0	0	1098
2012	3471	49677	21362	6943	2497	493	633	154	259	37	59	0	0	0	0	0	1142
2013	4149	17715	7711	8710	2899	693	343	40	44	217	43	0	0	0	0	0	687
2014	5943	25159	6425	7025	6438	2597	1193	239	155	38	79	0	0	0	0	0	1704
2015	7249	43271	34943	6950	2940	3947	888	313	238	39	13	0	0	0	0	0	1491
2016	14941	22682	22342	15500	1889	2536	1075	432	42	23	11	0	0	0	0	0	1583
2017	26493	24515	18650	11973	3735	1111	476	804	129	100	0	0	0	0	0	0	1509
2018	14985	15331	27274	10665	4071	914	172	145	13	1	0	0	0	0	0	0	331
2019	4130	25433	16810	15830	2913	453	342	18	21	34	0	0	0	0	0	0	415
2020	24349	34907	19827	13998	4592	838	115	119	19	5	0	0	0	0	0	0	258
2021	33070	22579	43621	7520	2258	1608	1400	82	109	1	0	0	0	0	0	0	1592

Table 23.7. Whiting in Subarea 4 and Division 7.d: Industrial bycatch numbers at age (thousands), as estimated by ICES. Data used to calculate the IBC fraction in the model estimates of catches.

Age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	6+
1978	658651	351432	98590	49263	6064	616	252	14	0	0	0	0	0	0	0	0	266
1979	471798	133207	232266	42339	4561	1420	73	33	14	0	0	0	0	0	0	0	120
1980	329065	158500	102869	45108	8162	744	55	18	0	0	0	0	0	0	0	0	73
1981	515996	108252	180623	104767	16729	2793	112	0	0	0	0	0	0	0	0	0	112
1982	82418	127998	40818	68242	10514	2448	902	2	0	0	0	0	0	0	0	0	904
1983	597587	42591	30789	17774	6723	1656	63	25	0	0	0	0	0	0	0	0	88
1984	141095	108431	30709	8868	3790	3577	91	0	0	0	0	0	0	0	0	0	91
1985	178225	46801	41731	9871	2522	685	284	26	0	0	0	0	0	0	0	0	310
1986	217207	159249	2086	14572	3987	1456	0	0	0	0	0	0	0	0	0	0	0
1987	74863	97446	93704	17420	1722	1	0	0	0	0	0	0	0	0	0	0	0
1988	395603	357861	158872	34205	4611	500	0	0	0	0	0	0	0	0	0	0	0
1989	80375	172438	108558	53491	12890	1842	1060	89	71	2	0	0	0	0	0	0	1222
1990	141387	168040	206916	51033	12601	2592	346	29	2	0	0	0	0	0	0	0	377
1991	1050381	42554	70343	20951	5376	2408	667	70	0	0	0	0	0	0	0	0	737
1992	251505	114899	58952	12318	8758	639	180	29	3	0	0	0	0	0	0	0	212
1993	578708	89219	38270	11162	4157	832	445	31	0	0	0	0	0	0	0	0	476
1994	209858	77530	24998	14316	4885	1878	1160	337	75	0	0	0	0	0	0	0	1572
1995	1564260	85510	34213	4351	738	73	0	0	0	0	0	0	0	0	0	0	0
1996	90925	30675	5421	2702	970	21	2	0	0	0	0	0	0	0	0	0	2
1997	6868	28247	22087	4146	1074	276	2	0	0	0	0	0	0	0	0	0	2
1998	64989	24782	6334	1511	746	62	12	0	0	0	0	0	0	0	0	0	12
1999	62145	76088	12381	5188	1440	684	27	0	0	0	0	0	0	0	0	0	27
2000	288	19000	16688	11341	6597	2113	580	73	0	0	0	0	0	0	0	0	653
2001	510	481	2453	1728	514	152	40	0	0	0	0	0	0	0	0	0	40
2002	134690	38131	18745	8585	2170	205	120	0	0	0	0	0	0	0	0	0	120

Age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	6+
2003	57140	17448	5034	2575	1213	390	49	0	0	0	0	0	0	0	0	0	49
2004	23732	12824	4499	1049	147	0	11	0	0	0	0	0	0	0	0	0	11
2005	12049	11043	726	494	28	32	54	10	8	0	0	0	0	0	0	0	72
2006	0	10892	5270	2222	806	223	63	7	1	0	0	0	0	0	0	0	71
2007	0	6155	2978	1256	456	126	36	4	1	0	0	0	0	0	0	0	41
2008	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2009	520	2473	1428	730	638	368	169	107	129	90	97	1	0	0	0	0	593
2010	227	1924	1862	1377	549	442	353	115	241	79	56	2	0	0	0	0	846
2011	101	928	1369	970	463	140	115	77	33	18	49	1	0	0	0	0	293
2012	77	1228	999	739	673	332	120	73	52	30	22	1	2	0	0	0	300
2013	192	939	829	1498	1038	775	226	71	43	38	17	0	0	0	0	0	395
2014	281	1415	776	986	1163	723	296	126	57	37	23	0	0	0	0	0	539
2015	320	2056	2666	962	696	984	380	156	85	45	30	0	0	0	0	0	696
2016	2267	3552	4725	5009	1318	1090	867	369	99	98	53	0	0	0	0	0	1486
2017	2231	2109	2156	2182	1856	399	234	239	128	103	3	0	0	0	0	0	707
2018	671	707	1939	1539	1172	483	106	70	61	2	13	3	0	0	0	0	255
2019	385	1560	1116	2411	1131	565	216	82	34	12	7	0	0	0	0	0	351
2020	1276	2189	2421	2748	2284	826	303	77	18	4	0	0	0	0	0	0	402
2021	1165	951	2437	1600	1068	772	229	85	6	1	0	0	0	0	0	0	321

Table 23.8. Whiting in Subarea 4 and Division 7.d: Total catch mean weights at age (kg), as estimated by ICES. Age 6 is a plus-group. Ages 0–6+ and years 1978–2021 are included in the final assessment. Model input.

Age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	6+
1978	0.01	0.074	0.182	0.234	0.321	0.428	0.428	0.466	0.615	0.702	1.539	0.589	0	0	0	0	0.442
1979	0.009	0.098	0.167	0.259	0.301	0.411	0.455	0.492	0.578	0.617	0.737	0.515	0	0	0	0	0.475
1980	0.013	0.075	0.176	0.252	0.328	0.337	0.457	0.459	0.568	0.539	0.79	0.688	1.711	0	0	0	0.464
1981	0.011	0.083	0.168	0.242	0.322	0.379	0.411	0.444	0.651	0.833	1.041	0.695	0	0	0	0	0.424
1982	0.029	0.061	0.184	0.253	0.314	0.376	0.478	0.504	0.702	0.772	1.141	0.853	1.081	0	0	0	0.497
1983	0.015	0.107	0.191	0.273	0.325	0.384	0.426	0.452	0.52	0.677	0.516	0	0	0	0	0	0.439
1984	0.02	0.089	0.189	0.271	0.337	0.381	0.39	0.462	0.575	0.514	0.871	0	0	0	0	0	0.409
1985	0.014	0.094	0.192	0.284	0.332	0.401	0.435	0.494	0.426	0.507	0.852	0.976	0	0	0	0	0.444
1986	0.015	0.105	0.183	0.255	0.318	0.378	0.475	0.468	0.54	1.226	0.99	0.535	0	0	0	0	0.482
1987	0.013	0.077	0.148	0.247	0.297	0.375	0.38	0.542	0.555	0.857	0.603	1.193	0	0	0	0	0.435
1988	0.013	0.054	0.146	0.223	0.301	0.346	0.424	0.506	0.856	0.585	0.648	0	0	0	0	0	0.455
1989	0.023	0.07	0.157	0.225	0.267	0.318	0.391	0.431	0.37	0.515	0.857	0.609	0	0	0	0	0.395
1990	0.016	0.084	0.137	0.21	0.252	0.279	0.411	0.498	0.636	0.351	0.918	0	0	0	0	0	0.441
1991	0.018	0.104	0.168	0.217	0.289	0.306	0.339	0.365	0.385	0.589	0.996	2.756	0	0	0	0	0.344
1992	0.013	0.085	0.185	0.257	0.277	0.331	0.346	0.313	0.481	0.763	1.728	0	0	0	0	0	0.339
1993	0.012	0.073	0.174	0.25	0.316	0.328	0.346	0.4	0.376	0.417	0.359	0	0	0	0	0	0.363
1994	0.013	0.084	0.167	0.255	0.328	0.382	0.376	0.419	0.438	0.392	0.499	0	0	0	0	0	0.381
1995	0.01	0.089	0.18	0.257	0.34	0.384	0.429	0.434	0.445	0.346	0.406	0	0	0	0	0	0.431
1996	0.018	0.094	0.167	0.235	0.302	0.388	0.407	0.431	0.439	0.404	0.376	0.398	0.287	0	0	0	0.415
1997	0.028	0.096	0.178	0.242	0.295	0.334	0.384	0.386	0.394	0.479	0.458	0	0	0	0	0	0.388
1998	0.018	0.09	0.179	0.236	0.281	0.314	0.34	0.333	0.335	0.494	0.434	0.6	0	0	0	0	0.34
1999	0.023	0.078	0.174	0.232	0.256	0.289	0.305	0.311	0.286	0.315	0.344	0	0	0	0	0	0.305
2000	0.034	0.117	0.182	0.238	0.287	0.286	0.276	0.275	0.268	0.264	0.28	0.321	0	0	0	0	0.275
2001	0.024	0.101	0.192	0.244	0.282	0.267	0.298	0.284	0.286	0.301	0.315	0.505	0	0	0	0	0.293

Age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	6+
2002	0.01	0.069	0.155	0.218	0.273	0.303	0.35	0.343	0.327	0.411	0.289	0.231	0.304	0.643	0	0	0.345
2003	0.012	0.057	0.118	0.193	0.259	0.299	0.354	0.385	0.342	0.462	0.62	0	0	0	0	0	0.36
2004	0.031	0.111	0.15	0.213	0.253	0.286	0.285	0.286	0.346	0.351	0.352	1.463	0.337	0	0	0	0.288
2005	0.032	0.124	0.199	0.239	0.25	0.282	0.305	0.298	0.271	0.376	0.316	0.337	0.67	0	0	0	0.302
2006	0.093	0.131	0.18	0.231	0.274	0.288	0.36	0.345	0.318	0.299	0.289	0	0	0	0	0	0.352
2007	0.059	0.098	0.206	0.257	0.325	0.345	0.309	0.309	0.325	0.288	0.328	0	0	0	0	0	0.311
2008	0.027	0.104	0.218	0.282	0.315	0.402	0.407	0.317	0.359	0.337	0.334	0.433	0	0	0	0	0.348
2009	0.042	0.091	0.213	0.286	0.37	0.374	0.373	0.344	0.351	0.335	0.33	0.35	0.419	0	0	0	0.35
2010	0.049	0.111	0.234	0.373	0.406	0.456	0.355	0.459	0.272	0.475	0.471	0.399	0.259	0	0.368	0	0.366
2011	0.048	0.114	0.214	0.298	0.374	0.415	0.424	0.364	0.341	0.372	0.32	0.55	0.894	0	0	0	0.379
2012	0.038	0.105	0.195	0.311	0.445	0.411	0.43	0.428	0.366	0.418	0.406	0.552	0.733	0	0	0	0.417
2013	0.028	0.11	0.222	0.273	0.39	0.468	0.496	0.465	0.424	0.34	0.406	0	0	0	0	0	0.461
2014	0.055	0.137	0.227	0.294	0.331	0.442	0.465	0.469	0.403	0.403	0.359	1.754	0	0	0	0	0.449
2015	0.044	0.125	0.218	0.307	0.368	0.386	0.469	0.464	0.374	0.372	0.4	0.778	0	0	0	0	0.447
2016	0.03	0.12	0.21	0.291	0.399	0.389	0.415	0.488	0.452	0.46	0.472	1.293	0	0	0	0	0.44
2017	0.026	0.078	0.212	0.32	0.409	0.436	0.487	0.444	0.457	0.419	0.528	0.489	0	0	0	0	0.457
2018	0.029	0.108	0.197	0.275	0.373	0.407	0.514	0.458	0.485	0.598	0.448	0.583	0	0	0	0	0.49
2019	0.021	0.106	0.204	0.279	0.354	0.42	0.436	0.44	0.368	0.355	0.577	0.736	0	0	0	0	0.427
2020	0.094	0.107	0.238	0.287	0.374	0.424	0.479	0.542	0.376	0.492	0.656	0.564	0	0	0	0	0.487
2021	0.038	0.125	0.189	0.319	0.391	0.461	0.403	0.538	0.336	0.681	1.065	0.779	0	0	0	0	0.43

Table 23.9. Whiting in Subarea 4 and Division 7.d: Landings mean weights at age (kg), as estimated by ICES. Age 6 is a plus-group.

Age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	6+
1978	0	0.185	0.233	0.25	0.334	0.426	0.434	0.466	0.615	0.702	1.539	0.589	0	0	0	0	0.447
1979	0.113	0.206	0.231	0.277	0.304	0.416	0.456	0.491	0.583	0.617	0.737	0.515	0	0	0	0	0.475
1980	0	0.204	0.239	0.273	0.335	0.358	0.473	0.457	0.568	0.539	0.79	0.688	1.711	0	0	0	0.478
1981	0.144	0.194	0.242	0.292	0.331	0.378	0.411	0.445	0.651	0.833	1.041	0.695	0	0	0	0	0.425
1982	0	0.186	0.23	0.282	0.34	0.396	0.461	0.507	0.702	0.772	1.141	0.853	1.081	0	0	0	0.489
1983	0.132	0.199	0.24	0.282	0.332	0.383	0.429	0.452	0.522	0.677	0.516	0	0	0	0	0	0.442
1984	0	0.194	0.231	0.279	0.346	0.391	0.403	0.472	0.575	0.514	0.871	0	0	0	0	0	0.421
1985	0.137	0.187	0.248	0.307	0.337	0.408	0.443	0.498	0.426	0.507	0.852	0.976	0	0	0	0	0.452
1986	0.131	0.189	0.23	0.279	0.327	0.376	0.484	0.472	0.546	1.226	0.99	0.535	0	0	0	0	0.489
1987	0.135	0.188	0.226	0.286	0.31	0.381	0.381	0.542	0.564	0.857	0.603	1.193	0	0	0	0	0.437
1988	0.117	0.194	0.226	0.256	0.328	0.351	0.425	0.506	0.887	0.585	0.648	0	0	0	0	0	0.456
1989	0.171	0.178	0.226	0.253	0.288	0.345	0.37	0.44	0.373	0.522	0.857	0.609	0	0	0	0	0.378
1990	0.167	0.206	0.222	0.263	0.296	0.337	0.455	0.533	0.64	0.351	0.918	0	0	0	0	0	0.485
1991	0.139	0.202	0.249	0.252	0.308	0.317	0.349	0.387	0.385	0.589	0.996	2.756	0	0	0	0	0.354
1992	0.145	0.194	0.246	0.289	0.306	0.34	0.356	0.383	0.473	0.763	1.728	0	0	0	0	0	0.363
1993	0.153	0.194	0.248	0.284	0.345	0.358	0.385	0.418	0.376	0.417	0.359	0	0	0	0	0	0.393
1994	0.132	0.182	0.248	0.297	0.346	0.392	0.382	0.412	0.414	0.392	0.499	0	0	0	0	0	0.385
1995	0.14	0.171	0.256	0.299	0.367	0.397	0.437	0.437	0.448	0.346	0.406	0	0	0	0	0	0.436
1996	0.143	0.169	0.222	0.274	0.329	0.408	0.415	0.452	0.439	0.404	0.376	0.398	0.287	0	0	0	0.424
1997	0.149	0.171	0.206	0.26	0.315	0.349	0.401	0.386	0.398	0.479	0.437	0	0	0	0	0	0.4
1998	0.138	0.164	0.208	0.259	0.304	0.331	0.361	0.348	0.392	0.504	0.603	0.6	0	0	0	0	0.362
1999	0.135	0.184	0.237	0.271	0.281	0.303	0.316	0.32	0.292	0.368	0.344	0	0	0	0	0	0.316
2000	0	0.166	0.227	0.272	0.299	0.292	0.313	0.276	0.269	0.264	0.28	0.321	0	0	0	0	0.296
2001	0.138	0.16	0.216	0.268	0.285	0.267	0.301	0.288	0.287	0.301	0.315	0.505	0	0	0	0	0.296
2002	0	0.183	0.214	0.26	0.293	0.313	0.364	0.35	0.325	0.39	0.311	0.231	0.304	0.643	0	0	0.354

Age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	6+
2003	0.128	0.208	0.228	0.258	0.308	0.311	0.374	0.391	0.342	0.462	0.62	0	0	0	0	0	0.376
2004	0	0.21	0.216	0.242	0.29	0.326	0.33	0.334	0.366	0.351	0.352	1.463	0.337	0	0	0	0.332
2005	0.164	0.205	0.253	0.277	0.27	0.308	0.339	0.313	0.296	0.381	0.316	0.337	0.67	0	0	0	0.331
2006	0.133	0.217	0.254	0.285	0.295	0.298	0.377	0.353	0.334	0.306	0.29	0	0	0	0	0	0.367
2007	0.202	0.199	0.264	0.28	0.351	0.361	0.319	0.332	0.342	0.318	0.334	0	0	0	0	0	0.327
2008	0	0.223	0.265	0.324	0.356	0.431	0.424	0.359	0.389	0.339	0.334	0.433	0	0	0	0	0.38
2009	0.114	0.184	0.239	0.299	0.375	0.376	0.373	0.346	0.349	0.336	0.327	0.35	0.419	0	0	0	0.349
2010	0.069	0.312	0.303	0.424	0.433	0.468	0.413	0.468	0.459	0.478	0.47	0.409	0.259	0	0.368	0	0.446
2011	0.046	0.194	0.263	0.363	0.397	0.455	0.459	0.367	0.342	0.374	0.322	0.55	0.894	0	0	0	0.389
2012	0.046	0.203	0.236	0.362	0.478	0.42	0.483	0.431	0.376	0.387	0.356	0.552	0.733	0	0	0	0.433
2013	0.038	0.203	0.247	0.295	0.417	0.477	0.515	0.46	0.419	0.413	0.391	0	0	0	0	0	0.479
2014	0.064	0.194	0.259	0.33	0.363	0.49	0.508	0.457	0.375	0.393	0.358	1.754	0	0	0	0	0.461
2015	0.103	0.197	0.253	0.355	0.401	0.428	0.495	0.466	0.406	0.38	0.4	0.778	0	0	0	0	0.465
2016	0.05	0.169	0.265	0.339	0.434	0.463	0.448	0.537	0.463	0.466	0.477	1.293	0	0	0	0	0.473
2017	0.035	0.146	0.249	0.394	0.434	0.493	0.552	0.498	0.465	0.432	0.528	0.489	0	0	0	0	0.497
2018	0.035	0.171	0.239	0.318	0.416	0.427	0.529	0.48	0.488	0.607	0.448	0.583	0	0	0	0	0.503
2019	0.033	0.194	0.269	0.324	0.375	0.429	0.458	0.438	0.373	0.351	0.577	0.736	0	0	0	0	0.44
2020	0.132	0.214	0.33	0.358	0.416	0.444	0.491	0.603	0.4	0.535	0.656	0.564	0	0	0	0	0.507
2021	0.064	0.173	0.235	0.367	0.44	0.514	0.534	0.574	0.854	0.724	1.065	0.779	0	0	0	0	0.551

Table 23.10. Whiting in Subarea 4 and Division 7.d: Discards mean weights at age (kg), as estimated by ICES. Age 6 is a plus-group.

Age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	6+
1978	0.036	0.145	0.158	0.185	0.209	0.222	0.239	0	0	0	0	0	0	0	0	0	0.239
1979	0.08	0.104	0.158	0.191	0.189	0.234	0.265	0.295	0	0	0	0	0	0	0	0	0.271
1980	0.03	0.107	0.166	0.202	0.244	0.253	0.264	0	0	0	0	0	0	0	0	0	0.264
1981	0.071	0.131	0.164	0.197	0.23	0.289	0.252	0.268	0	0	0	0	0	0	0	0	0.253
1982	0.047	0.091	0.182	0.211	0.225	0.241	0.244	0.261	0	0	0	0	0	0	0	0	0.245
1983	0.036	0.114	0.167	0.235	0.264	0.29	0.317	0.277	0.365	0	0	0	0	0	0	0	0.315
1984	0.038	0.101	0.162	0.216	0.246	0.265	0.248	0.278	0	0	0	0	0	0	0	0	0.252
1985	0.022	0.105	0.169	0.213	0.238	0.242	0.253	0.255	0	0	0	0	0	0	0	0	0.253
1986	0.028	0.123	0.166	0.19	0.208	0.227	0.194	0.217	0.311	0	0	0	0	0	0	0	0.21
1987	0.016	0.09	0.149	0.206	0.205	0.263	0.257	0	0.292	0	0	0	0	0	0	0	0.271
1988	0.03	0.063	0.146	0.181	0.21	0.219	0.235	0	0.284	0	0	0	0	0	0	0	0.243
1989	0.033	0.083	0.164	0.191	0.213	0.227	0.241	0.351	0.221	0	0	0	0	0	0	0	0.246
1990	0.024	0.095	0.13	0.183	0.186	0.196	0.249	0.302	0	0	0	0	0	0	0	0	0.263
1991	0.041	0.089	0.154	0.177	0.213	0.23	0.253	0.268	0	0	0	0	0	0	0	0	0.259
1992	0.037	0.093	0.173	0.21	0.215	0.241	0.245	0.22	1.183	0	0	0	0	0	0	0	0.228
1993	0.023	0.087	0.16	0.205	0.237	0.235	0.225	0.213	0	0	0	0	0	0	0	0	0.223
1994	0.04	0.09	0.151	0.203	0.23	0.244	0.254	0.332	0	0	0	0	0	0	0	0	0.254
1995	0.032	0.102	0.163	0.204	0.233	0.247	0.247	0.332	0.29	0	0	0	0	0	0	0	0.277
1996	0.031	0.094	0.151	0.198	0.225	0.281	0.265	0.304	0	0	0	0	0	0	0	0	0.282
1997	0.031	0.125	0.181	0.213	0.225	0.233	0.256	0.617	0.32	0.601	0.773	0	0	0	0	0	0.261
1998	0.026	0.086	0.173	0.204	0.228	0.234	0.224	0.247	0.191	0.18	0.284	0	0	0	0	0	0.226
1999	0.062	0.1	0.166	0.197	0.201	0.225	0.231	0.212	0.231	0.22	0	0	0	0	0	0	0.228
2000	0.033	0.127	0.167	0.195	0.226	0.209	0.219	0.222	0.264	0	0	0	0	0	0	0	0.222
2001	0.023	0.084	0.183	0.217	0.259	0.248	0.24	0.225	0.243	0	0	0	0	0	0	0	0.235
2002	0.039	0.13	0.167	0.196	0.224	0.224	0.225	0.272	0.334	1.12	0.217	0	0	0	0	0	0.27

Age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	6+
2003	0.048	0.062	0.105	0.17	0.214	0.262	0.257	0.293	0.237	0	0	0	0	0	0	0	0.259
2004	0.079	0.131	0.158	0.203	0.223	0.239	0.235	0.227	0.204	0.351	0	0	0	0	0	0	0.234
2005	0.07	0.124	0.177	0.207	0.221	0.223	0.235	0.245	0.222	0.293	0	0	0	0	0	0	0.236
2006	0.093	0.131	0.161	0.193	0.229	0.233	0.247	0.273	0.239	0.279	0.289	0	0	0	0	0	0.252
2007	0.05	0.065	0.17	0.214	0.225	0.247	0.237	0.215	0.229	0.166	0.241	0.35	0	0	0	0	0.224
2008	0.027	0.072	0.181	0.213	0.23	0.265	0.328	0.244	0.291	0.317	0.057	0	0	0	0	0	0.269
2009	0.042	0.086	0.177	0.24	0.333	0.36	0.375	0.265	0.426	0.273	0.594	0	0	0	0	0	0.374
2010	0.049	0.102	0.207	0.283	0.331	0.381	0.242	0.277	0.182	0.362	0.521	0.337	0	0	0.368	0	0.211
2011	0.048	0.1	0.176	0.231	0.264	0.285	0.316	0.346	0.291	0.305	0.251	0	0	0	0	0	0.321
2012	0.038	0.1	0.175	0.229	0.29	0.296	0.261	0.405	0.333	0.877	0.746	0	0	0	0	0	0.342
2013	0.028	0.101	0.199	0.236	0.283	0.353	0.346	0.578	0.484	0.205	0.484	0	0	0	0	0	0.332
2014	0.055	0.13	0.189	0.245	0.27	0.294	0.348	0.556	0.547	0.55	0.361	0	0	0	0	0	0.4
2015	0.043	0.12	0.202	0.254	0.293	0.289	0.358	0.454	0.253	0.271	0.393	0	0	0	0	0	0.359
2016	0.03	0.117	0.188	0.241	0.291	0.267	0.287	0.29	0.309	0.305	0.315	0	0	0	0	0	0.289
2017	0.026	0.076	0.199	0.257	0.322	0.298	0.255	0.335	0.392	0.291	0.362	0.459	0	0	0	0	0.312
2018	0.029	0.103	0.178	0.219	0.247	0.292	0.411	0.34	0.316	0.296	0.311	0.369	0	0	0	0	0.376
2019	0.021	0.098	0.18	0.219	0.259	0.297	0.27	0.544	0.251	0.384	0	0	0	0	0	0	0.29
2020	0.092	0.092	0.192	0.219	0.253	0.307	0.285	0.313	0.216	0.266	0	0	0	0	0	0	0.292
2021	0.037	0.117	0.177	0.24	0.199	0.25	0.251	0.216	0.203	0.251	1.065	1.395	0	0	0	0	0.246

Table 23.11. Whiting in Subarea 4 and Division 7.d: Industrial bycatch mean weights at age (kg), as estimated by ICES. Age 6 is a plus-group.

Age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	6+
1978	0.009	0.059	0.158	0.22	0.295	0.529	0.351	0.449	0	0	0	0	0	0	0	0	0.356
1979	0.008	0.069	0.141	0.249	0.428	0.477	0.467	0.605	0.482	0	0	0	0	0	0	0	0.507
1980	0.013	0.051	0.164	0.281	0.412	0.38	0.389	0.561	0	1	0	0	0	0	0	0	0.431
1981	0.011	0.056	0.141	0.218	0.318	0.433	0.596	0.6	0.8	0	0	0	0	0	0	0	0.596
1982	0.025	0.038	0.133	0.232	0.32	0.366	0.674	0.284	0.8	1	1.2	0	0	0	0	0	0.673
1983	0.012	0.058	0.148	0.311	0.431	0.651	0.565	0.602	0.8	1	0	0	0	0	0	0	0.576
1984	0.018	0.053	0.173	0.289	0.343	0.39	0.228	0.6	0.8	1	0	0	0	0	0	0	0.228
1985	0.014	0.054	0.15	0.263	0.382	0.454	0.504	0.584	0.8	1	0	0	0	0	0	0	0.511
1986	0.014	0.054	0.15	0.262	0.381	0.455	0.5	0.6	0.8	0	0	0	0	0	0	0	0
1987	0.012	0.043	0.085	0.173	0.262	0.4	0.5	0.6	0.8	1	0	0	0	0	0	0	0
1988	0.012	0.05	0.115	0.197	0.245	0.38	0.5	0.6	0.8	0	0	0	0	0	0	0	0
1989	0.022	0.053	0.137	0.224	0.285	0.344	0.482	0.396	0.385	0.401	0	0	0	0	0	0	0.47
1990	0.007	0.073	0.123	0.181	0.201	0.28	0.355	0.335	0.472	0	0	0	0	0	0	0	0.354
1991	0.018	0.105	0.136	0.215	0.272	0.265	0.279	0.322	0	0	0	0	0	0	0	0	0.283
1992	0.012	0.068	0.151	0.235	0.244	0.364	0.219	0.256	0.282	0	0	0	0	0	0	0	0.225
1993	0.011	0.045	0.156	0.26	0.264	0.307	0.235	0.392	0	0	0	0	0	0	0	0	0.245
1994	0.012	0.055	0.131	0.259	0.388	0.521	0.555	0.44	0.555	0	0	0	0	0	0	0	0.53
1995	0.009	0.072	0.16	0.312	0.373	0.511	0	0	0	0	0	0	0	0	0	0	0
1996	0.016	0.064	0.151	0.239	0.233	0.347	0.25	0	0	0	0	0	0	0	0	0	0.25
1997	0.012	0.051	0.145	0.252	0.321	0.348	0.588	0	0	0	0	0	0	0	0	0	0.588
1998	0.015	0.049	0.115	0.22	0.304	0.286	0	0	0	0	0	0	0	0	0	0	0
1999	0.013	0.027	0.077	0.144	0.194	0.286	0	0	0	0	0	0	0	0	0	0	0
2000	0.038	0.051	0.166	0.242	0.289	0.339	0	0.588	0	0	0	0	0	0	0	0	0.066
2001	0.012	0.055	0.118	0.225	0.32	0.351	0.386	0	0	0	0	0	0	0	0	0	0.386
2002	0.01	0.044	0.101	0.185	0.294	0.415	0.38	0	0	0	0	0	0	0	0	0	0.38

Age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	6+
2003	0.01	0.035	0.102	0.189	0.302	0.418	0.462	0	0	0	0	0	0	0	0	0	0.462
2004	0.01	0.032	0.083	0.143	0.264	0	0.38	0	0	0	0	0	0	0	0	0	0.38
2005	0.014	0.043	0.133	0.196	0.205	0.366	0.438	0.541	0.53	0	0	0	0	0	0	0	0.463
2006	0	0.046	0.119	0.208	0.277	0.362	0.401	0.564	0.53	0	0	0	0	0	0	0	0.419
2007	0	0.046	0.119	0.208	0.277	0.362	0.401	0.564	0.53	0	0	0	0	0	0	0	0.42
2008	0	0.046	0.119	0.208	0.277	0.362	0.401	0.564	0.53	0	0	0	0	0	0	0	0
2009	0.042	0.092	0.213	0.286	0.37	0.374	0.373	0.343	0.351	0.335	0.331	0.35	0.419	0	0	0	0.35
2010	0.049	0.111	0.234	0.373	0.407	0.455	0.355	0.458	0.272	0.475	0.471	0.398	0.259	0	0.368	0	0.364
2011	0.048	0.114	0.214	0.298	0.374	0.415	0.424	0.364	0.34	0.372	0.32	0.55	0.894	0	0	0	0.379
2012	0.038	0.105	0.194	0.311	0.445	0.411	0.43	0.428	0.366	0.418	0.407	0.552	0.733	0	0	0	0.418
2013	0.028	0.11	0.222	0.273	0.391	0.468	0.496	0.464	0.424	0.341	0.406	0	0	0	0	0	0.464
2014	0.055	0.137	0.227	0.294	0.331	0.442	0.465	0.469	0.403	0.402	0.359	1.754	0	0	0	0	0.451
2015	0.044	0.125	0.218	0.308	0.368	0.386	0.469	0.464	0.374	0.372	0.4	0.778	0	0	0	0	0.447
2016	0.03	0.12	0.21	0.291	0.399	0.389	0.415	0.488	0.452	0.46	0.472	1.293	0	0	0	0	0.441
2017	0.026	0.078	0.212	0.32	0.409	0.436	0.487	0.444	0.457	0.419	0.526	0.488	0	0	0	0	0.457
2018	0.029	0.108	0.196	0.275	0.373	0.407	0.514	0.458	0.485	0.594	0.448	0.583	0	0	0	0	0.49
2019	0.021	0.107	0.204	0.279	0.354	0.42	0.435	0.44	0.369	0.355	0.577	0.736	0	0	0	0	0.43
2020	0.094	0.106	0.237	0.287	0.374	0.425	0.479	0.542	0.376	0.494	0.656	0.564	0	0	0	0	0.487
2021	0.037	0.125	0.189	0.319	0.391	0.461	0.403	0.538	0.335	0.685	1.065	0.779	0	0	0	0	0.438

Table 23.12. Whiting in Subarea 4 and Division 7.d: Catch component as estimated by ICES in tonnes, model input. Discards include BMS.

Year	Catch	Landings	Discards	IBC
1978	188222	97553	35382	55287
1979	243570	107231	77391	58948
1980	223361	100775	77003	45584
1981	192119	89583	35894	66641
1982	140250	80576	26620	33055
1983	161316	88002	49562	23753
1984	145636	86275	40483	18878
1985	100330	56059	28961	15310
1986	161494	64019	79523	17953
1987	138737	68317	53901	16519
1988	133215	56100	28146	48969
1989	123533	45103	35787	42643
1990	152602	45662	55603	51337
1991	126742	51929	35058	39755
1992	108555	50946	32564	25045
1993	116911	51818	44370	20723
1994	101650	48486	35692	17473
1995	105494	45938	32176	27379
1996	76123	40503	30505	5116
1997	61435	35563	19660	6213
1998	47475	28288	15693	3494
1999	60845	30130	25677	5038
2000	63806	28583	26063	9160
2001	45242	25061	19237	944
2002	46450	20675	18501	7275
2003	45640	16161	26745	2734
2004	33557	13295	19048	1214
2005	28883	15471	12525	888
2006	36769	18535	16310	1924
2007	26974	18915	6971	1088
2008	28247	17951	10296	0
2009	28430	18403	8684	1344
2010	34436	19846	12683	1907
2011	30668	18461	11173	1035
2012	30221	17407	11697	1117
2013	26573	18211	6795	1654
2014	28375	17027	9725	1623
2015	36287	17299	16891	2097

Year	Catch	Landings	Discards	IBC
2016	33396	16118	12726	4551
2017	29344	15361	11348	2635
2018	28407	16160	10588	1658
2019	30523	18579	10080	1864
2020	34924	18014	13795	3115
2021	33186	16499	14638	2048

Table 23.13. Whiting in Subarea 4 and Division 7.d: Stock weights at age (kg), as estimated from scaled (using IBTS Q1) commercial catch weights at age. Age 6 is a plus-group. Model input.

AGE	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	6+
1978	0.00334	0.024716	0.093548	0.161928	0.256158	0.390336	0.438022	0.438022	0.438022	0.438022	0.438022	0.438022	0.438022	0.438022	0.438022	0.438022	0.438022
1979	0.003006	0.032732	0.085838	0.179228	0.240198	0.374832	0.470725	0.470725	0.470725	0.470725	0.470725	0.470725	0.470725	0.470725	0.470725	0.470725	0.470725
1980	0.004342	0.02505	0.090464	0.174384	0.261744	0.307344	0.459824	0.459824	0.459824	0.459824	0.459824	0.459824	0.459824	0.459824	0.459824	0.459824	0.459824
1981	0.003674	0.027722	0.086352	0.167464	0.256956	0.345648	0.420184	0.420184	0.420184	0.420184	0.420184	0.420184	0.420184	0.420184	0.420184	0.420184	0.420184
1982	0.009686	0.020374	0.094576	0.175076	0.250572	0.342912	0.492527	0.492527	0.492527	0.492527	0.492527	0.492527	0.492527	0.492527	0.492527	0.492527	0.492527
1983	0.00501	0.035738	0.098174	0.188916	0.25935	0.350208	0.435049	0.435049	0.435049	0.435049	0.435049	0.435049	0.435049	0.435049	0.435049	0.435049	0.435049
1984	0.00668	0.029726	0.097146	0.187532	0.268926	0.347472	0.405319	0.405319	0.405319	0.405319	0.405319	0.405319	0.405319	0.405319	0.405319	0.405319	0.405319
1985	0.004676	0.031396	0.098688	0.196528	0.264936	0.365712	0.440004	0.440004	0.440004	0.440004	0.440004	0.440004	0.440004	0.440004	0.440004	0.440004	0.440004
1986	0.00501	0.03507	0.094062	0.17646	0.253764	0.344736	0.477662	0.477662	0.477662	0.477662	0.477662	0.477662	0.477662	0.477662	0.477662	0.477662	0.477662
1987	0.004342	0.025718	0.076072	0.170924	0.237006	0.342	0.431085	0.431085	0.431085	0.431085	0.431085	0.431085	0.431085	0.431085	0.431085	0.431085	0.431085
1988	0.004342	0.018036	0.075044	0.154316	0.240198	0.315552	0.450905	0.450905	0.450905	0.450905	0.450905	0.450905	0.450905	0.450905	0.450905	0.450905	0.450905
1989	0.007682	0.02338	0.080698	0.1557	0.213066	0.290016	0.391445	0.391445	0.391445	0.391445	0.391445	0.391445	0.391445	0.391445	0.391445	0.391445	0.391445
1990	0.005344	0.028056	0.070418	0.14532	0.201096	0.254448	0.437031	0.437031	0.437031	0.437031	0.437031	0.437031	0.437031	0.437031	0.437031	0.437031	0.437031
1991	0.006012	0.034736	0.086352	0.150164	0.230622	0.279072	0.340904	0.340904	0.340904	0.340904	0.340904	0.340904	0.340904	0.340904	0.340904	0.340904	0.340904
1992	0.004342	0.02839	0.09509	0.177844	0.221046	0.301872	0.335949	0.335949	0.335949	0.335949	0.335949	0.335949	0.335949	0.335949	0.335949	0.335949	0.335949
1993	0.004008	0.024382	0.089436	0.173	0.252168	0.299136	0.359733	0.359733	0.359733	0.359733	0.359733	0.359733	0.359733	0.359733	0.359733	0.359733	0.359733
1994	0.004342	0.028056	0.085838	0.17646	0.261744	0.348384	0.377571	0.377571	0.377571	0.377571	0.377571	0.377571	0.377571	0.377571	0.377571	0.377571	0.377571
1995	0.00334	0.029726	0.09252	0.177844	0.27132	0.350208	0.427121	0.427121	0.427121	0.427121	0.427121	0.427121	0.427121	0.427121	0.427121	0.427121	0.427121
1996	0.006012	0.031396	0.085838	0.16262	0.240996	0.353856	0.411265	0.411265	0.411265	0.411265	0.411265	0.411265	0.411265	0.411265	0.411265	0.411265	0.411265
1997	0.009352	0.032064	0.091492	0.167464	0.23541	0.304608	0.384508	0.384508	0.384508	0.384508	0.384508	0.384508	0.384508	0.384508	0.384508	0.384508	0.384508
1998	0.006012	0.03006	0.092006	0.163312	0.224238	0.286368	0.33694	0.33694	0.33694	0.33694	0.33694	0.33694	0.33694	0.33694	0.33694	0.33694	0.33694
1999	0.007682	0.026052	0.089436	0.160544	0.204288	0.263568	0.302255	0.302255	0.302255	0.302255	0.302255	0.302255	0.302255	0.302255	0.302255	0.302255	0.302255
2000	0.011356	0.039078	0.093548	0.164696	0.229026	0.260832	0.272525	0.272525	0.272525	0.272525	0.272525	0.272525	0.272525	0.272525	0.272525	0.272525	0.272525
2001	0.008016	0.033734	0.098688	0.168848	0.225036	0.243504	0.290363	0.290363	0.290363	0.290363	0.290363	0.290363	0.290363	0.290363	0.290363	0.290363	0.290363

AGE	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	6+
2002	0.00334	0.023046	0.07967	0.150856	0.217854	0.276336	0.341895	0.341895	0.341895	0.341895	0.341895	0.341895	0.341895	0.341895	0.341895	0.341895	0.341895
2003	0.004008	0.019038	0.060652	0.133556	0.206682	0.272688	0.35676	0.35676	0.35676	0.35676	0.35676	0.35676	0.35676	0.35676	0.35676	0.35676	0.35676
2004	0.010354	0.037074	0.0771	0.147396	0.201894	0.260832	0.285408	0.285408	0.285408	0.285408	0.285408	0.285408	0.285408	0.285408	0.285408	0.285408	0.285408
2005	0.010688	0.041416	0.102286	0.165388	0.1995	0.257184	0.299282	0.299282	0.299282	0.299282	0.299282	0.299282	0.299282	0.299282	0.299282	0.299282	0.299282
2006	0.031062	0.043754	0.09252	0.159852	0.218652	0.262656	0.348832	0.348832	0.348832	0.348832	0.348832	0.348832	0.348832	0.348832	0.348832	0.348832	0.348832
2007	0.019706	0.032732	0.105884	0.177844	0.25935	0.31464	0.308201	0.308201	0.308201	0.308201	0.308201	0.308201	0.308201	0.308201	0.308201	0.308201	0.308201
2008	0.009018	0.034736	0.112052	0.195144	0.25137	0.366624	0.344868	0.344868	0.344868	0.344868	0.344868	0.344868	0.344868	0.344868	0.344868	0.344868	0.344868
2009	0.014028	0.030394	0.109482	0.197912	0.29526	0.341088	0.34685	0.34685	0.34685	0.34685	0.34685	0.34685	0.34685	0.34685	0.34685	0.34685	0.34685
2010	0.016366	0.037074	0.120276	0.258116	0.323988	0.415872	0.362706	0.362706	0.362706	0.362706	0.362706	0.362706	0.362706	0.362706	0.362706	0.362706	0.362706
2011	0.016032	0.038076	0.109996	0.206216	0.298452	0.37848	0.375589	0.375589	0.375589	0.375589	0.375589	0.375589	0.375589	0.375589	0.375589	0.375589	0.375589
2012	0.012692	0.03507	0.10023	0.215212	0.35511	0.374832	0.413247	0.413247	0.413247	0.413247	0.413247	0.413247	0.413247	0.413247	0.413247	0.413247	0.413247
2013	0.009352	0.03674	0.114108	0.188916	0.31122	0.426816	0.456851	0.456851	0.456851	0.456851	0.456851	0.456851	0.456851	0.456851	0.456851	0.456851	0.456851
2014	0.01837	0.045758	0.116678	0.203448	0.264138	0.403104	0.444959	0.444959	0.444959	0.444959	0.444959	0.444959	0.444959	0.444959	0.444959	0.444959	0.444959
2015	0.014696	0.04175	0.112052	0.212444	0.293664	0.352032	0.442977	0.442977	0.442977	0.442977	0.442977	0.442977	0.442977	0.442977	0.442977	0.442977	0.442977
2016	0.01002	0.04008	0.10794	0.201372	0.318402	0.354768	0.43604	0.43604	0.43604	0.43604	0.43604	0.43604	0.43604	0.43604	0.43604	0.43604	0.43604
2017	0.008684	0.026052	0.108968	0.22144	0.326382	0.397632	0.452887	0.452887	0.452887	0.452887	0.452887	0.452887	0.452887	0.452887	0.452887	0.452887	0.452887
2018	0.009686	0.036072	0.101258	0.1903	0.297654	0.371184	0.48559	0.48559	0.48559	0.48559	0.48559	0.48559	0.48559	0.48559	0.48559	0.48559	0.48559
2019	0.007014	0.035404	0.104856	0.193068	0.282492	0.38304	0.423157	0.423157	0.423157	0.423157	0.423157	0.423157	0.423157	0.423157	0.423157	0.423157	0.423157
2020	0.031396	0.035738	0.122332	0.198604	0.298452	0.386688	0.482617	0.482617	0.482617	0.482617	0.482617	0.482617	0.482617	0.482617	0.482617	0.482617	0.482617
2021	0.012692	0.04175	0.097146	0.220748	0.312018	0.420432	0.42613	0.42613	0.42613	0.42613	0.42613	0.42613	0.42613	0.42613	0.42613	0.42613	0.42613

Table 23.14. Whiting in Subarea 4 and Division 7.d: Estimated proportion mature at age as used in the assessment. Model input.

Age	0	1	2	3	4	5	6+
1978	0	0.185	0.838	0.997	1	1	1
1979	0	0.185	0.838	0.997	1	1	1
1980	0	0.185	0.838	0.997	1	1	1
1981	0	0.185	0.838	0.997	1	1	1
1982	0	0.185	0.838	0.997	1	1	1
1983	0	0.185	0.838	0.997	1	1	1
1984	0	0.185	0.838	0.997	1	1	1
1985	0	0.185	0.838	0.997	1	1	1
1986	0	0.185	0.838	0.997	1	1	1
1987	0	0.185	0.838	0.997	1	1	1
1988	0	0.185	0.838	0.997	1	1	1
1989	0	0.185	0.838	0.997	1	1	1
1990	0	0.185	0.838	0.997	1	1	1
1991	0	0.185	0.838	0.997	1	1	1
1992	0	0.186	0.829	0.992	1	1	1
1993	0	0.187	0.82	0.987	1	1	1
1994	0	0.19	0.81	0.981	0.998	0.999	1
1995	0	0.194	0.799	0.975	0.996	0.999	1
1996	0	0.2	0.788	0.968	0.994	0.998	1
1997	0	0.207	0.776	0.96	0.991	0.998	1
1998	0	0.218	0.764	0.951	0.988	0.997	1
1999	0	0.231	0.751	0.943	0.986	0.997	1
2000	0	0.246	0.739	0.935	0.984	0.996	1
2001	0	0.263	0.732	0.931	0.983	0.996	1
2002	0	0.279	0.73	0.93	0.983	0.997	1
2003	0	0.294	0.733	0.932	0.984	0.997	1
2004	0	0.307	0.74	0.936	0.986	0.998	1
2005	0	0.319	0.75	0.941	0.988	0.998	1
2006	0	0.329	0.763	0.947	0.99	0.999	1
2007	0	0.338	0.776	0.953	0.992	0.999	1
2008	0	0.344	0.789	0.959	0.994	1	1
2009	0	0.35	0.801	0.964	0.996	1	1
2010	0	0.354	0.811	0.968	0.997	1	1
2011	0	0.357	0.819	0.971	0.997	1	1
2012	0	0.36	0.825	0.973	0.998	1	1
2013	0	0.361	0.829	0.974	0.998	1	1
2014	0	0.363	0.832	0.974	0.998	1	1
2015	0	0.367	0.835	0.975	0.998	1	1

Age	0	1	2	3	4	5	6+
2016	0	0.372	0.838	0.976	0.998	1	1
2017	0	0.379	0.841	0.976	0.997	1	1
2018	0	0.389	0.843	0.976	0.997	1	1
2019	0	0.402	0.846	0.976	0.997	1	1
2020	0	0.418	0.85	0.977	0.997	1	1
2021	0	0.439	0.855	0.977	0.996	1	1

Table 23.15. Whiting in Subarea 4 and Division 7.d: Natural mortality at age estimates based on ICES WGSAM (2021b). Model input.

Age	0	1	2	3	4	5	6+
1978	1.351	1.42	0.833	0.546	0.514	0.454	0.402
1979	1.378	1.406	0.814	0.537	0.507	0.45	0.374
1980	1.406	1.392	0.795	0.529	0.499	0.446	0.4
1981	1.429	1.377	0.776	0.52	0.491	0.442	0.386
1982	1.446	1.357	0.756	0.512	0.484	0.437	0.377
1983	1.455	1.334	0.736	0.504	0.476	0.433	0.377
1984	1.459	1.311	0.715	0.496	0.469	0.43	0.38
1985	1.46	1.291	0.695	0.489	0.462	0.427	0.379
1986	1.463	1.278	0.676	0.484	0.457	0.425	0.336
1987	1.469	1.271	0.66	0.48	0.454	0.424	0.364
1988	1.48	1.268	0.645	0.477	0.451	0.424	0.377
1989	1.499	1.266	0.633	0.474	0.449	0.425	0.39
1990	1.524	1.266	0.623	0.472	0.447	0.426	0.382
1991	1.556	1.267	0.615	0.469	0.445	0.426	0.399
1992	1.595	1.27	0.61	0.466	0.444	0.425	0.395
1993	1.642	1.276	0.607	0.464	0.442	0.425	0.386
1994	1.696	1.285	0.606	0.462	0.441	0.424	0.408
1995	1.758	1.296	0.606	0.462	0.441	0.424	0.396
1996	1.827	1.311	0.608	0.463	0.441	0.424	0.394
1997	1.9	1.328	0.609	0.465	0.442	0.424	0.403
1998	1.978	1.347	0.612	0.468	0.444	0.425	0.411
1999	2.057	1.366	0.616	0.472	0.446	0.427	0.413
2000	2.137	1.384	0.622	0.477	0.449	0.429	0.415
2001	2.217	1.4	0.63	0.483	0.454	0.432	0.418
2002	2.293	1.411	0.639	0.49	0.459	0.436	0.422
2003	2.36	1.411	0.648	0.497	0.464	0.44	0.43
2004	2.415	1.399	0.656	0.503	0.469	0.444	0.435
2005	2.457	1.378	0.661	0.508	0.472	0.446	0.436
2006	2.486	1.351	0.663	0.51	0.474	0.447	0.435
2007	2.505	1.321	0.662	0.511	0.474	0.447	0.431

Age	0	1	2	3	4	5	6+
2008	2.516	1.29	0.659	0.51	0.472	0.446	0.422
2009	2.522	1.258	0.654	0.508	0.47	0.445	0.421
2010	2.526	1.229	0.649	0.507	0.468	0.443	0.413
2011	2.523	1.204	0.645	0.505	0.466	0.442	0.396
2012	2.508	1.184	0.641	0.505	0.466	0.442	0.384
2013	2.478	1.169	0.638	0.505	0.466	0.442	0.375
2014	2.433	1.158	0.637	0.505	0.467	0.443	0.359
2015	2.37	1.152	0.638	0.506	0.467	0.444	0.347
2016	2.289	1.15	0.642	0.507	0.468	0.445	0.337
2017	2.192	1.151	0.647	0.508	0.468	0.446	0.31
2018	2.083	1.151	0.652	0.51	0.469	0.447	0.305
2019	1.967	1.151	0.658	0.511	0.469	0.448	0.309
2020	1.967	1.151	0.658	0.511	0.469	0.448	0.319
2021	1.967	1.151	0.658	0.511	0.469	0.448	0.321

Table 23.16a. Whiting in Subarea 4 and Division 7.d: NS IBTS tuning series used in the assessment and forecast; model input.

IBTS–Q1					
Age	1	2	3	4	5
1983	1.265	1.211	1.078	0.765	0.337
1984	4.265	1.645	0.805	0.276	0.267
1985	3.243	3.449	0.617	0.171	0.079
1986	4.511	2.826	2.127	0.349	0.093
1987	6.680	5.395	0.864	0.428	0.060
1988	4.329	8.312	2.998	0.308	0.173
1989	14.246	5.205	3.946	1.033	0.172
1990	5.140	8.397	1.992	0.988	0.201
1991	9.341	7.593	3.660	0.735	0.336
1992	9.984	4.501	2.423	0.748	0.573
1993	10.613	5.507	1.928	0.880	0.392
1994	7.317	5.711	1.922	0.677	0.135
1995	6.563	4.709	2.040	0.643	0.135
1996	4.796	4.686	2.174	0.676	0.351
1997	3.165	2.610	1.598	0.820	0.235
1998	5.107	1.621	1.175	0.484	0.220
1999	6.108	2.638	1.461	0.672	0.274
2000	8.133	4.628	1.857	0.317	0.181
2001	6.462	5.632	2.507	0.723	0.289
2002	5.347	3.505	2.588	0.484	0.124
2003	1.370	2.729	2.468	1.264	0.444

IBTS–Q1					
Age	1	2	3	4	5
2004	1.874	0.932	1.599	0.778	0.435
2005	1.284	0.753	0.511	0.425	0.287
2006	1.931	1.052	0.476	0.223	0.160
2007	0.638	1.485	0.640	0.217	0.112
2008	2.571	1.993	0.556	0.183	0.095
2009	2.115	2.873	0.681	0.173	0.162
2010	3.379	1.961	1.721	0.515	0.735
2011	1.751	3.521	1.350	0.708	0.188
2012	2.204	5.620	1.001	0.396	0.293
2013	0.525	1.629	2.447	0.670	0.346
2014	2.585	1.873	0.978	0.607	0.337
2015	3.241	2.032	0.510	0.244	0.225
2016	3.510	2.933	0.849	0.241	0.140
2017	5.651	2.333	1.012	0.305	0.111
2018	1.215	2.304	0.736	0.328	0.121
2019	2.175	1.749	1.169	0.442	0.129
2020	5.190	2.023	0.785	0.526	0.164
2021	5.994	7.009	1.139	0.405	0.154
2022	2.809	6.888	2.683	0.462	0.103

Table 23.16b. Whiting in Subarea 4 and Division 7.d: NS IBTS tuning series used in the assessment and forecast, model input.

IBTS-Q3						
Age	0	1	2	3	4	5
1991	5.065	6.776	1.478	0.858	0.297	0.169
1992	13.232	5.468	2.504	0.709	0.539	0.316
1993	8.781	6.247	1.803	0.426	0.246	0.169
1994	5.687	6.932	2.358	0.494	0.186	0.106
1995	7.035	6.252	2.730	0.712	0.209	0.090
1996	2.832	4.446	3.279	1.267	0.347	0.099
1997	19.735	2.902	1.655	1.192	0.265	0.202
1998	25.563	3.176	1.386	0.539	0.315	0.124
1999	23.860	11.486	1.775	0.521	0.226	0.102
2000	18.681	8.953	3.048	0.582	0.172	0.084
2001	34.265	6.447	2.677	0.845	0.220	0.081
2002	2.566	7.703	2.390	1.275	0.344	0.075
2003	3.481	2.502	2.735	1.193	0.676	0.189
2004	6.800	1.377	0.597	0.629	0.428	0.246
2005	1.639	1.451	0.810	0.314	0.429	0.315

IBTS-Q3						
Age	0	1	2	3	4	5
2006	1.894	1.653	0.775	0.287	0.228	0.183
2007	7.773	0.853	0.611	0.336	0.155	0.082
2008	7.281	3.425	0.615	0.294	0.131	0.066
2009	5.553	5.414	3.361	0.504	0.131	0.089
2010	4.725	2.160	1.336	0.433	0.125	0.123
2011	2.311	4.031	1.360	0.593	0.191	0.082
2012	2.828	2.494	2.097	0.630	0.215	0.146
2013	3.083	0.627	0.575	0.624	0.198	0.072
2014	19.385	2.073	0.908	0.580	0.329	0.097
2015	19.307	2.926	2.093	0.539	0.265	0.176
2016	9.005	2.752	2.226	0.663	0.200	0.089
2017	1.710	8.764	1.926	0.825	0.260	0.114
2018	1.687	2.363	2.842	0.807	0.317	0.210
2019	13.649	4.285	1.461	0.831	0.220	0.150
2020	12.224	14.487	2.086	0.594	0.424	0.346
2021	6.02	11.442	4.037	0.633	0.204	0.102

Table 23.17. Whiting in Subarea 4 and Division 7.d: Final fishing mortality estimates from SAM, model output.

Age	0	1	2	3	4	5	6+
1978	0.019	0.086	0.277	0.528	0.653	0.8	0.8
1979	0.02	0.093	0.297	0.569	0.674	0.817	0.817
1980	0.018	0.086	0.284	0.595	0.745	0.908	0.908
1981	0.019	0.09	0.272	0.567	0.726	0.881	0.881
1982	0.019	0.095	0.258	0.505	0.63	0.766	0.766
1983	0.022	0.119	0.319	0.596	0.71	0.833	0.833
1984	0.023	0.131	0.351	0.677	0.842	0.983	0.983
1985	0.02	0.117	0.295	0.584	0.798	0.967	0.967
1986	0.022	0.134	0.347	0.649	0.906	1.07	1.07
1987	0.021	0.127	0.354	0.664	0.915	1.111	1.111
1988	0.021	0.134	0.351	0.603	0.799	0.993	0.993
1989	0.019	0.119	0.333	0.555	0.73	0.939	0.939
1990	0.02	0.129	0.379	0.574	0.681	0.83	0.83
1991	0.017	0.111	0.329	0.492	0.54	0.632	0.632
1992	0.017	0.114	0.325	0.485	0.53	0.562	0.562
1993	0.016	0.116	0.341	0.547	0.613	0.646	0.646
1994	0.014	0.107	0.315	0.539	0.641	0.682	0.682
1995	0.012	0.094	0.279	0.483	0.575	0.625	0.625
1996	0.01	0.082	0.249	0.433	0.527	0.568	0.568

Age	0	1	2	3	4	5	6+
1997	0.008	0.074	0.225	0.383	0.479	0.51	0.51
1998	0.007	0.069	0.206	0.339	0.437	0.483	0.483
1999	0.007	0.073	0.23	0.377	0.475	0.522	0.522
2000	0.005	0.057	0.199	0.351	0.455	0.518	0.518
2001	0.004	0.046	0.147	0.253	0.344	0.397	0.397
2002	0.004	0.052	0.147	0.227	0.288	0.314	0.314
2003	0.006	0.078	0.19	0.238	0.271	0.281	0.281
2004	0.005	0.072	0.163	0.201	0.234	0.258	0.258
2005	0.005	0.072	0.16	0.19	0.214	0.24	0.24
2006	0.005	0.083	0.181	0.225	0.24	0.264	0.264
2007	0.004	0.074	0.165	0.217	0.231	0.243	0.243
2008	0.004	0.07	0.157	0.217	0.236	0.245	0.245
2009	0.003	0.062	0.14	0.209	0.245	0.272	0.272
2010	0.003	0.053	0.13	0.208	0.255	0.293	0.293
2011	0.003	0.051	0.125	0.196	0.235	0.268	0.268
2012	0.003	0.055	0.12	0.184	0.233	0.275	0.275
2013	0.002	0.048	0.109	0.18	0.239	0.299	0.299
2014	0.002	0.045	0.117	0.2	0.263	0.331	0.331
2015	0.003	0.048	0.142	0.238	0.296	0.357	0.357
2016	0.002	0.039	0.13	0.244	0.306	0.347	0.347
2017	0.002	0.031	0.109	0.216	0.285	0.292	0.292
2018	0.002	0.029	0.105	0.211	0.271	0.253	0.253
2019	0.002	0.028	0.106	0.218	0.269	0.234	0.234
2020	0.002	0.024	0.097	0.203	0.247	0.204	0.204
2021	0.001	0.02	0.08	0.168	0.217	0.187	0.187

Table 23.18. Whiting in Subarea 4 and Division 7.d: Final abundance estimates from SAM, model output.

Age	0	1	2	3	4	5	6+
1978	41514893	10123115	1874844	821429	222176	16553	20663
1979	32952922	10625873	2261050	618000	283378	68789	10922
1980	16380174	8270573	2346132	738982	203923	88779	22777
1981	14832658	3852077	1981961	786339	236686	58370	29140
1982	13078987	3476532	877818	727665	261909	68810	23604
1983	19031550	2971962	803532	321283	273866	86072	28018
1984	14888804	4428885	691405	278453	106251	86710	32735
1985	25443849	3291871	1063059	236197	84918	28614	29842
1986	24055566	5916769	790724	412886	81195	24076	14860
1987	18708678	5491854	1458015	280056	137362	20506	9092
1988	25693010	4145623	1418868	526944	88294	35148	6447

Age	0	1	2	3	4	5	6+
1989	16254631	5878555	985685	540246	178918	25468	10149
1990	14326692	3527049	1506496	375313	196982	55044	9025
1991	15709216	3029514	865886	544447	133456	63970	18201
1992	18032192	3273921	765171	333322	207816	50994	28348
1993	17521334	3595192	799804	301726	130074	81124	29175
1994	16106570	3337576	880242	302223	112013	44760	38339
1995	12554264	2948840	822600	347315	111357	37612	27451
1996	10520357	2112018	735786	336607	135716	40513	22740
1997	16158169	1658439	516644	314707	134176	52684	23213
1998	26703170	2354370	405828	224766	132322	53535	29818
1999	30080187	3665592	552931	182876	102728	54271	33687
2000	25319749	3822628	833655	231817	78437	41264	34399
2001	24404204	2954450	926064	349353	96290	32154	29272
2002	12453417	2650308	707984	445679	163230	41505	26392
2003	12778803	1231795	622408	336963	219489	76418	31438
2004	15115751	1198560	261482	264715	166994	105561	52740
2005	14885042	1344079	273405	114708	129265	83884	79024
2006	11603766	1308082	321111	119953	58156	64879	83714
2007	17991045	951035	312288	142778	57839	28073	74826
2008	17703740	1486558	243461	136431	70592	28575	53021
2009	17267764	1426187	386075	107520	66304	36065	42694
2010	17531478	1385154	376182	172168	51448	34641	39946
2011	11750419	1429473	389466	173533	83029	24861	36403
2012	8615069	950574	435999	174999	84696	41506	30876
2013	13770710	682931	264073	210597	88560	42569	35790
2014	16709968	1173497	205536	124727	105693	44094	38321
2015	14890907	1448128	364108	98746	60510	51087	39247
2016	17032380	1344898	422871	165909	47863	28226	41866
2017	10133907	1750752	398110	188050	77624	22266	33359
2018	11885469	1120255	532007	186170	88418	36717	28095
2019	22090037	1483489	348117	242764	91438	41477	33505
2020	21131946	3155838	449434	164244	113351	44457	39025
2021	14371814	2977400	986622	207448	80608	54177	45526

Table 23.19. Whiting in Subarea 4 and Division 7.d: Final SAM summary table. Model output. Units are individuals and tonnes.

Year	R (age 0)	Low	High	SSB	Low	High	F (2–5)	Low	High	TSB	Low	High
1978	41514893	32459238	53096944	397350	348997	452402	0.564	0.455	0.699	769687	685617	864065
1979	32952922	25217802	43060656	435931	386356	491868	0.589	0.489	0.71	850702	754832	958747
1980	16380174	12971088	20685242	434365	383997	491339	0.633	0.527	0.761	710542	633618	796805
1981	14832658	11788905	18662272	386077	340698	437500	0.612	0.507	0.737	557350	499688	621666
1982	13078987	10451911	16366375	309463	273600	350028	0.54	0.448	0.65	508779	457991	565200
1983	19031550	15075673	24025454	259164	230637	291219	0.614	0.522	0.722	454501	409849	504017
1984	14888804	11843774	18716709	204483	182828	228703	0.713	0.61	0.834	422467	379641	470124
1985	25443849	20327702	31847645	198807	176604	223802	0.661	0.563	0.776	419750	375676	468995
1986	24055566	19013703	30434379	209363	186948	234465	0.743	0.634	0.871	511257	454716	574829
1987	18708678	14977047	23370069	209820	186773	235711	0.761	0.639	0.906	424743	380423	474227
1988	25693010	20526803	32159453	218373	193272	246734	0.686	0.573	0.822	409329	366879	456691
1989	16254631	13101938	20165950	224974	199824	253289	0.639	0.524	0.779	475448	426329	530226
1990	14326692	11573824	17734338	218464	193865	246183	0.616	0.507	0.748	393704	353738	438186
1991	15709216	12713584	19410694	218452	193559	246546	0.498	0.411	0.604	411039	369136	457699
1992	18032192	14621672	22238220	207259	183676	233869	0.476	0.395	0.573	374136	336096	416480
1993	17521334	14193218	21629847	194132	171965	219156	0.537	0.451	0.64	349176	313299	389162
1994	16106570	13033394	19904378	190631	168685	215431	0.544	0.45	0.657	351850	315037	392965
1995	12554264	10126246	15564459	193011	169955	219195	0.491	0.402	0.599	322574	287719	361650
1996	10520357	8433997	13122832	172134	150890	196369	0.444	0.362	0.546	303850	269926	342037
1997	16158169	12639049	20657127	154532	134716	177262	0.399	0.325	0.49	360818	313247	415614
1998	26703170	20986117	33977666	133487	115908	153732	0.366	0.296	0.453	360407	309702	419413
1999	30080187	23687678	38197820	131960	113909	152871	0.401	0.323	0.498	450856	384950	528045
2000	25319749	19936080	32157258	167906	144472	195142	0.381	0.297	0.488	591179	501066	697499

Year	R (age 0)	Low	High	SSB	Low	High	F (2–5)	Low	High	TSB	Low	High
2001	24404204	19379539	30731649	185542	157400	218716	0.285	0.218	0.373	483666	413510	565726
2002	12453417	9823829	15786879	176107	148527	208809	0.244	0.188	0.316	282365	243415	327547
2003	12778803	10207451	15997903	153119	128151	182951	0.245	0.193	0.31	234841	201878	273185
2004	15115751	11949947	19120246	140840	117935	168194	0.214	0.169	0.271	336423	287179	394111
2005	14885042	11764332	18833579	127270	106726	151769	0.201	0.159	0.254	332707	282856	391343
2006	11603766	9222126	14600471	118478	99635	140886	0.228	0.182	0.284	525513	438979	629104
2007	17991045	14261560	22695813	107146	90758	126493	0.214	0.172	0.267	491014	407479	591674
2008	17703740	14011340	22369196	111238	94782	130551	0.214	0.172	0.266	311700	264859	366824
2009	17267764	13675307	21803948	116122	98875	136376	0.217	0.173	0.271	395814	332325	471432
2010	17531478	13499022	22768519	143389	121713	168926	0.221	0.174	0.282	473522	392284	571584
2011	11750419	9273937	14888212	137069	115943	162045	0.206	0.161	0.263	369298	312060	437035
2012	8615069	6778900	10948591	142989	120234	170051	0.203	0.159	0.26	282434	240024	332339
2013	13770710	10796381	17564447	134793	112535	161454	0.207	0.162	0.265	285874	240847	339319
2014	16709968	12806741	21802816	126865	105797	152127	0.228	0.177	0.293	472759	384351	581504
2015	14890907	11378405	19487714	129799	107547	156654	0.258	0.199	0.335	394212	320969	484169
2016	17032380	13086575	22167907	134385	110150	163952	0.257	0.195	0.338	347131	284468	423597
2017	10133907	7717908	13306204	143654	116464	177193	0.226	0.168	0.303	267933	220067	326210
2018	11885469	8860050	15943971	149239	119870	185804	0.21	0.155	0.283	298420	241306	369052
2019	22090037	15855554	30775952	153550	122037	193202	0.207	0.152	0.282	346729	272935	440475
2020	21131946	14464246	30873310	195513	152679	250363	0.188	0.136	0.259	933697	680480	1281139
2021	14371814	8648430	23882836	248436	189206	326207	0.163	0.115	0.232	515683	378972	701711

Table 23.20. Whiting in Subarea 4 and Division 7.d: Final summary catch table estimated by SAM, model output. Units: tonnes.

Year	Catch	Low	High
1978	191677	159578	230233
1979	225485	193293	263040
1980	217154	185592	254084
1981	187558	159887	220017
1982	147191	125526	172595
1983	143740	124161	166406
1984	130673	112551	151714
1985	111328	95498	129783
1986	143108	122427	167283
1987	133941	114870	156178
1988	129257	110338	151419
1989	132033	113477	153623
1990	129732	110551	152241
1991	113028	96910	131826
1992	104870	90493	121532
1993	105227	90723	122050
1994	101581	87693	117668
1995	93301	80384	108294
1996	75772	65372	87826
1997	62920	54307	72900
1998	51280	44473	59129
1999	55729	48054	64630
2000	63136	54303	73405
2001	52807	44665	62433
2002	45954	39392	53610
2003	41328	35426	48212
2004	33921	29467	39048
2005	30145	26204	34679
2006	32739	28180	38035
2007	27105	23444	31338
2008	27256	23655	31407
2009	27676	24005	31909
2010	33130	28663	38293
2011	29766	25786	34361
2012	30180	26161	34817
2013	28135	24339	32522
2014	29280	25466	33666
2015	32600	28186	37706

Year	Catch	Low	High
2016	31811	27511	36784
2017	30129	25918	35024
2018	29427	25359	34146
2019	30381	26140	35309
2020	33587	29033	38856
2021	34593	29342	40784

Table 23.21. Whiting in Subarea 4 and Division 7.d: SAM model parameters.

	par	sd(par)	exp(par)	Low	High
logFpar_0	-13.172	0.078	0	0	0
logFpar_1	-12.053	0.078	0	0	0
logFpar_2	-11.988	0.08	0	0	0
logFpar_3	-12.192	0.085	0	0	0
logFpar_4	-13.333	0.098	0	0	0
logFpar_5	-12.25	0.098	0	0	0
logFpar_6	-12.022	0.099	0	0	0
logFpar_7	-12.218	0.104	0	0	0
logFpar_8	-12.314	0.115	0	0	0
logSdLogFsta_0	-1.744	0.155	0.175	0.128	0.239
logSdLogN_0	-1.076	0.135	0.341	0.26	0.447
logSdLogN_1	-2.747	0.413	0.064	0.028	0.146
logSdLogObs_0	0.2	0.126	1.222	0.95	1.57
logSdLogObs_1	-1.598	0.094	0.202	0.168	0.244
logSdLogObs_2	-0.873	0.079	0.418	0.357	0.489
logSdLogObs_3	-0.763	0.08	0.466	0.398	0.547
transfIRARdist_0	-1.125	0.172	0.325	0.23	0.458
transfIRARdist_1	-0.393	0.232	0.675	0.424	1.074
transfIRARdist_2	0.988	0.458	2.686	1.075	6.707
transfIRARdist_3	-1.014	0.283	0.363	0.206	0.639
itrans_rho_0	0.971	0.202	2.641	1.764	3.954

Table 23.22. Whiting in Subarea 4 and Division 7.d: Mohn's rho.

Mohn's rho	
R(age 0)	0.2785
SSB	0.1522
Fbar(2-6)	-0.0556

Table 23.23. Whiting in Subarea 4 and Division 7.d: Reference points as determined in during WGNSSK 2022 (Annex 8).

Reference point	value
B_{lim}	107 146 t (B_{loss})
F_{lim}	0.935
B_{pa}	148 888 t (MSY $B_{trigger}$)
F_{pa}	0.473
$F_{p.05}$ (with $B_{trigger}$)	0.473
F_{MSY}	0.393

Table 23.24. Whiting in Subarea 4 and Division 7.d: Recruitment estimates (in millions) as used in the short-term forecast.

Year	Geometric mean of recruitment Time series 2002–2021
2022	14591
2023	14591
2024	14591

Table 23.25. Whiting in Subarea 4 and Division 7.d: Short-term forecast inputs. Forecasted SSB in the intermediate year used average maturities and stock weights at age (2019–2021).

MFDP version 1a						
Run: 1						
Time and date: 19:04 27/04/2022						
Fbar age range (Total): 2-5						
Fbar age range Fleet 1: 2-5						
Fbar age range Fleet 2: 2-5						
2022*						
Age	N	M	Mat	PF	PM	SWt
0	14590855	1.967	0	0	0	0.017034
1	1981020	1.151	0.4196	0	0	0.037631
2	942886	0.658	0.8502	0	0	0.108111
3	468762	0.511	0.9766	0	0	0.20414
4	106260	0.469	0.9966	0	0	0.297654
5	39742	0.448	1	0	0	0.39672
6	56125	0.321	1	0	0	0.443968
Catch						
Age	Sel	CWt	DSel	DCWt		
0	0.00003	0.076333	0.00133	0.05		
1	0.00234	0.193667	0.01765	0.102333		
2	0.02093	0.278	0.05714	0.183		
3	0.08935	0.349667	0.06969	0.226		
4	0.15379	0.410333	0.04163	0.237		
5	0.14238	0.462333	0.02271	0.284667		
6	0.13377	0.499333	0.03248	0.276		
IBC						
Age	Sel	CWt				
0	0.00008	0.051				
1	0.00098	0.112667				
2	0.00452	0.210333				
3	0.013	0.295				
4	0.01908	0.373				
5	0.01778	0.435				
6	0.01662	0.448				
2023						
Age	N	M	Mat	PF	PM	SWt
0	14590855	1.967	0	0	0	0.017034
1	.	1.151	0.4196	0	0	0.037631
2	.	0.658	0.8502	0	0	0.108111
3	.	0.511	0.9766	0	0	0.20414
4	.	0.469	0.9966	0	0	0.297654

5	.	0.448	1	0	0	0.39672
6	.	0.321	1	0	0	0.443968
Catch						
Age	Sel	CWt	DSel	DCWt		
0	0.00003	0.076333	0.00133	0.05		
1	0.00234	0.193667	0.01765	0.102333		
2	0.02093	0.278	0.05714	0.183		
3	0.08935	0.349667	0.06969	0.226		
4	0.15379	0.410333	0.04163	0.237		
5	0.14238	0.462333	0.02271	0.284667		
6	0.13377	0.499333	0.03248	0.276		
IBC						
Age	Sel	CWt				
0	0.00008	0.051				
1	0.00098	0.112667				
2	0.00452	0.210333				
3	0.013	0.295				
4	0.01908	0.373				
5	0.01778	0.435				
6	0.01662	0.448				
2024						
Age	N	M	Mat	PF	PM	SWt
0	14590855	1.967	0	0	0	0.017034
1	.	1.151	0.4196	0	0	0.037631
2	.	0.658	0.8502	0	0	0.108111
3	.	0.511	0.9766	0	0	0.20414
4	.	0.469	0.9966	0	0	0.297654
5	.	0.448	1	0	0	0.39672
6	.	0.321	1	0	0	0.443968
Catch						
Age	Sel	CWt	DSel	DCWt		
0	0.00003	0.076333	0.00133	0.05		
1	0.00234	0.193667	0.01765	0.102333		
2	0.02093	0.278	0.05714	0.183		
3	0.08935	0.349667	0.06969	0.226		
4	0.15379	0.410333	0.04163	0.237		
5	0.14238	0.462333	0.02271	0.284667		
6	0.13377	0.499333	0.03248	0.276		
IBC						
Age	Sel	CWt				
0	0.00008	0.051				

1	0.00098	0.112667
2	0.00452	0.210333
3	0.013	0.295
4	0.01908	0.373
5	0.01778	0.435
6	0.01662	0.448
Input units are thousands and kg - output in tonnes		

Table 23.26. Whiting in Subarea 4 and Division 7.d: MFDP output table for short-term forecasts.

MFDP version 1a; Run: 1. Time and date: 19:04 27/04/2022; Basis: F(2022) = average exploitation (2019-2021),scaled to 2021 Fsq = 0.163; SSB (2022) = 283 606 t; Recruitment (2022-2024)=14 591 million; TAC 27.4 (2022) = 26 636 t; Landings 4 (2021) = 14 163 t; Discards (2021) = 14 638 t; IBC (2021) = 2 048 t.

Output units in tonnes

2022																
		Catch			Landings					Discards		IBC				0.75*Fbar
Biomass	SSB	FMult	FBar	Yield	FBar	Yield	27.4+27.7d HC catch	27.4 HC catch	27.7d HC catch	FBar	Yield	FMult	FBar	Yield		0.122
593031	283606	1	0.163	44160	0.1016	24774	40965	31785	9180	0.0478	16191	1	0.0136	3195		

2023																	2024		2022 TAC 27.4	26636
		Catch			Landings					Discards			IBC		Landings					
Biomass	**SSB**	**FMult**	**FBar**	**Yield**	**FBar**	**Yield**	**27.4+27.7d HC catch**	**27.4 HC catch**	**27.7d HC catch**	**FBar**	**Yield**	**FMult**	**FBar**	**Yield**	**Biomass**	**SSB**	**27.4 TAC change**	**SSB change**		
599552	294175	0	0.014	3941	0	0	0	0	0	0	0	1	0.014	3941	628829	323506	-100.00%	10.00%	No HC fishery	
.	294175	0.1	0.029	8604	0.01	3163	4691	3640	1051	0.005	1528	1	0.014	3913	625279	319999	-86.30%	8.80%		
.	294175	0.2	0.044	13204	0.02	6279	9319	7231	2088	0.01	3040	1	0.014	3885	621783	316545	-72.90%	7.60%		
.	294175	0.3	0.058	17742	0.031	9349	13885	10774	3111	0.014	4536	1	0.014	3857	618341	313145	-59.60%	6.40%		
.	294175	0.4	0.073	22218	0.041	12372	18389	14268	4121	0.019	6017	1	0.014	3829	614951	309798	-46.40%	5.30%		
.	294175	0.5	0.088	26635	0.051	15350	22833	17717	5116	0.024	7483	1	0.014	3802	611612	306501	-33.50%	4.20%		
.	294175	0.6	0.103	30993	0.061	18284	27218	21119	6099	0.029	8934	1	0.014	3775	608324	303256	-20.70%	3.10%		
.	294175	0.7	0.118	35293	0.071	21174	31544	24476	7068	0.034	10370	1	0.014	3749	605087	300060	-8.10%	2.00%		
.	294175	0.8	0.133	39536	0.081	24022	35814	27789	8025	0.038	11792	1	0.014	3722	601898	296912	4.30%	0.90%		
.	294175	0.9	0.148	43723	0.092	26827	40027	31058	8969	0.043	13200	1	0.014	3696	598757	293813	16.60%	-0.10%		
.	294175	1	0.163	47853	0.102	29590	44183	34282	9901	0.048	14593	1	0.014	3670	595664	290761	28.70%	-1.20%	Fsq	
.	294175	1.1	0.178	51930	0.112	32313	48285	37465	10820	0.053	15972	1	0.014	3645	592618	287756	40.70%	-2.20%		
.	294175	1.2	0.193	55954	0.122	34996	52334	40607	11727	0.057	17338	1	0.014	3620	589617	284796	52.50%	-3.20%		
.	294175	1.3	0.208	59923	0.132	37638	56328	43706	12622	0.062	18690	1	0.014	3595	586662	281881	64.10%	-4.20%		
.	294175	1.4	0.223	63841	0.142	40243	60271	46765	13506	0.067	20028	1	0.014	3570	583751	279011	75.60%	-5.20%		
.	294175	1.5	0.238	67708	0.152	42808	64162	49784	14378	0.072	21354	1	0.014	3546	580884	276184	86.90%	-6.10%		
.	294175	1.6	0.253	71523	0.163	45336	68002	52764	15238	0.077	22666	1	0.014	3521	578059	273399	98.10%	-7.10%		
.	294175	1.7	0.268	75291	0.173	47828	71794	55706	16088	0.081	23966	1	0.014	3497	575277	270657	109.10%	-8.00%		
.	294175	1.8	0.283	79009	0.183	50282	75535	58609	16926	0.086	25253	1	0.014	3474	572536	267956	120.00%	-8.90%		
.	294175	1.9	0.298	82679	0.193	52701	79229	61475	17754	0.091	26528	1	0.014	3450	569837	265296	130.80%	-9.80%		
.	294175	2	0.312	86302	0.203	55085	82875	64304	18571	0.096	27790	1	0.014	3427	567177	262675	141.40%	-10.70%		
.	294175	0.75	0.126	36570	0.076	21964	32830	25473	7357	0.036	10866	1	0.014	3740	604216	299207	-4.40%	1.70%	0.75 * Fsq	
.	294175	1.25	0.2	57135	0.127	35716	53524	41530	11994	0.06	17808	1	0.014	3611	588826	284022	55.90%	-3.50%	1.25 * Fsq	
.	294175	0.66	0.113	32941	0.067	19536	29179	22641	6539	0.032	9643	1	0.014	3762	606934	301888	-15.00%	2.60%	15% TAC decrease (27.4)	

2023																	2024		2022 TAC 27.4	26636
		Catch			Landings					Discards			IBC		Landings					
Biomass	SSB	FMult	FBar	Yield	FBar	Yield	27.4+27.7d HC catch	27.4 HC catch	27.7d HC catch	FBar	Yield	FMult	FBar	Yield	Biomass	SSB	27.4 TAC change	SSB change		
.	294175	0.91	0.15	43176	0.093	26381	39478	30631	8846	0.044	13096	1	0.014	3698	599273	294330	15.00%	0.10%	15% TAC increase (27.4)	
.	294175	0.79	0.131	38059	0.08	22959	34328	26636	7692	0.038	11370	1	0.014	3730	603103	298109	0.00%	1.30%	Rollover TAC	
.	294175	3.07	0.473	132198	0.312	85910	129055	100136	28919	0.147	43146	1	0.014	3142	532651	228596	275.90%	-22.30%	Fpa	
.	294175	-0.09		1973	-0.009	-1170	-1982	-1538	-444	-0.004	-812	1	0.014	3956	630108	324753	-105.80%	10.40%	Fp05 without AR	
.	294175	6.17	0.935	259393	0.627	170964	257045	199446	57599	0.295	86081	1	0.014	2348	437460	134676	648.80%	-54.20%	Flim	
.	294175	5.69	0.864	239816	0.578	157873	237346	184161	53185	0.272	79473	1	0.014	2470	452111	148888	591.40%	-49.30%	Bpa, MSY Btrigger	
.	294175	7.06	1.069	296251	0.718	195610	294133	228223	65910	0.338	98522	1	0.014	2118	409877	107146	756.80%	-63.50%	Blim	
.	294175	1.86	0.292	82366	0.189	52587	78912	61229	17683	0.089	26325	1	0.014	3454	569944	265392	129.90%	-9.80%	Fmsylower	
.	294175	2.54	0.393	110172	0.258	71182	106892	82940	23953	0.121	35711	1	0.014	3280	549134	244860	211.40%	-16.80%	Fmsy	
.	294175	3.07	0.473	132198	0.312	85910	129055	100136	28919	0.147	43146	1	0.014	3142	532651	228596	275.90%	-22.30%	Fmsyupper	
.	294175	0.62	0.106	31236	0.063	18396	27463	21309	6154	0.03	9067	1	0.014	3773	608211	303148	-20.00%	3.10%	20% TAC decrease (27.4)	
.	294175	0.99	0.162	46588	0.101	28663	42911	33295	9616	0.047	14248	1	0.014	3677	596719	291810	25.00%	-0.80%	25% TAC increase (27.4)	
.	294175	1.86	0.292	82366	0.189	52587	78912	61229	17683	0.089	26325	1	0.014	3454	569944	265392	129.90%	-9.80%	Fmsylower	

Table 23.27 Whiting in Subarea 4 and Division 7.d: NS IBTS tuning series for northern component used in the area-specific SURBAR analysis.

	Q1	North				Q3	North				
Age	1	2	3	4	5	0	1	2	3	4	5
1983	143.401	154.856	150.829	113.598	50.897						
1984	323.567	212.552	106.415	41.278	40.292						
1985	412.895	341.159	81.823	23.344	11.227						
1986	587.697	385.153	239.606	39.83	12.625						
1987	707.64	788.303	122.369	57.297	8.179						
1988	301.643	1115.424	435.943	44.031	23.551						
1989	2049.504	668.536	580.893	160.983	20.942						
1990	490.822	1251.354	261.582	138.013	29.097						
1991	754.334	999.549	477.884	76.369	31.452	190.132	285.241	124.822	88.607	26.92	13.102
1992	1384.302	545.011	317.356	90.528	78.729	1357.232	615.218	191.926	84.976	65.436	33.848
1993	1529.746	810.122	269.711	122.998	52.18	339.611	578.148	248.966	55.832	30.695	21.417
1994	1058.43	853.101	299.173	105.475	20.999	237.937	712.663	324.467	57.501	16.051	11.43
1995	894.427	651.711	308.658	95.983	19.891	330.847	810.471	360.665	101.783	28.238	12.829
1996	603.663	651.987	314.636	96.581	45.633	83.743	444.379	388.123	165.359	48.308	13.145
1997	445.667	378.412	240.241	117.637	32.536	2750.385	330.418	225.354	161.952	35.658	29.341
1998	744.221	222.632	173.569	73.104	32.244	2484.246	405.455	197.391	75.867	44.141	17.651
1999	858.032	335.233	193.737	96.323	41.596	1723.648	810.794	242.511	74.55	33.258	15.492
2000	1127.728	652.372	272.851	45.871	27.249	1456.711	767.782	342.896	73.195	20.076	11.358
2001	413.843	588.073	343.71	77.607	29.033	291.479	642.804	296.602	111.774	25.051	9.898
2002	513.057	428.163	386.74	72.702	17.767	105.617	603.626	300.637	173.636	46.367	10.344
2003	156.456	311.894	344.993	184.118	64.629	413.41	245.277	326.312	166.634	88.931	24.592
2004	270.146	130.282	237.838	116.137	65.129	211.061	190.845	76.868	90.696	63.2	36.431
2005	160.63	70.445	71.669	61.544	43.237	154.069	195.852	97.403	45.119	64.845	47.659
2006	261.558	86.555	64.824	30.563	22.823	44.878	190.902	104.718	40.801	34.285	27.364

	Q1	North				Q3	North				
Age	**1**	**2**	**3**	**4**	**5**	**0**	**1**	**2**	**3**	**4**	**5**
2007	62.938	202.914	93.486	31.871	16.757	346.981	74.776	78.557	48.2	22.754	12.043
2008	198.753	195.499	78.913	27.568	14.458	848.142	334.74	72.776	39.989	18.66	9.79
2009	156.742	239.482	72.965	20.13	20.976	560.618	257.218	134.847	32.409	13.392	10.651
2010	302.33	269.377	239.438	76.001	110.69	70.104	248.174	175.906	57.992	16.82	16.516
2011	185.922	504.592	198.931	105.466	28.249	94.343	411.617	163.839	65.764	23.956	11.099
2012	266.626	796.159	145.62	58.537	44.488	316.803	238.565	268.773	84.896	30.912	21.17
2013	59.098	212.457	350.904	98.115	52.337	141.998	58.759	57.269	79.205	26.334	9.801
2014	367.829	274.711	147.237	91.846	51.213	2017.069	202.053	73.682	48.725	42.318	13.446
2015	423.217	250.756	67.447	34.917	33.132	2113.574	244.567	195.931	55.372	37.056	25.098
2016	263.992	199.177	97.841	31.325	18.422	729.877	318.709	194.394	72.089	26.372	11.006
2017	455.449	241.933	136.348	43.761	15.935	148.347	633.78	210.029	107.555	34.8	16.409
2018	84.998	236.167	92.087	52.645	20.466	204.112	147.061	258.238	97.385	39.992	27.824
2019	268.933	201.402	156.042	63.584	19.824	749.566	375.037	145.446	99.861	28.428	20.008
2020	473.535	186.89	100.121	70.15	21.446	654.4	1011.846	188.023	69.895	43.277	30.275
2021	483.497	830.364	143.204	53.927	21.881	48.177	538.947	416.742	73.307	28.946	17.553
2022	191.406	827.707	318.493	62.731	15.872						

Table 23.28 Whiting in Subarea 4 and Division 7.d: NS IBTS tuning series for southern component used in the area-specific SURBAR analysis.

	Q1	South				Q3	South				
Age	1	2	3	4	5	0	1	2	3	4	5
1983	85.45	99.851	52.686	19.987	5.019						
1984	593.881	84.243	43.152	4.049	2.825						
1985	114.689	330.4	30.889	11.822	3.018						
1986	155.459	93.19	215.536	54.7	7.664						
1987	542.592	86.81	27.029	26.761	3.098						
1988	487.545	262.104	50.705	6.855	6.541						
1989	291.589	229.438	71.118	4.646	11.552						
1990	470.323	118.887	87.744	32.48	4.558						
1991	1106.472	287.446	151.874	66.871	37.686	958.688	1334.419	170.203	64.644	31.132	22.847
1992	265.104	258.351	117.67	56.676	27.94	1200.775	406.283	311.477	40.846	30.723	26.147
1993	140.264	59.43	62.389	31.774	23.154	1626.475	671.101	63.728	21.692	15.256	9.817
1994	191.711	156.048	25.782	8.463	4.159	951.75	640.529	84.975	43.115	25.091	10.09
1995	222.579	239.969	49.752	19.783	6.47	1219.269	222.51	80.845	7.972	6.656	1.232
1996	231.472	233.724	70.389	33.571	37.795	499.52	417.706	205.879	47.99	11.737	6.928
1997	67.325	43.278	13.87	22.699	10.577	480.258	227.918	35.787	32.328	8.812	2.345
1998	95.505	56.861	23.986	6.323	8.272	2229.932	238.089	36.015	15.326	9.628	3.981
1999	153.527	147.624	127.128	30.833	6.278	2794.07	1724.311	49.323	13.413	4.241	0.809
2000	219.275	151.941	55.605	10.679	3.761	2456.096	1090.356	226.153	30.001	12.365	2.95
2001	942.456	448.546	84.966	70.175	31.13	8867.757	697.026	218.85	36.408	18.91	5.883
2002	457.447	120.386	34.448	13.216	7.754	385.891	989.146	113.49	32.153	12.349	3.461
2003	96.052	216.304	81.629	29.913	8.828	227.231	288.794	171.351	28.265	26.959	8.576
2004	38.818	53.641	34.87	14.43	10.014	1641.775	81.054	65.172	14.855	5.381	3.609
2005	89.895	67.155	22.92	11.112	9.571	208.437	54.154	4.017	2.917	2.161	1.504
2006	48.506	67.392	25.404	10.769	8.899	443.497	74.551	15.069	4.141	3.422	2.752
2007	77.838	58.664	12.349	5.486	3.344	2203.686	142.166	20.52	6.177	1.968	0.942
2008	427.504	247.607	26.007	4.196	2.12	546.391	596.203	54.246	16.16	4.215	0.806
2009	438.147	459.551	74.428	18.35	15.819	634.897	1044.568	664.476	76.08	11.132	6.005
2010	508.82	81.019	64.927	17.96	9.475	914.23	154.524	49.117	12.785	3.941	3.783
2011	465.753	207.833	44.203	12.609	5.268	511.566	444.079	87.814	51.98	10.342	2.203
2012	244.074	196.178	21.112	13.571	10.862	208.426	295.544	101.813	22.997	3.231	1.612
2013	137.181	93.381	52.843	10.687	10.847	772.182	100.621	55.296	26.365	5.548	1.584
2014	1129.913	147.201	35.603	17.16	13.996	1884.952	283.798	169.738	124.258	70.136	15.764
2015	340.564	393.71	134.634	21.941	19.974	1622.776	462.836	309.691	79.912	13.378	5.747
2016	633.544	643.699	111.985	27.244	15.101	1245.384	208.678	157.555	55.207	9.166	6.349
2017	989.077	266.91	52.213	10.761	6.419	229.522	1442.214	199.056	49.837	12.495	3.198
2018	185.133	192.633	47.576	21.585	11.409	111.591	391.478	376.988	65.935	19.927	9.468
2019	152.457	74.143	38.974	21.925	3.684	2247.084	335.335	87.211	68.268	12.984	5.108
2020	531.832	171.634	32.164	24.288	10.189	2381.931	1825.626	248.69	51.606	47.583	50.993
2021	817.832	443.208	66.728	13.645	5.105	1643.416	2308.425	517.862	80.788	17.508	7.127
2022	599.092	819.588	335.835	68.347	2.94						

Table 23.29 Whiting in Subarea 4 and Division 7.d: Maturity estimates for northern component used in the area-specific SURBAR analysis. Before 1991 used values of 1991.

Age	0	1	2	3	4	5	6+
1991	0	0.171	0.821	0.987	1	1	1
1992	0	0.174	0.817	0.985	1	1	1
1993	0	0.178	0.812	0.983	1	1	1
1994	0	0.183	0.807	0.981	0.999	1	1
1995	0	0.189	0.8	0.977	0.998	0.999	1
1996	0	0.196	0.793	0.973	0.997	0.999	1
1997	0	0.205	0.784	0.968	0.995	0.998	1
1998	0	0.216	0.776	0.962	0.994	0.998	1
1999	0	0.229	0.766	0.956	0.992	0.998	1
2000	0	0.244	0.758	0.951	0.991	0.997	1
2001	0	0.26	0.753	0.948	0.99	0.998	1
2002	0	0.274	0.753	0.947	0.99	0.998	1
2003	0	0.286	0.757	0.949	0.991	0.998	1
2004	0	0.294	0.764	0.952	0.992	0.999	1
2005	0	0.3	0.774	0.956	0.993	0.999	1
2006	0	0.303	0.786	0.961	0.994	0.999	1
2007	0	0.304	0.799	0.967	0.996	1	1
2008	0	0.303	0.811	0.972	0.997	1	1
2009	0	0.303	0.822	0.976	0.998	1	1
2010	0	0.302	0.83	0.979	0.999	1	1
2011	0	0.303	0.835	0.981	0.999	1	1
2012	0	0.302	0.838	0.982	1	1	1
2013	0	0.301	0.839	0.982	1	1	1
2014	0	0.3	0.838	0.981	1	1	1
2015	0	0.301	0.838	0.981	1	1	1
2016	0	0.304	0.838	0.98	0.999	1	1
2017	0	0.311	0.836	0.979	0.999	1	1
2018	0	0.32	0.835	0.978	0.998	1	1
2019	0	0.331	0.833	0.978	0.997	1	1
2020	0	0.346	0.832	0.977	0.997	1	1
2021	0	0.363	0.832	0.976	0.996	1	1
2022	0	0.383	0.833	0.976	0.996	1	1

Table 23.30 Whiting in Subarea 4 and Division 7.d: Maturity estimates for southern component used in the area-specific SURBAR analysis. Before 1991 used values of 1991.

Age	0	1	2	3	4	5	6+
1991	0	0.298	0.863	0.996	1	1	1
1992	0	0.296	0.824	0.981	1	1	1
1993	0	0.292	0.79	0.968	0.999	1	1
1994	0	0.283	0.762	0.953	0.995	1	1
1995	0	0.268	0.737	0.937	0.988	0.997	0.999
1996	0	0.247	0.709	0.915	0.978	0.991	0.996
1997	0	0.229	0.686	0.89	0.962	0.983	0.991
1998	0	0.224	0.672	0.863	0.942	0.971	0.985
1999	0	0.231	0.651	0.831	0.918	0.957	0.977
2000	0	0.251	0.621	0.797	0.895	0.944	0.97
2001	0	0.276	0.596	0.775	0.882	0.938	0.966
2002	0	0.305	0.586	0.771	0.882	0.939	0.967
2003	0	0.336	0.591	0.779	0.889	0.945	0.971
2004	0	0.366	0.605	0.793	0.9	0.952	0.975
2005	0	0.391	0.627	0.812	0.913	0.96	0.981
2006	0	0.416	0.656	0.835	0.927	0.969	0.986
2007	0	0.442	0.693	0.861	0.942	0.977	0.992
2008	0	0.467	0.73	0.887	0.956	0.984	0.996
2009	0	0.486	0.764	0.909	0.967	0.989	0.998
2010	0	0.5	0.79	0.926	0.975	0.993	1
2011	0	0.508	0.807	0.937	0.98	0.995	1
2012	0	0.511	0.814	0.942	0.982	0.996	1
2013	0	0.509	0.815	0.943	0.982	0.997	1
2014	0	0.506	0.818	0.945	0.983	0.997	1
2015	0	0.503	0.827	0.95	0.985	0.997	1
2016	0	0.496	0.836	0.956	0.988	0.998	1
2017	0	0.49	0.844	0.961	0.99	0.998	1
2018	0	0.489	0.85	0.966	0.992	0.998	1
2019	0	0.499	0.858	0.969	0.993	0.998	1
2020	0	0.519	0.873	0.975	0.994	0.998	1
2021	0	0.547	0.895	0.983	0.996	0.999	1
2022	0	0.579	0.919	0.992	0.999	1	1

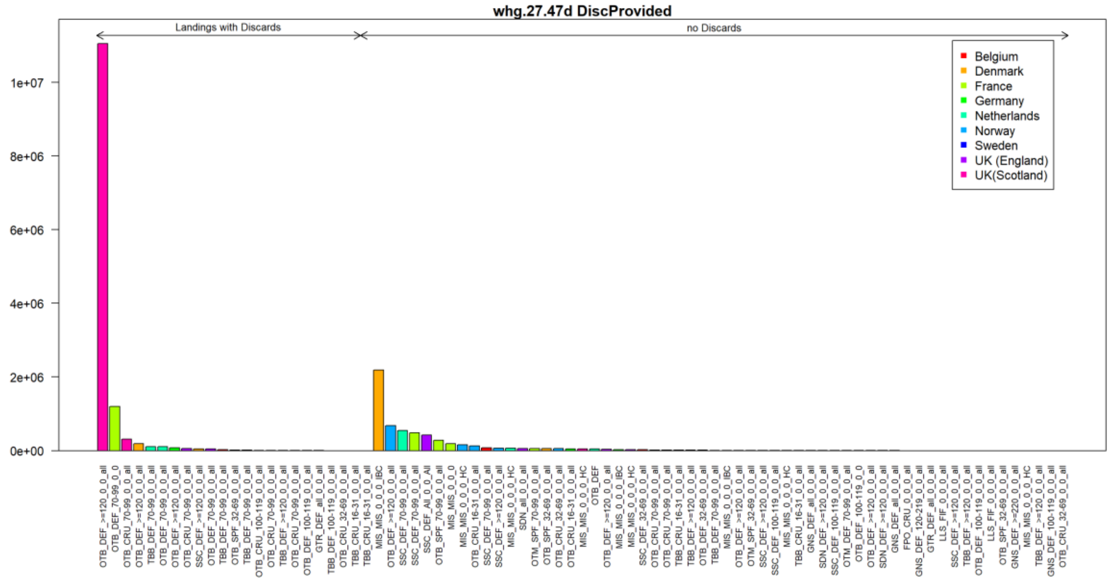


Figure 23.1. Whiting in Subarea 4 and Division 7.d: Landings with provided discards. Métier with industrial bycatch landings (MIS_MIS_0_0_0_IBC, Denmark, orange) generally does not have discards.

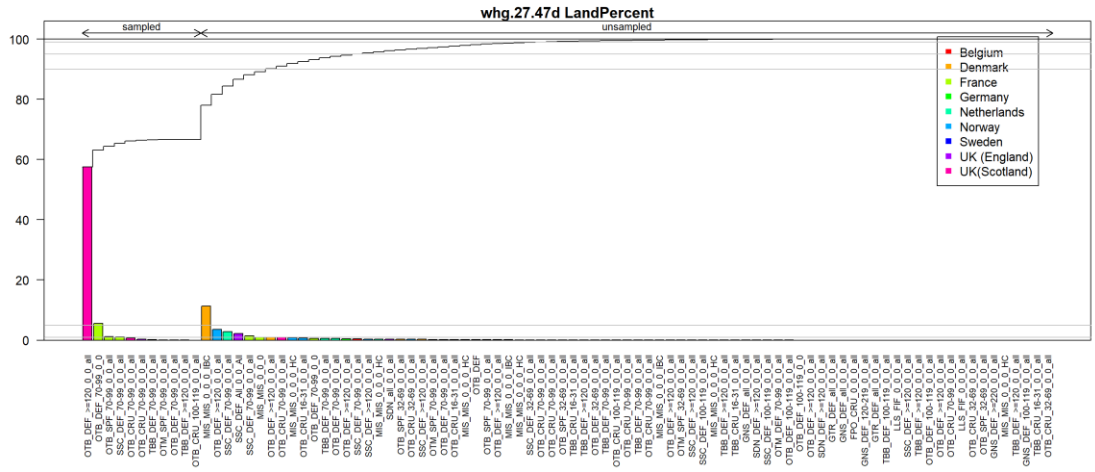


Figure 23.2a. Whiting in Subarea 4 and Division 7.d: Reported landings (in percent, colored bars) for each sampled and unsampled fleet, along with cumulative landings (in percent, black line) for fleets in descending order of yield.

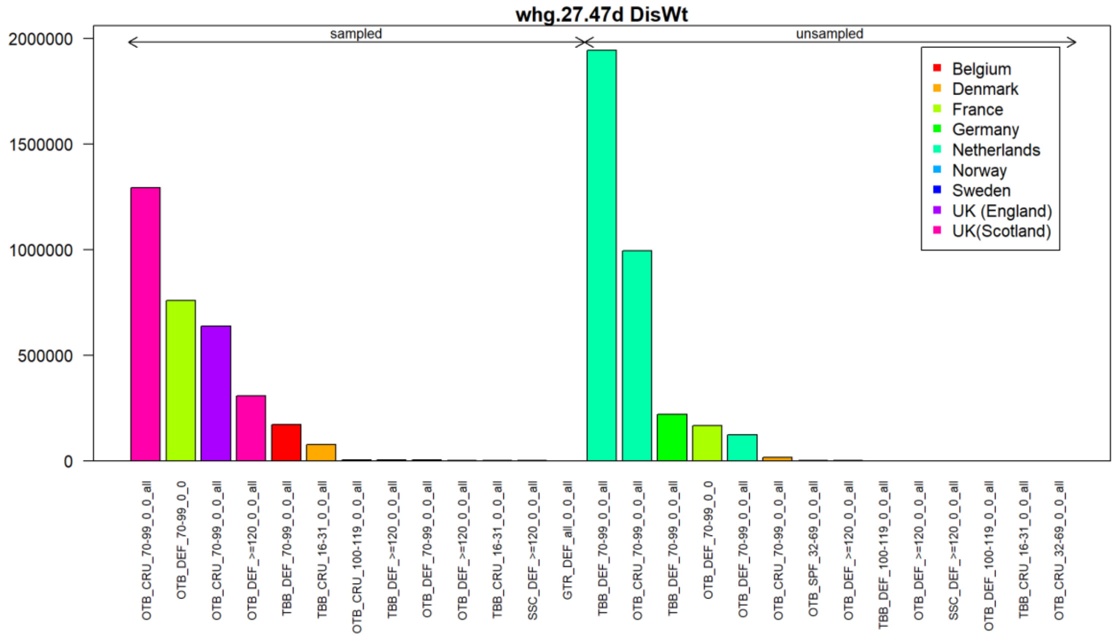


Figure 23.2b. Whiting in Subarea 4 and Division 7.d: Reported discards (in tonnes, colored bars) for each sampled and unsampled fleet, in descending order of yield.

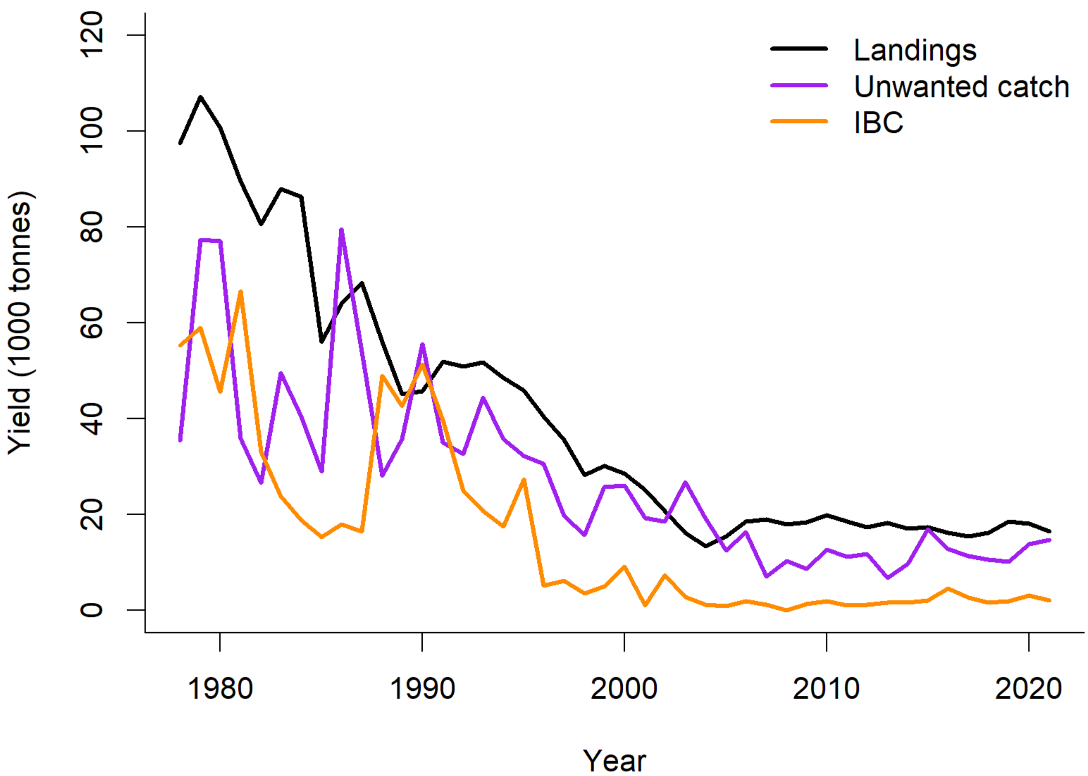


Figure 23.3. Whiting in Subarea 4 and Division 7.d: Yield by catch component. Unwanted catch or discards include BMS landings as estimated by ICES.

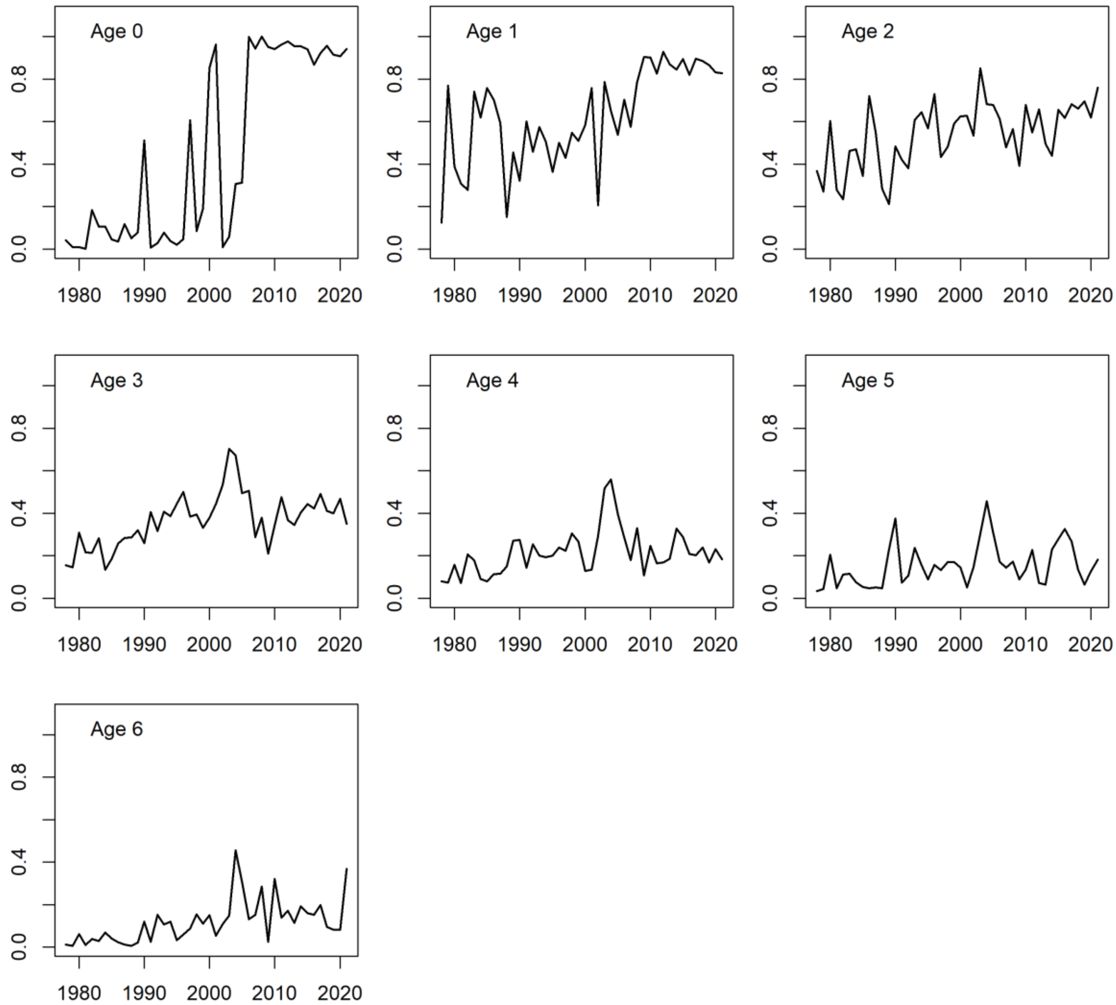


Figure 23.4. Whiting in Subarea 4 and Division 7.d: Proportion of discards in total catch, by age and year.

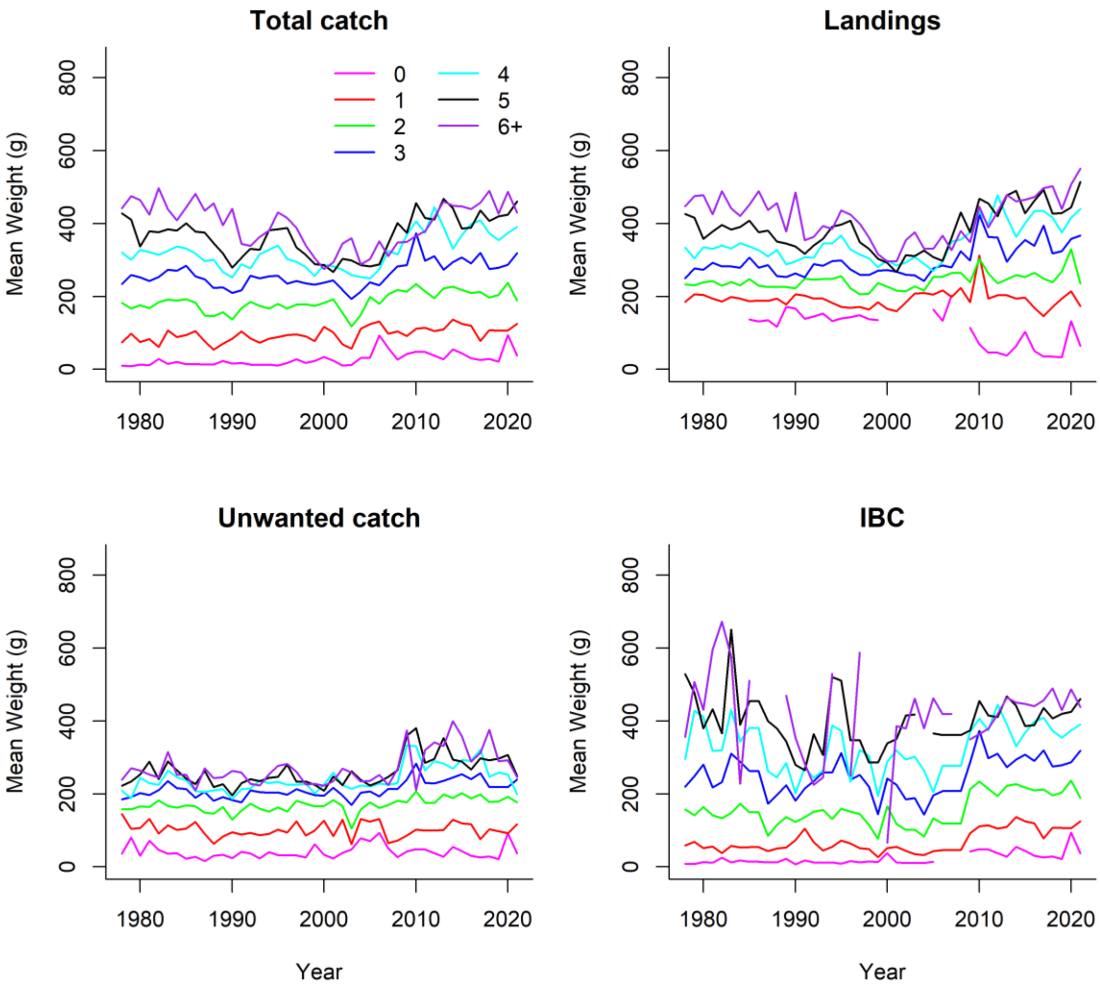


Figure 23.5. Whiting in Subarea 4 and Division 7.d: Mean weights-at-age (g) by catch component (age 0–6+).

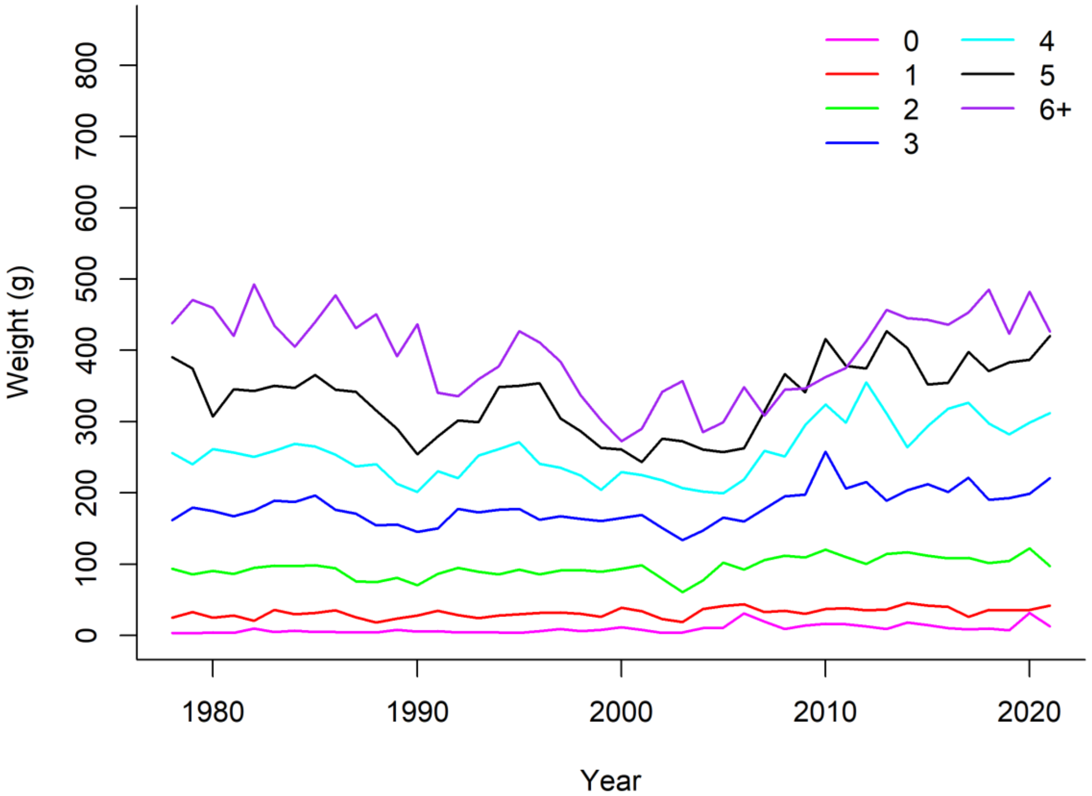


Figure 23.6. Whiting in Subarea 4 and Division 7.d: Stock mean weights-at-age (g) (age 0–6+).

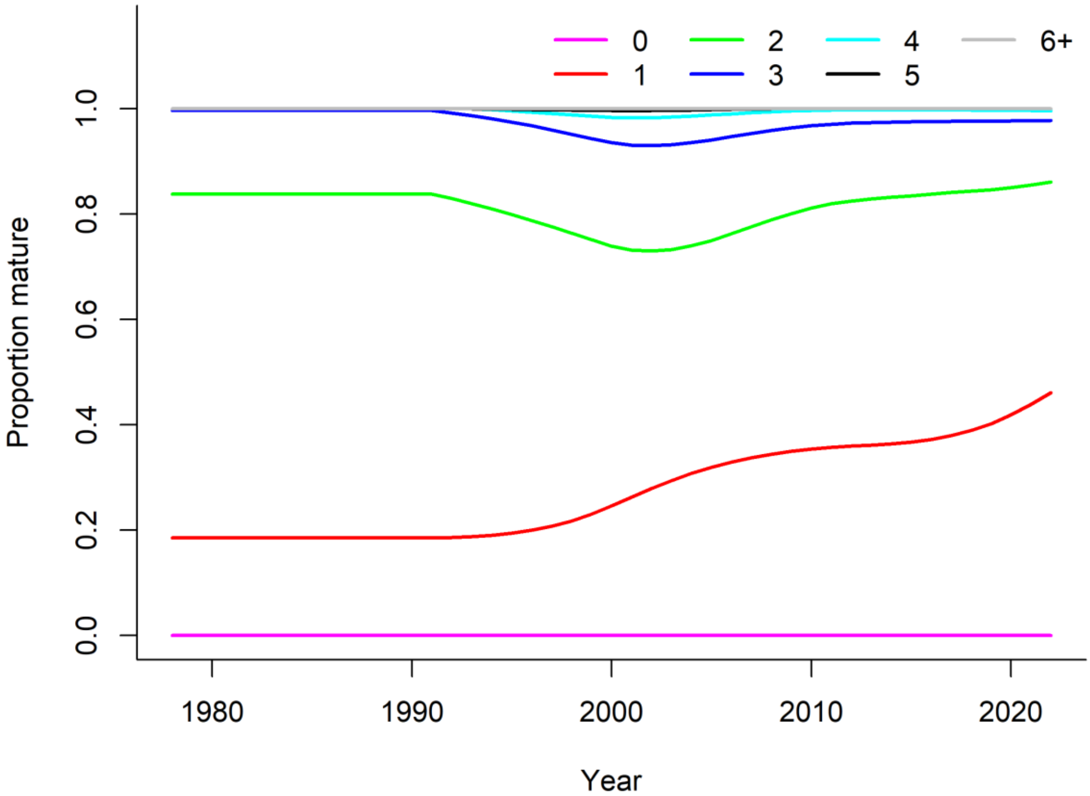


Figure 23.7. Whiting in Subarea 4 and Division 7.d: Maturity estimates from NS IBTS Q1 data. Ages 6+ have the same maturity values. Estimates prior 1991 are assumed constant using values of 1991.

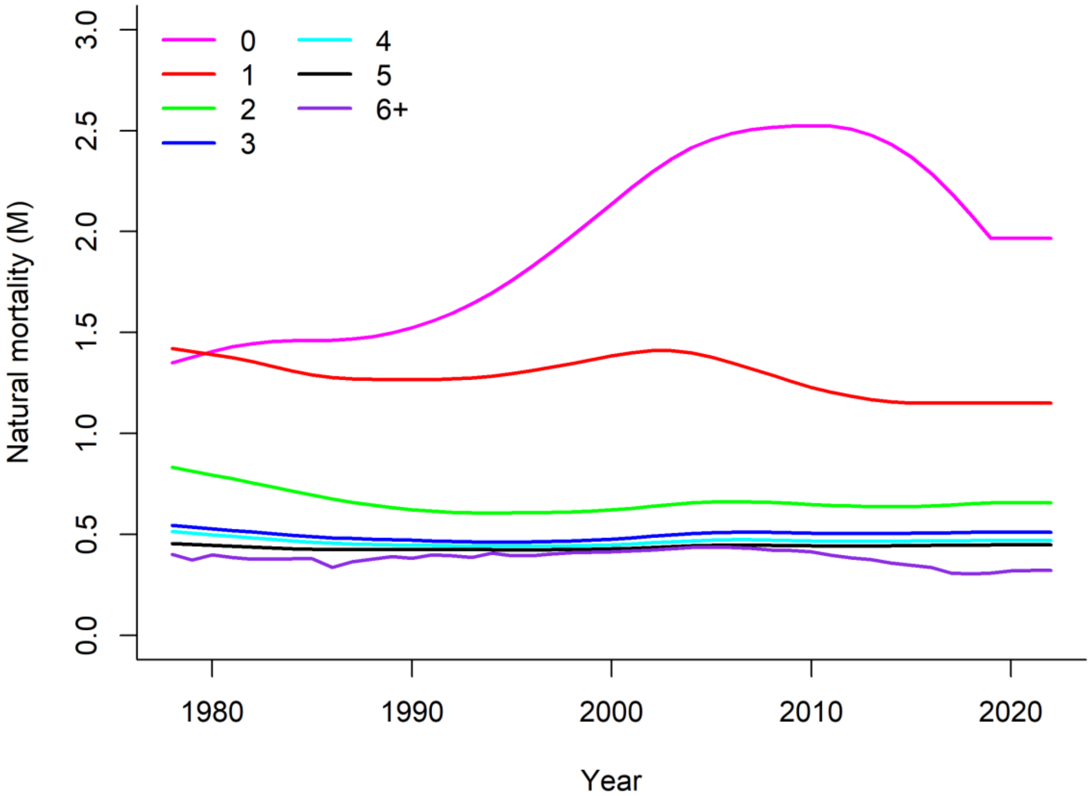


Figure 23.8. Whiting in Subarea 4 and Division 7.d: Natural mortality estimates from the 2020 update of SMS key run (WGSAM, 2021b) used in assessment.

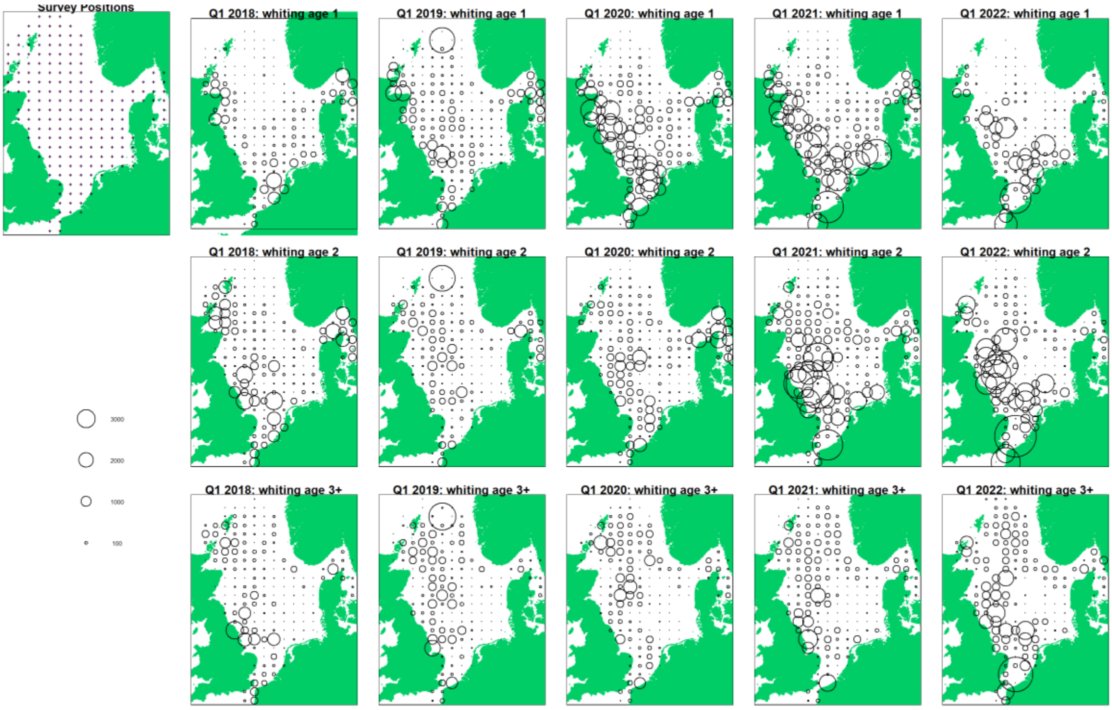


Figure 23.9. Whiting in Subarea 4 and Division 7.d: Survey distribution maps for Ages 1–3+ Q1 2017–2022. Size of the bubbles indicates numbers caught per 30 minutes for each age (on a log10 scale). The maps are based on the IBTS–Q1 survey in the North Sea.

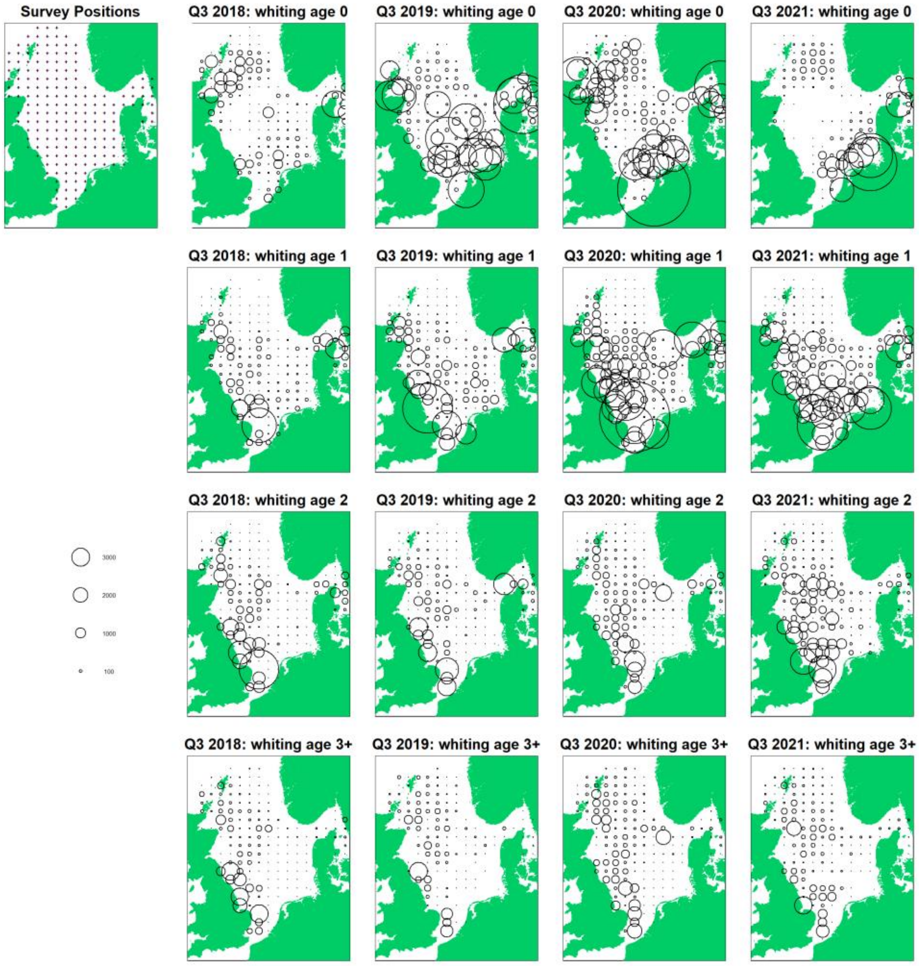


Figure 23.10. Whiting in Subarea 4 and Division 7.d: Survey distribution maps for ages 0–3+ Q3 2017–2021. Size of the bubbles indicates numbers caught per 30 minutes for each age (on a log10 scale). The maps are based on the IBTS–Q3 survey in the North Sea.

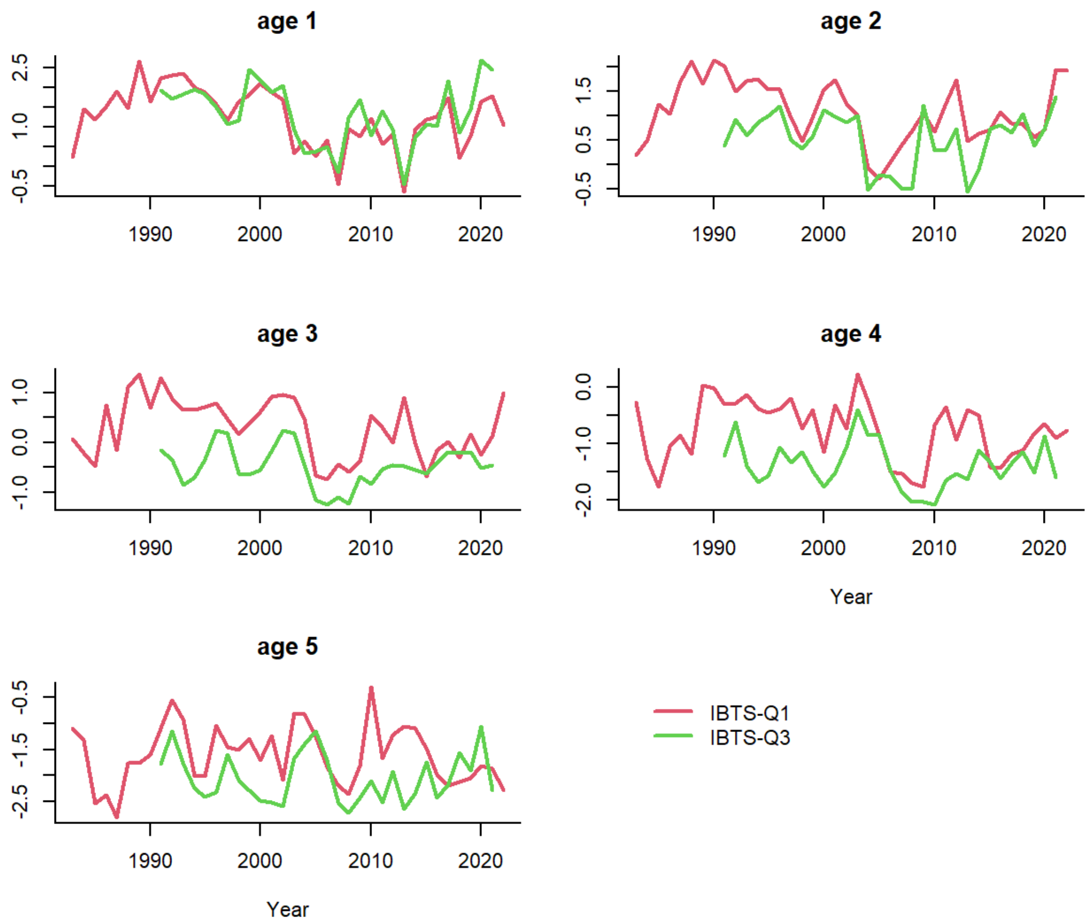


Figure 23.11. Whiting in Subarea 4 and Division 7.d: Survey log CPUE (catch per unit effort) at age.

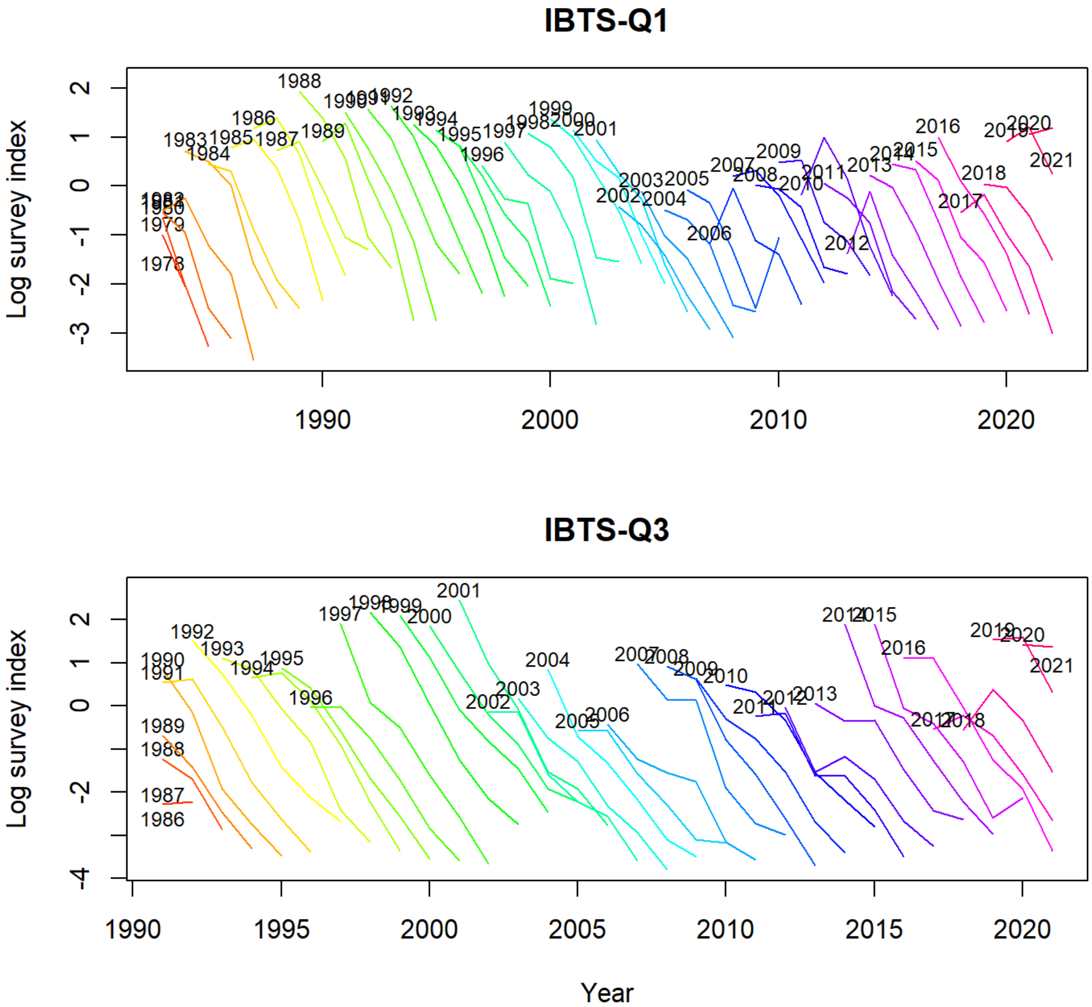


Figure 23.12. Whiting in Subarea 4 and Division 7.d: Log survey indices by cohort for each of the two surveys. The spawning year for each cohort is indicated at the start of each line.

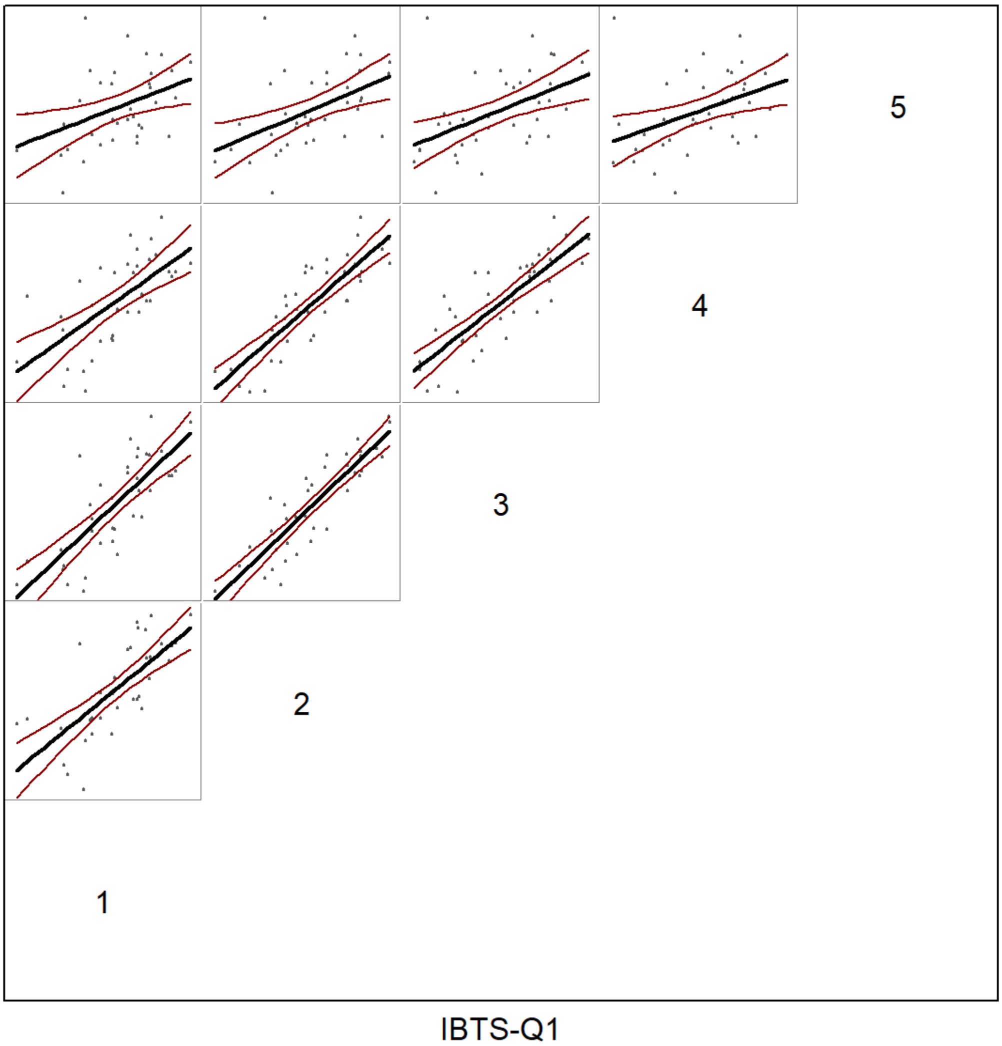


Figure 23.13. Within-survey correlations for the IBTS–Q1 survey series, comparing index values at different ages for the same year-classes (cohorts). In each plot, the straight line is a normal linear model fit: a thick line (with black points) represents a significant ($p < 0.05$) regression, while a thin line (with blue points) is not significant. Approximate 95% confidence intervals for each fit are also shown.

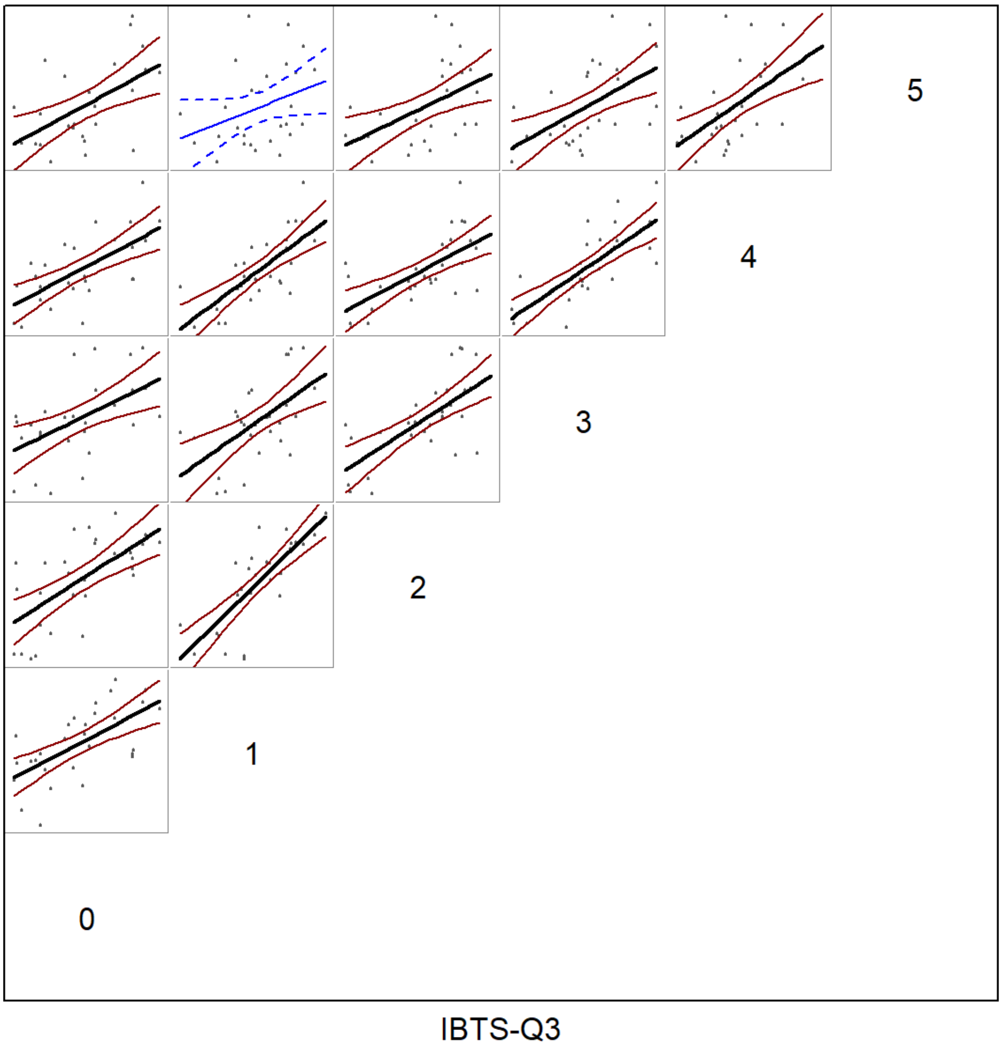


Figure 23.14. Within-survey correlations for the IBTS–Q3 survey series, comparing index values at different ages for the same year-classes (cohorts). In each plot, the straight line is a normal linear model fit: a thick line (with black points) represents a significant ($p < 0.05$) regression, while a thin line (with blue points) is not significant. Approximate 95% confidence intervals for each fit are also shown.

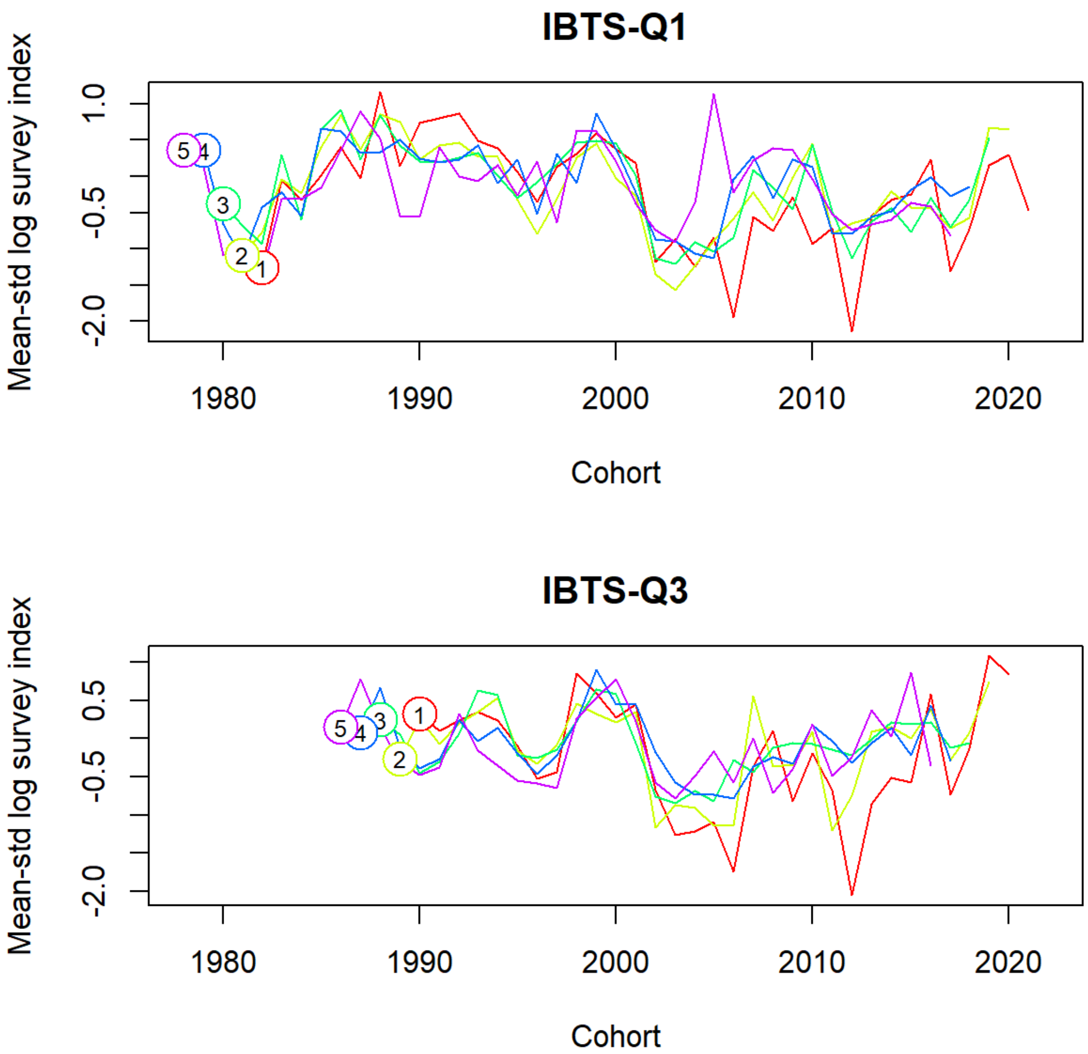


Figure 23.15. Whiting in Subarea 4 and Division 7.d: Survey log CPUE (catch per unit effort) for the IBTS–Q1 and Q3 surveys, by cohort. Each line shows the log CPUE for the age indicated at the start of the line.

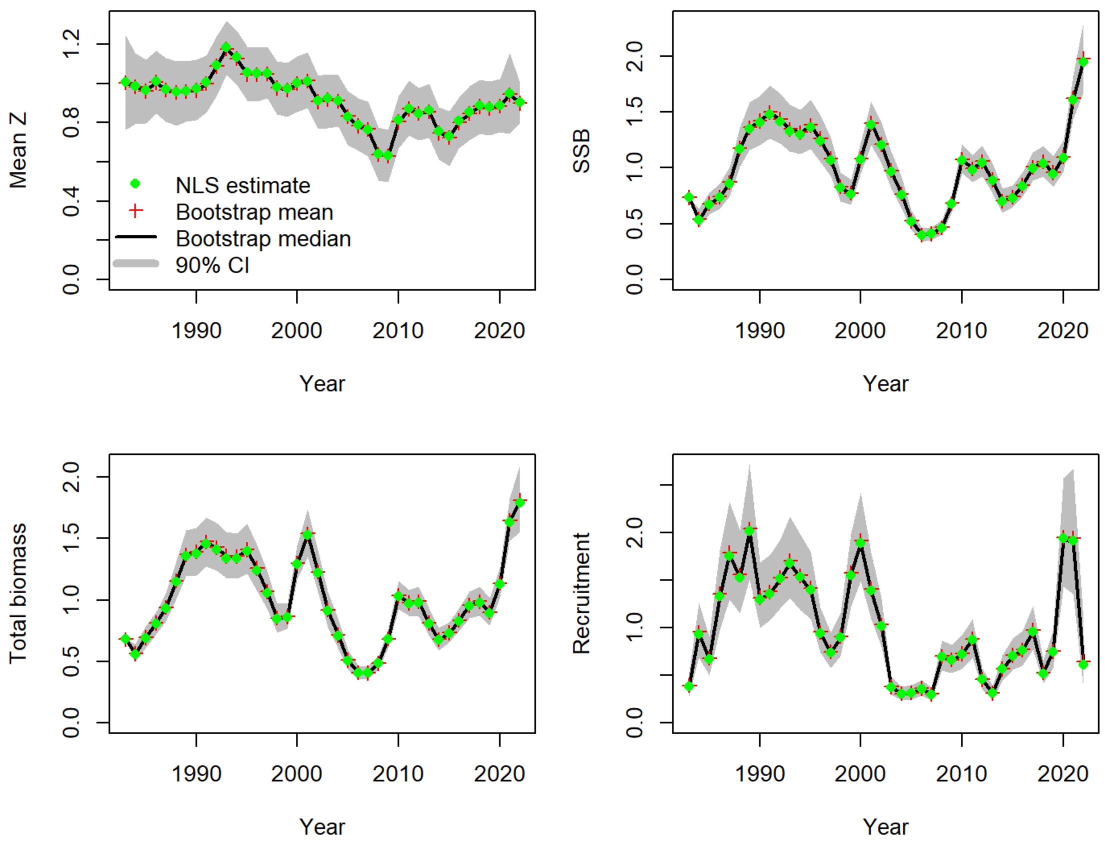
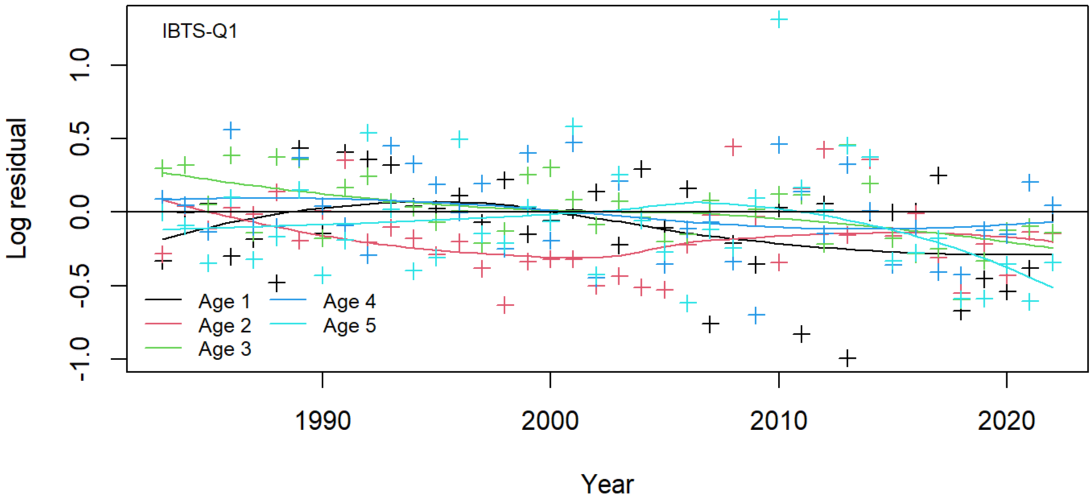


Figure 23.16. Whiting in Subarea 4 and Division 7.d: Summary plots from an exploratory SURBAR assessment, using both available surveys (IBTS–Q1 and Q3). Mean mortality Z (ages 2 to 4), relative spawning stock biomass (SSB), relative total biomass (TSB), and relative recruitment (age 1). Shaded grey areas correspond to the 90% CI. Green points give the model estimates, while red crosses and black lines give (respectively) the mean and median values from the uncertainty estimation bootstrap.



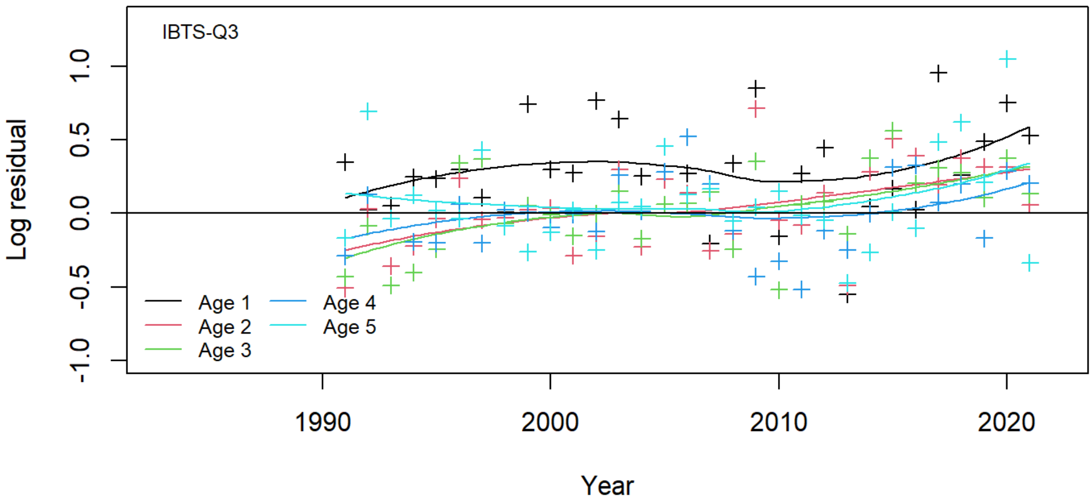


Figure 23.17. Whiting in Subarea 4 and Division 7.d: Log survey residuals from the SURBAR analysis. Ages are color-coded, and a LOESS smoother (span = 2) has been fitted through each age time-series.

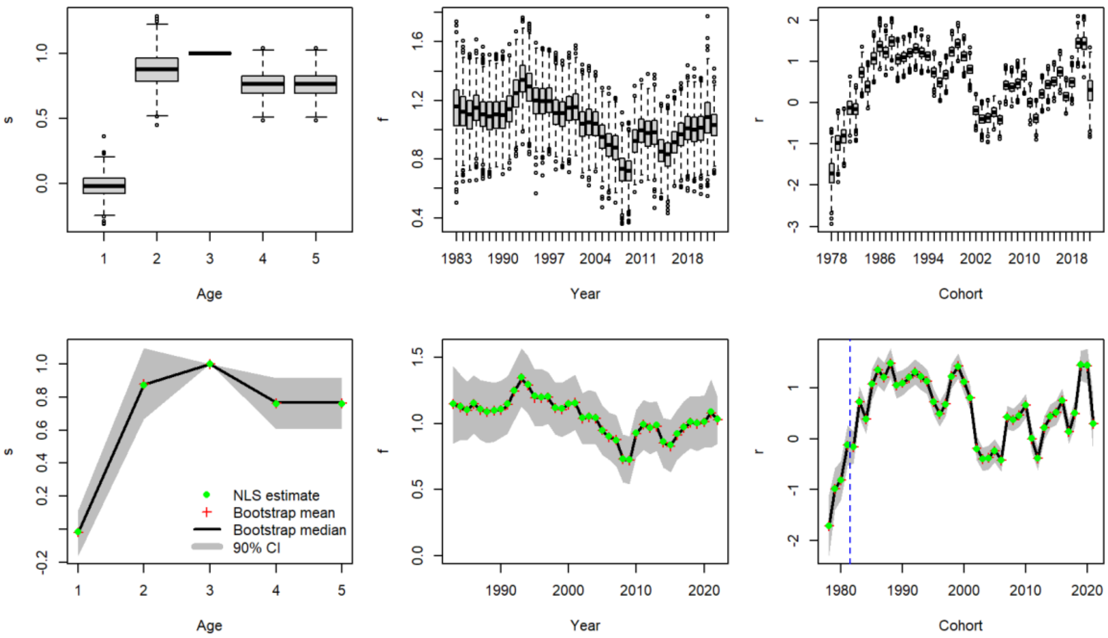


Figure 23.18. Whiting in Subarea 4 and Division 7.d: Parameter estimates from SURBAR analysis. Top row: age, year and cohort effect estimates as box-and-whisker plots. Bottom row: estimates as line plots with 90% confidence intervals.

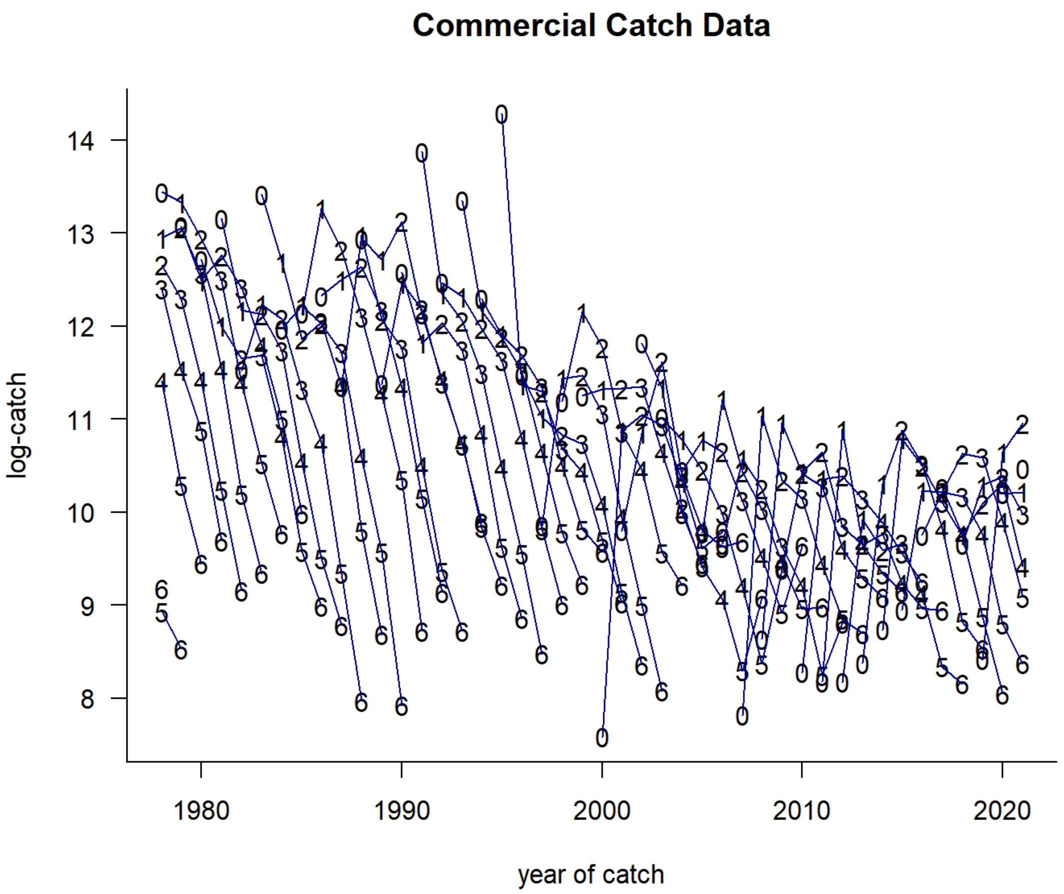


Figure 23.19. Whiting in Subarea 4 and Division 7.d: Log-catch curves by cohort for total catches (ages 0–6+).

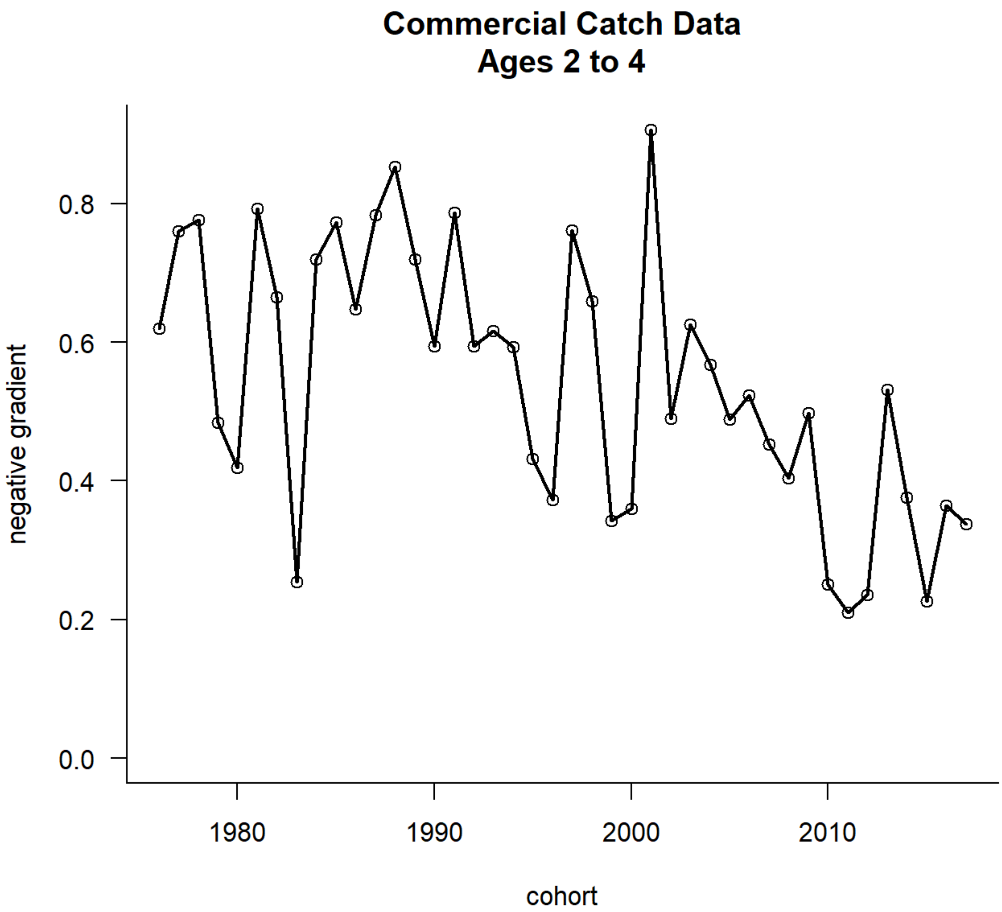


Figure 23.20. Whiting in Subarea 4 and Division 7.d: Negative gradients of log catches per cohort, averaged over ages 2–4. The x-axis represents the spawning year of each cohort.

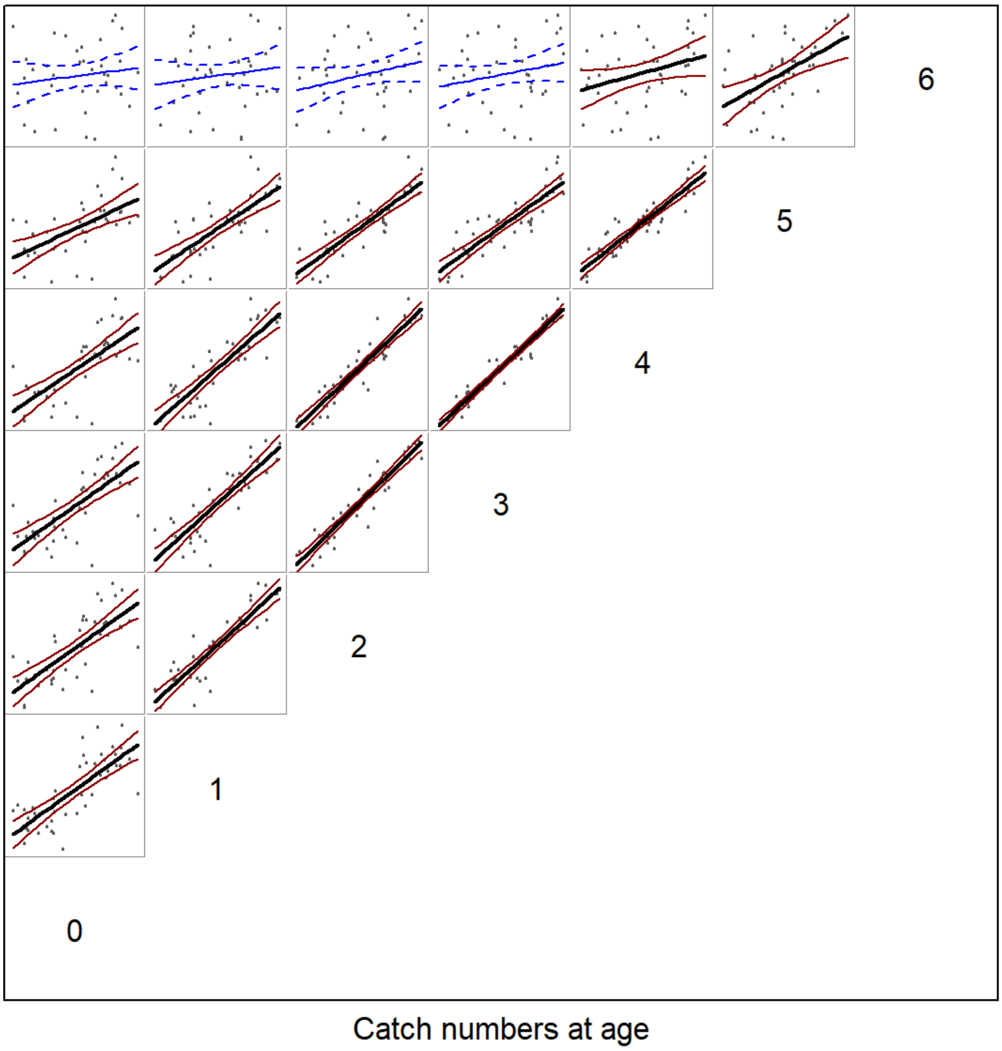
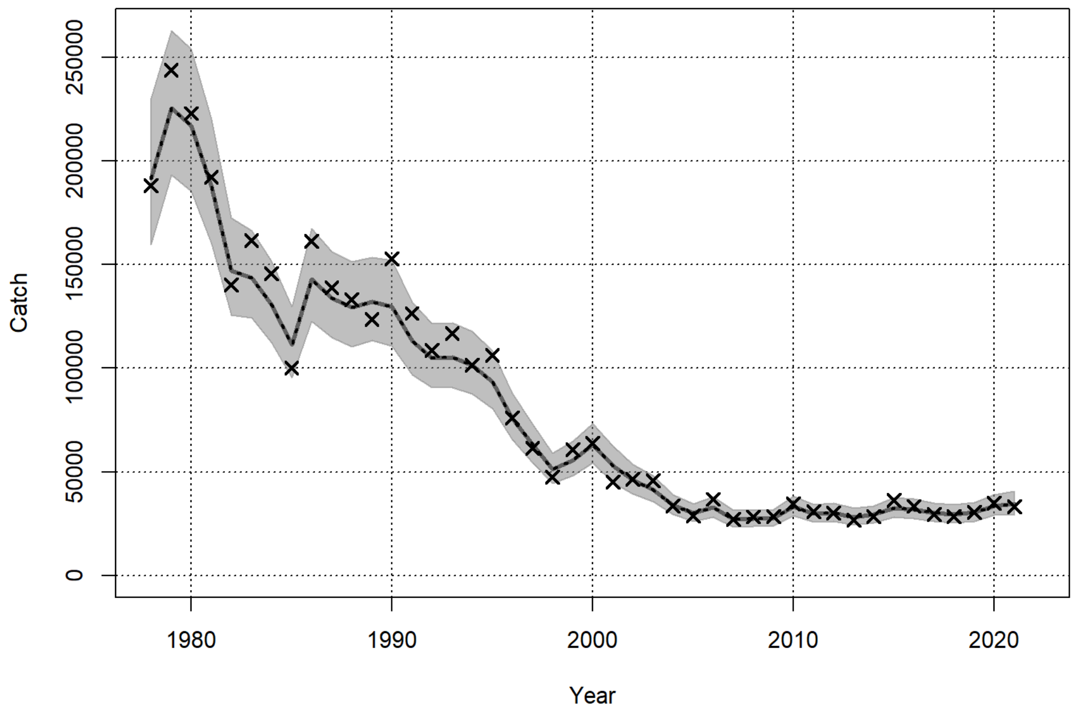
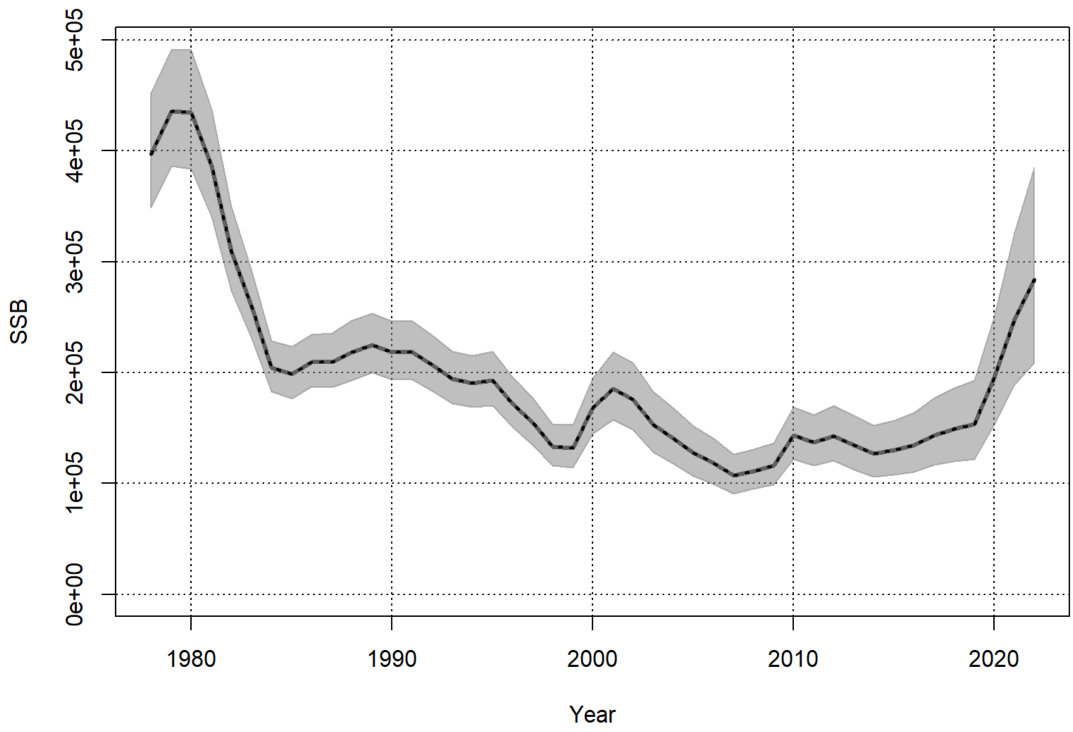
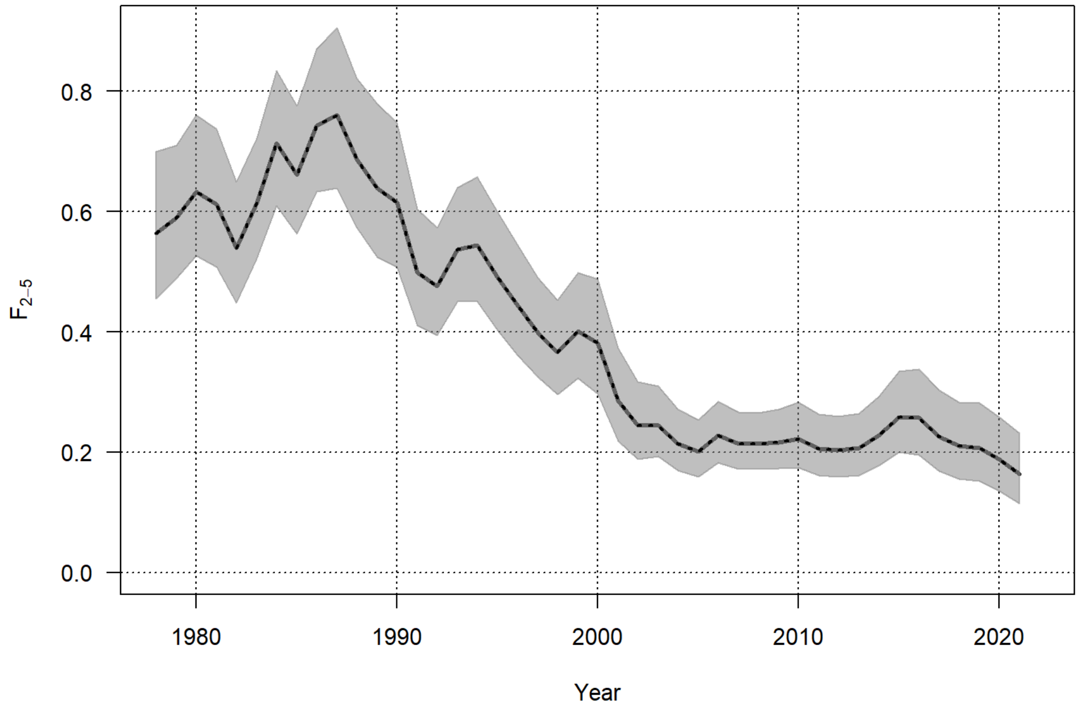


Figure 23.21. Whiting in Subarea 4 and Division 7.d: Correlations in the catch-at-age matrix (including the plus-group for ages 68 and older), comparing estimates at different ages for the same year-classes (cohorts). In each plot, the straight line is a normal linear model fit: a thick line (and black points) represents a significant ($p < 0.05$) regression, while a thin line (and blue points) is not significant. Approximate 95% confidence intervals for each fit are also shown.


Catch
Year
0
50000
100000
150000
200000
250000
1980
1990
2000
2010
2020


SSB
Year
0e+00
1e+05
2e+05
3e+05
4e+05
5e+05
1980
1990
2000
2010
2020



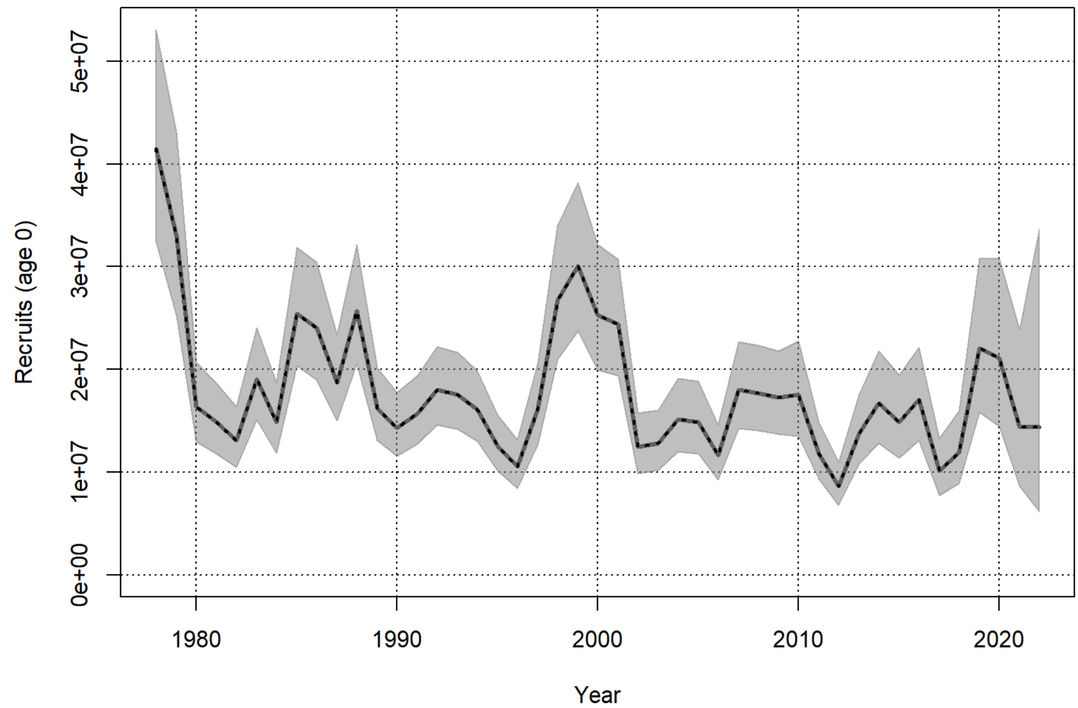


Figure 23.22. Whiting in Subarea 4 and Division 7.d: SAM assessment results using catch data series (1978–2021) with IBTS survey data starting in 1983 (Q1) and 1991 (Q3). Estimates with 95% Confidence intervals for total catch weight, SSB, mean fishing mortality and recruitment (at age 0).

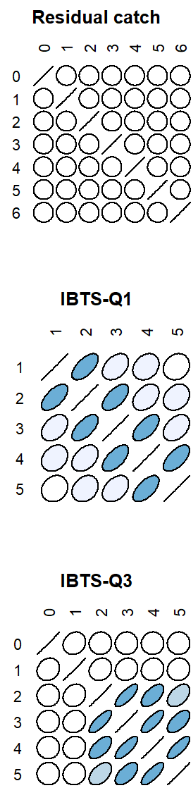


Figure 23.23. Whiting in Subarea 4 and Division 7.d: SAM estimated correlations between age groups for each fleet.

Figure 23.24. Whiting in Subarea 4 and Division 7.d: SAM standardised joint-sample residuals of process increments (for stock size N and fishing mortality F processes).

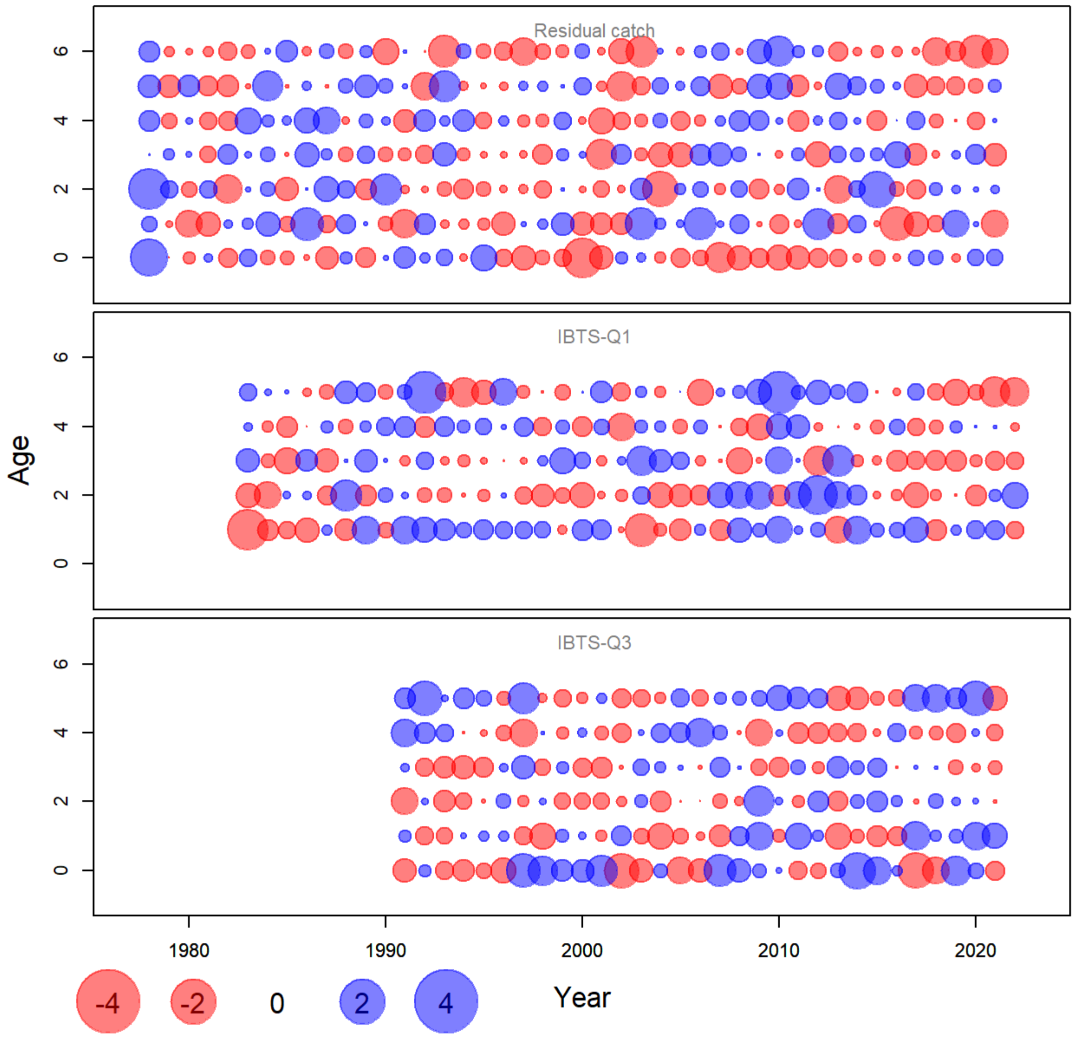


Figure 23.25. Whiting in Subarea 4 and Division 7.d: SAM standardized one-observation-ahead residuals.

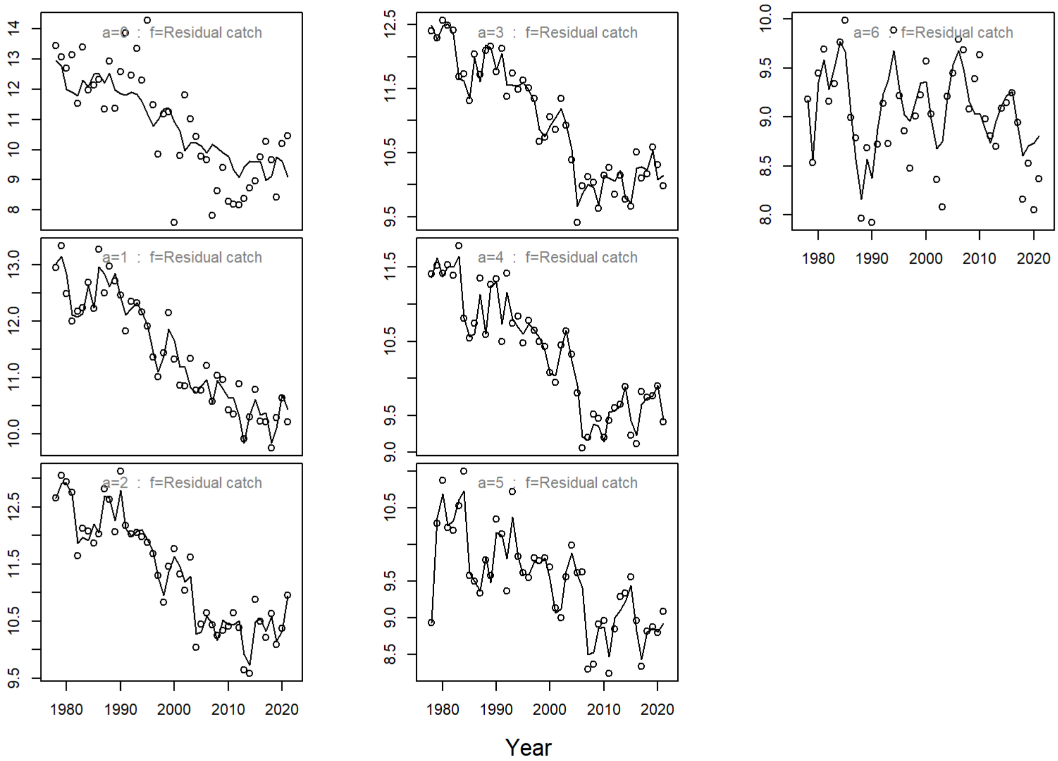


Figure 23.26. Whiting in Subarea 4 and Division 7.d: SAM predicted line and observed points (log scale) for the catch fleet.

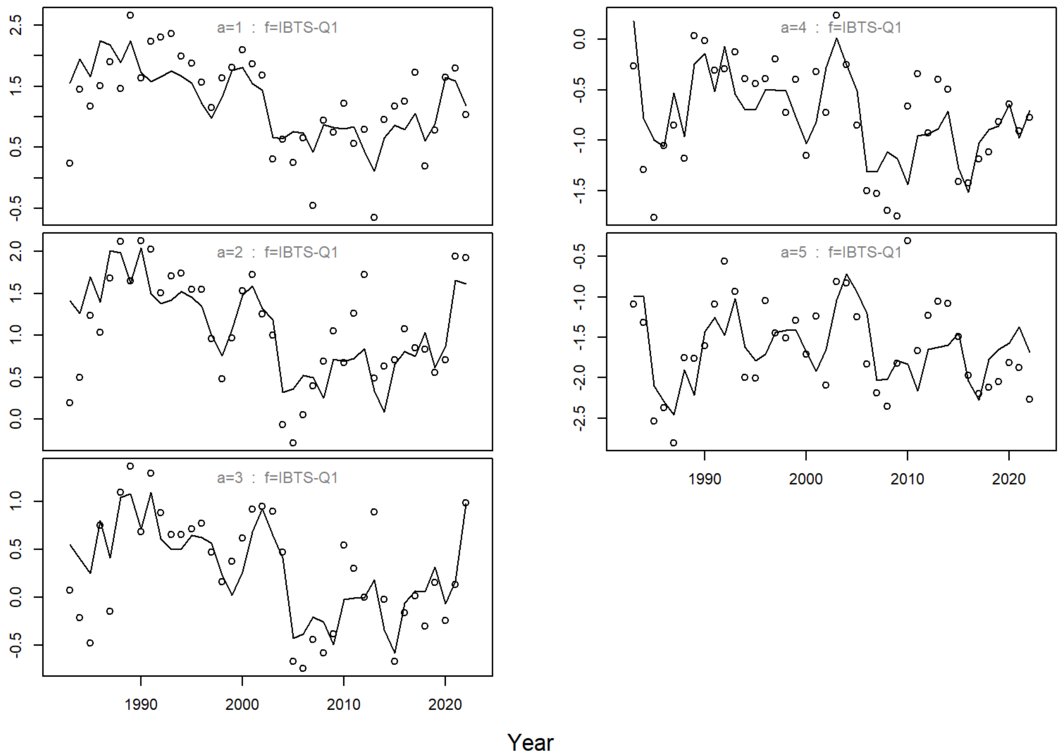


Figure 23.27. Whiting in Subarea 4 and Division 7.d: SAM predicted line and observed points (log scale), for survey fleet IBTS Q1.

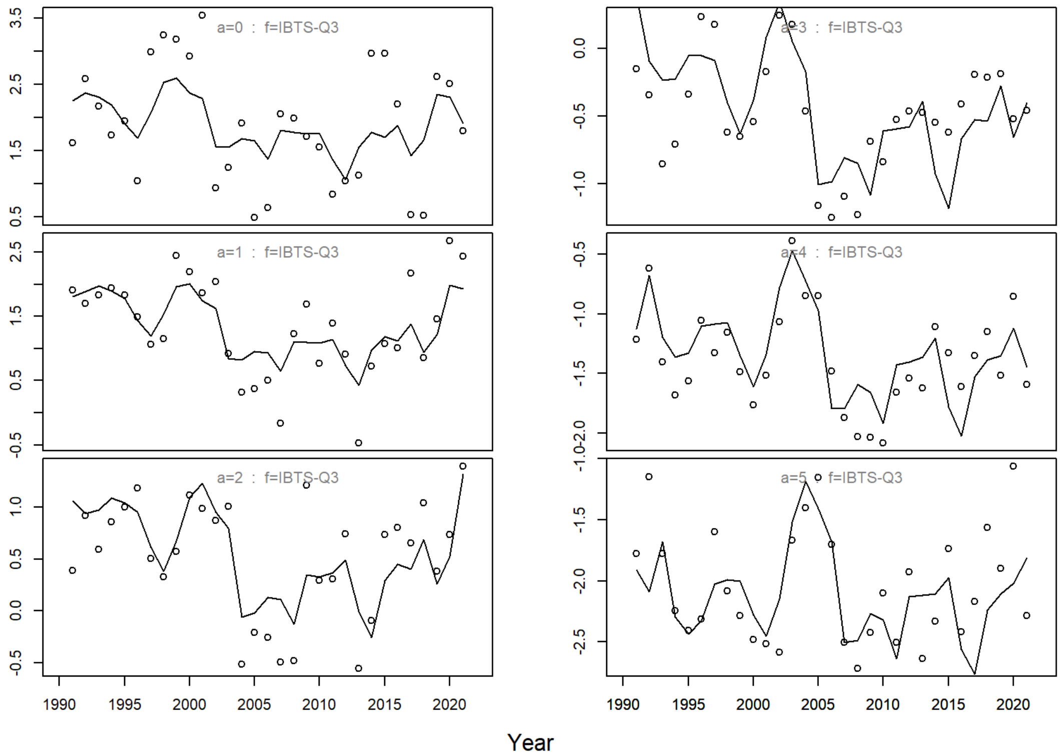
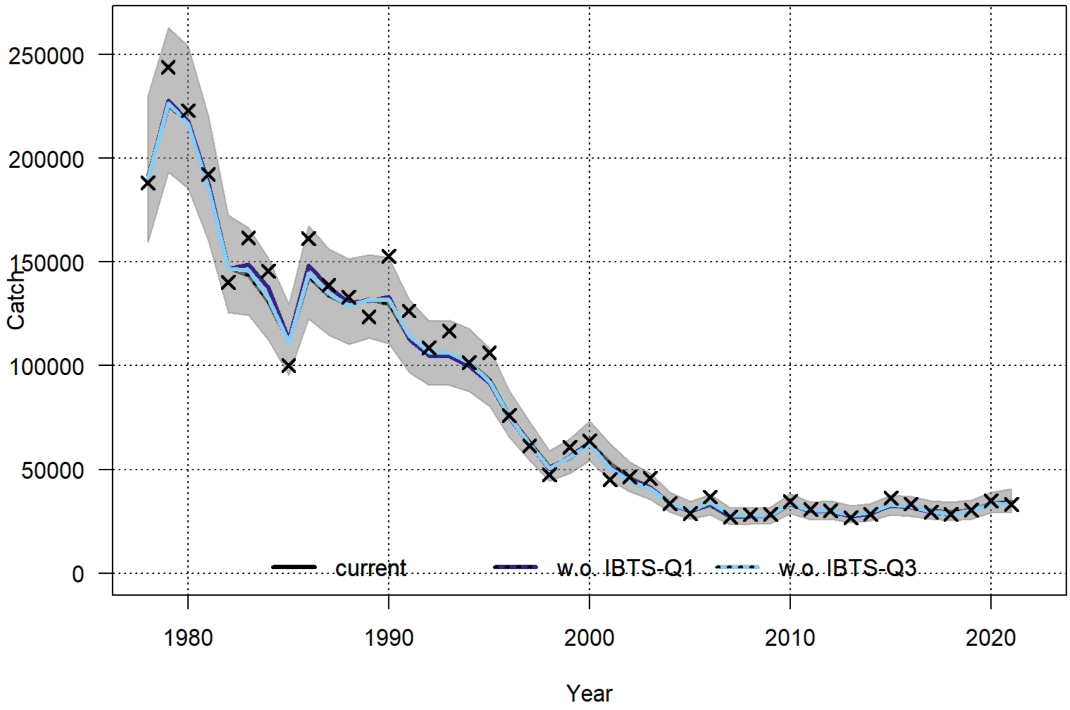
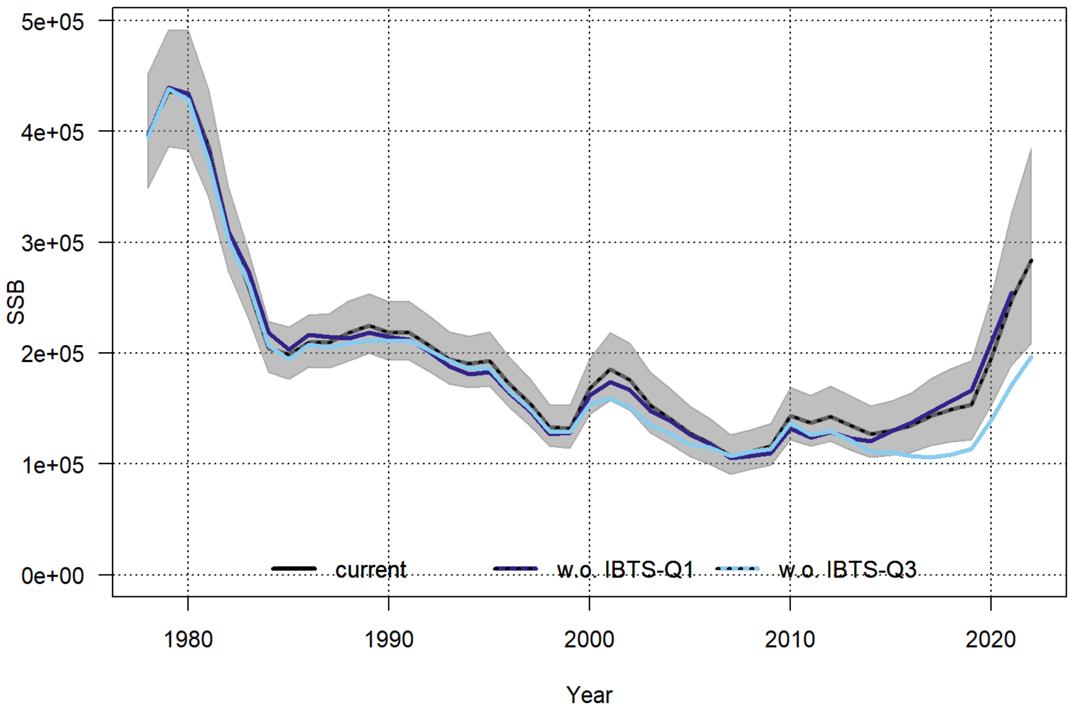


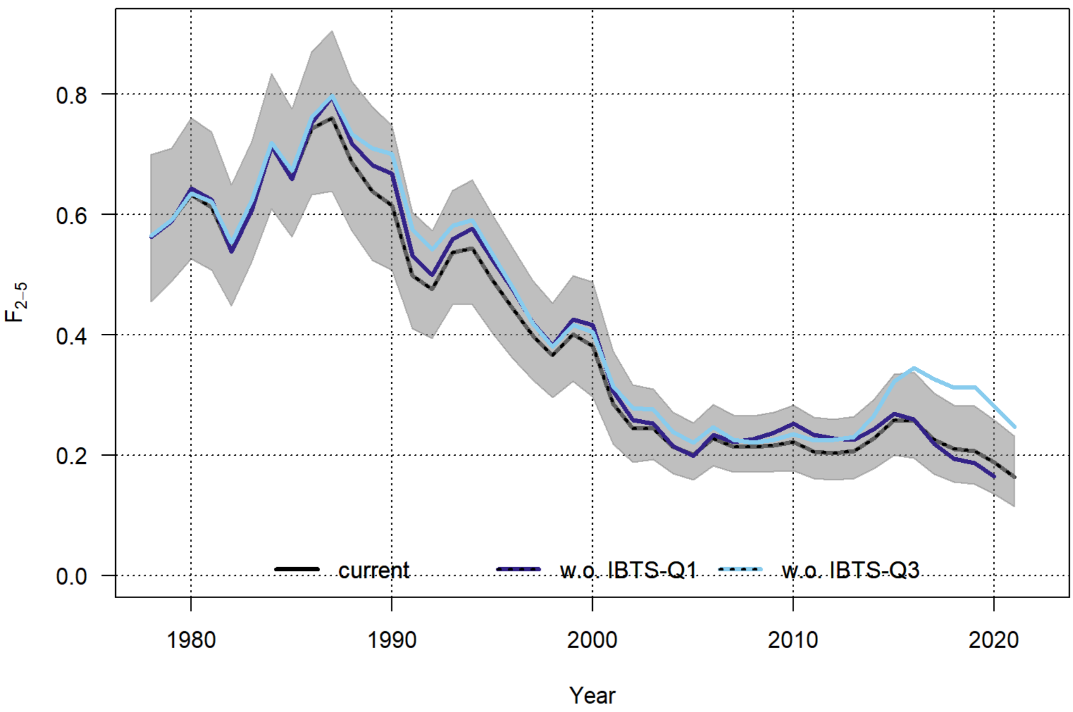
Figure 23.28. Whiting in Subarea 4 and Division 7.d: SAM predicted line and observed points (log scale), for survey fleet IBTS Q3.



Catch
250000
200000
150000
100000
50000
0
current
w.o. IBTS-Q1
w.o. IBTS-Q3
1980
1990
2000
2010
2020
Year



SSB
5e+05
4e+05
3e+05
2e+05
1e+05
0e+00
current
w.o. IBTS-Q1
w.o. IBTS-Q3
1980
1990
2000
2010
2020
Year



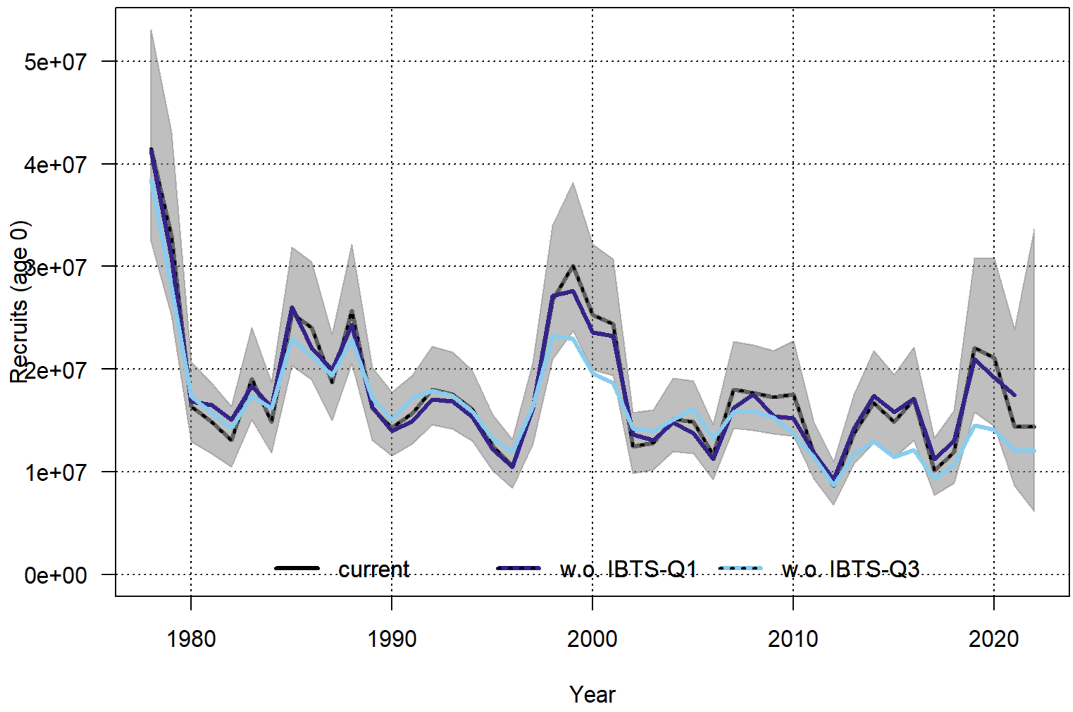
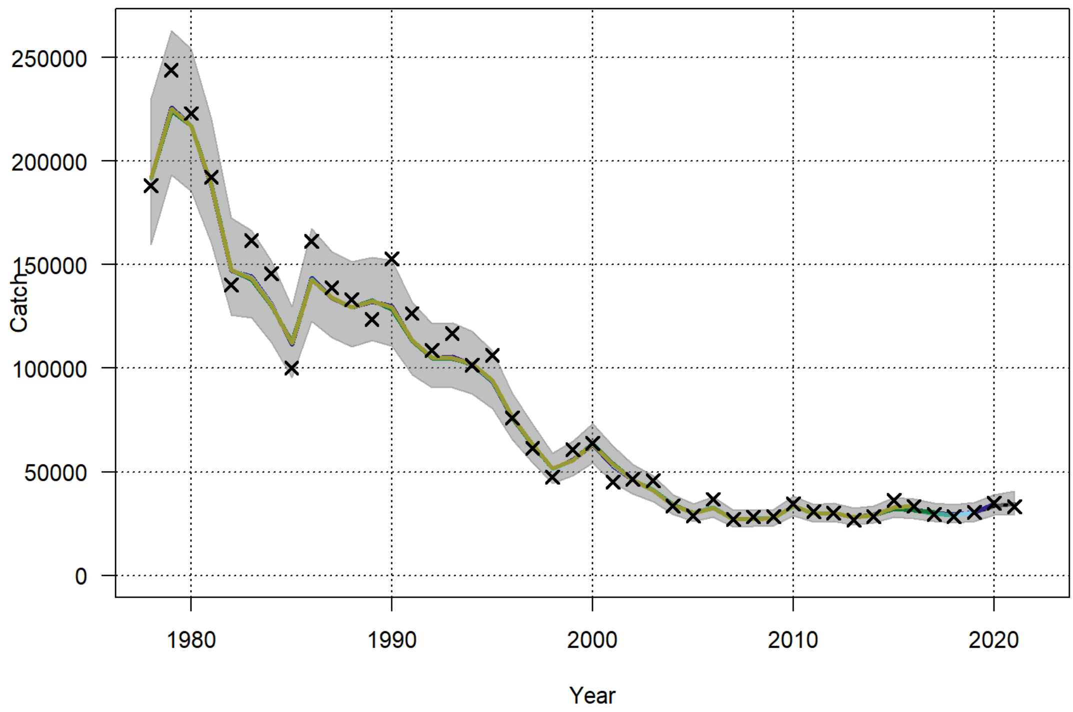
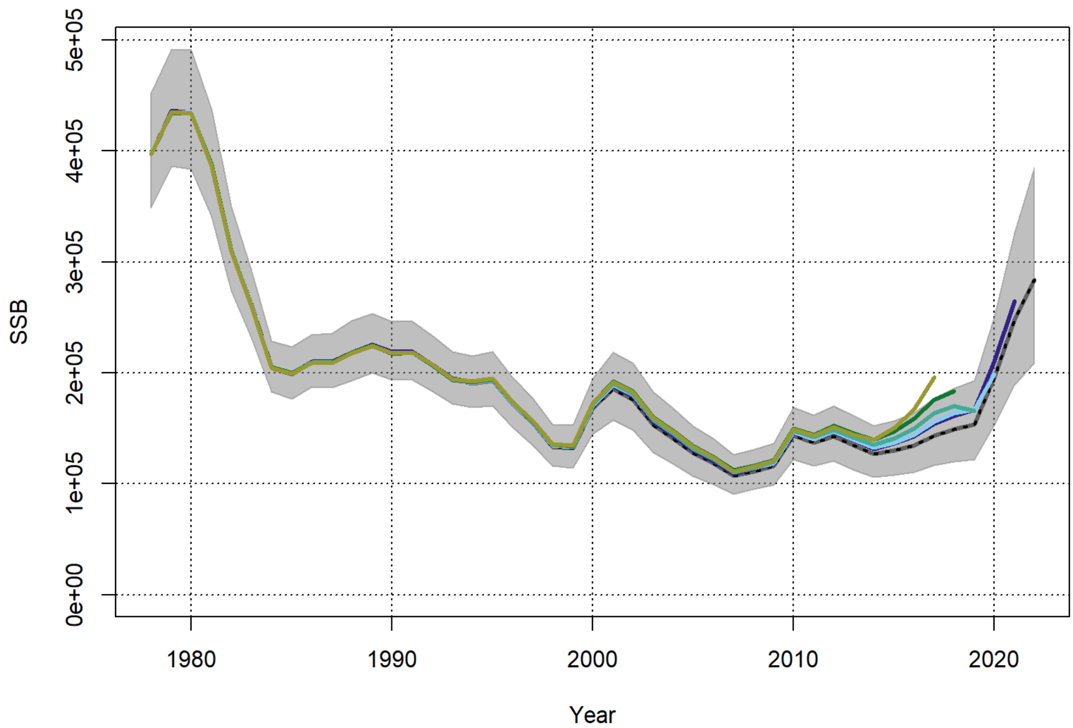


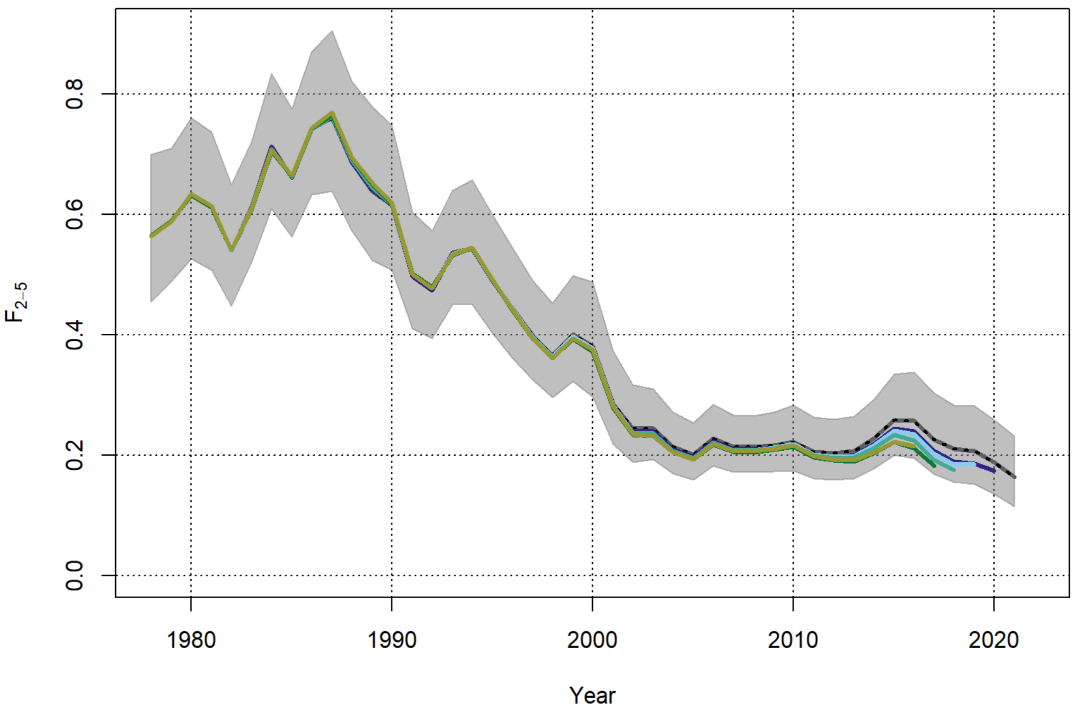
Figure 23.29. Whiting in Subarea 4 and Division 7.d: SAM leave-one-out diagnostics. Final run (black), run without IBTS Q1 (dark blue), run without IBTS Q3 (light blue).



Catch
250000
200000
150000
100000
50000
0
1980
1990
2000
2010
2020
Year



SSB
5e+05
4e+05
3e+05
2e+05
1e+05
0e+00
1980
1990
2000
2010
2020
Year



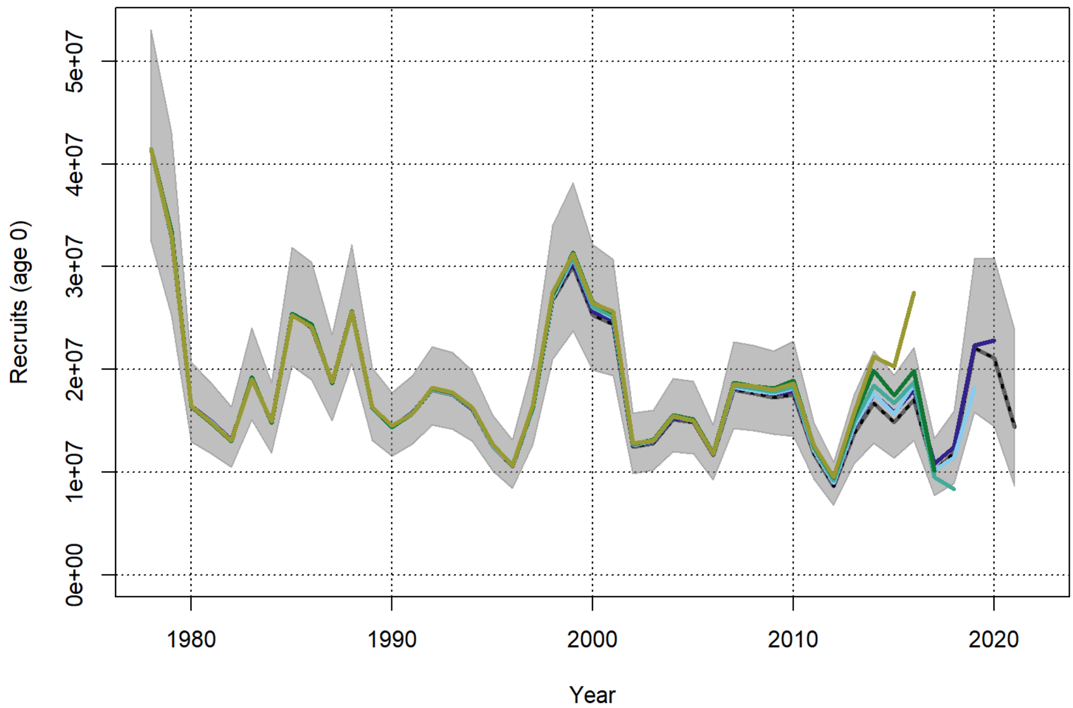


Figure 23.30. Whiting in Subarea 4 and Division 7.d: SAM Retrospective pattern in catch estimates, SSB, fishing mortality and recruitment.

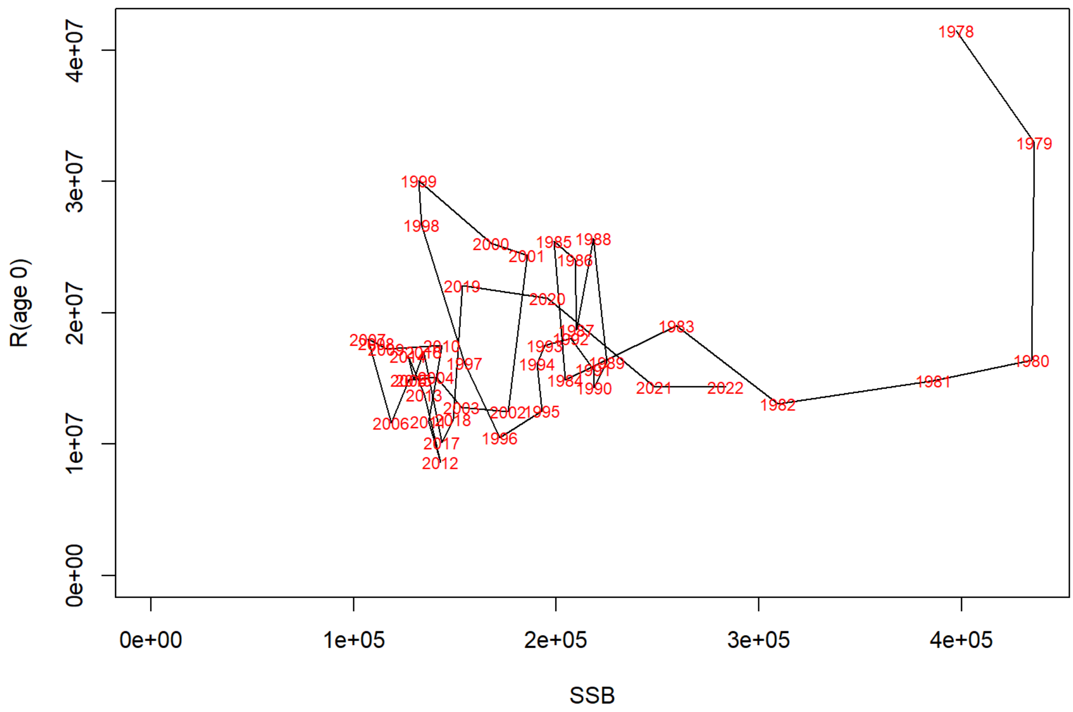


Figure 23.31. Whiting in Subarea 4 and Division 7.d: Stock-recruitment relationship.

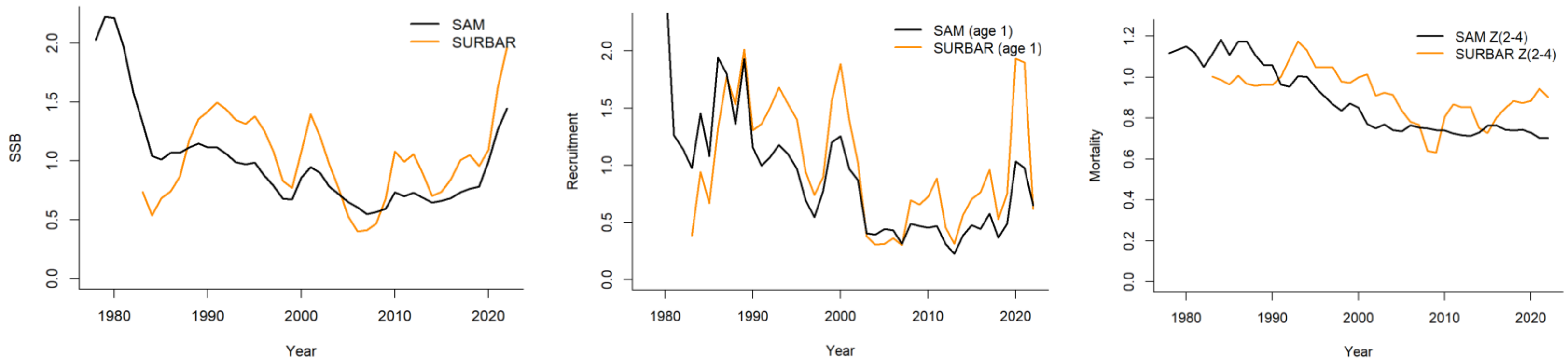


Figure 23.32. Whiting in Subarea 4 and Division 7.d: Comparisons of stock summary estimates from the final SAM (black) and SURBAR (orange) models. To facilitate comparison, recruitment and SSB values have been mean-standardised using the year range for which estimates are available from all three models. Mortality is presented as total mortality Z(2–4) for SAM and for SURBAR.

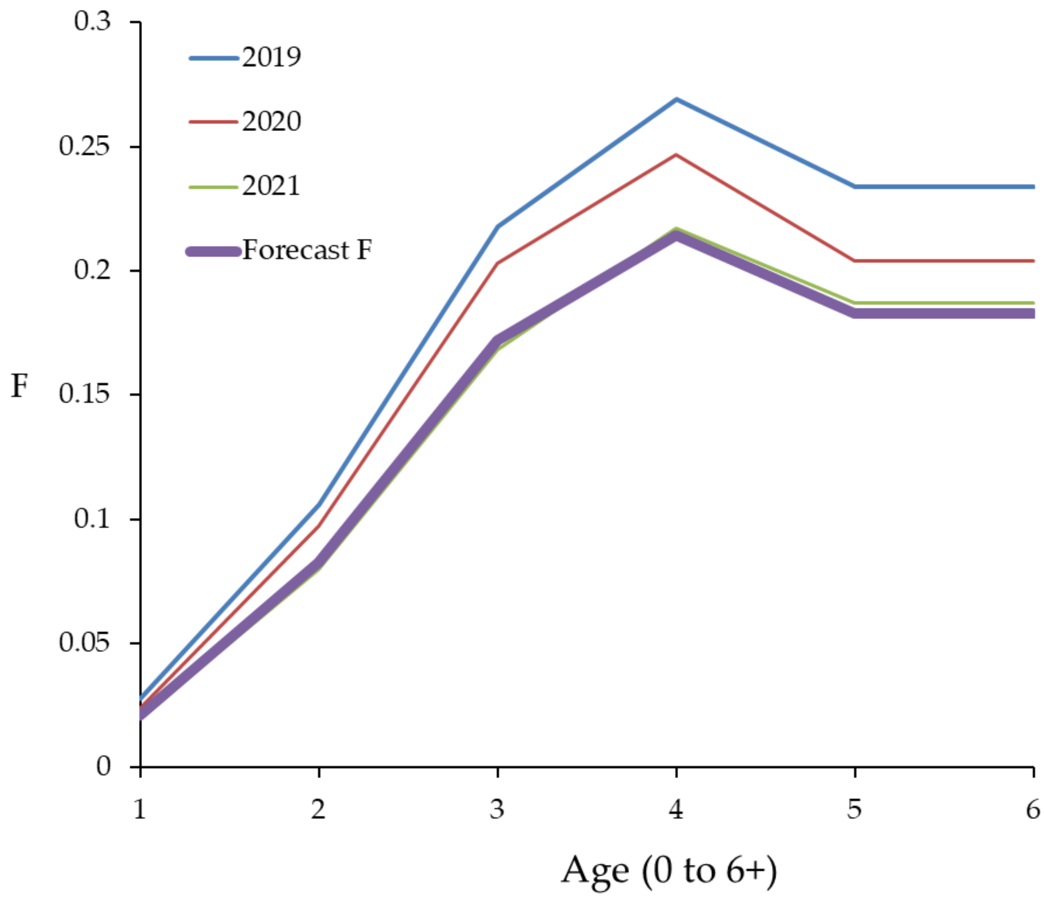


Figure 23.33. Whiting in Subarea 4 and Division 7.d: SAM F at age estimates for 2019–2021, along with scaled mean exploitation used for the forecast.

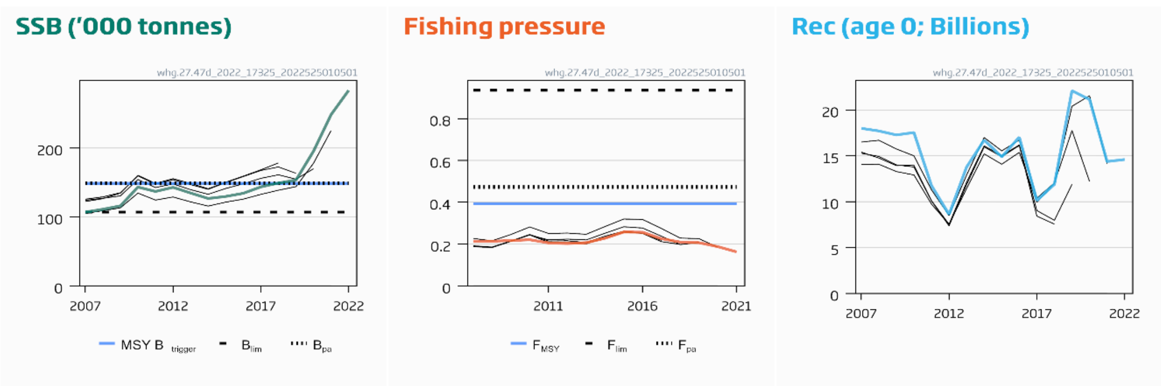


Figure 23.34. Whiting in Subarea 4 and Division 7.d: Historical assessments from Standard graphs.

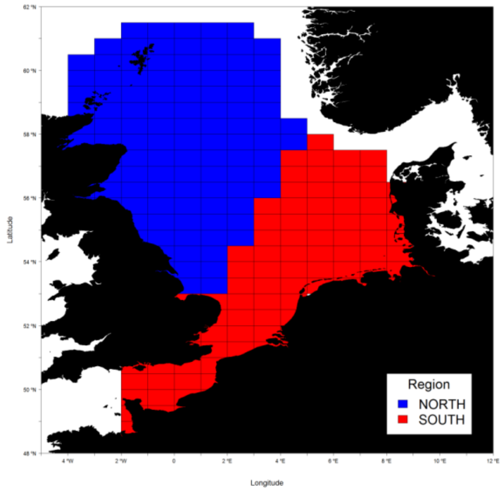
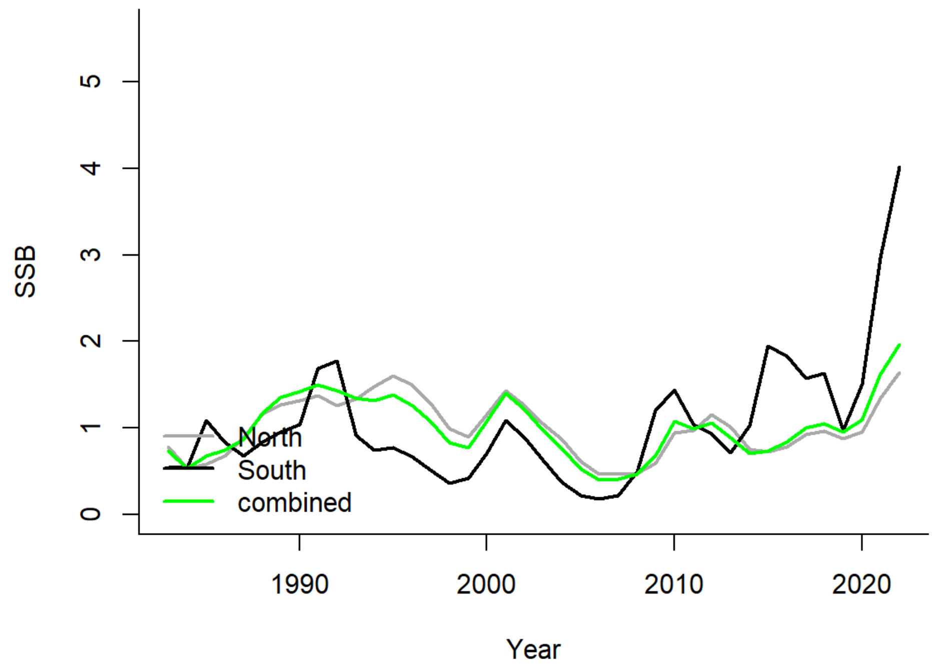
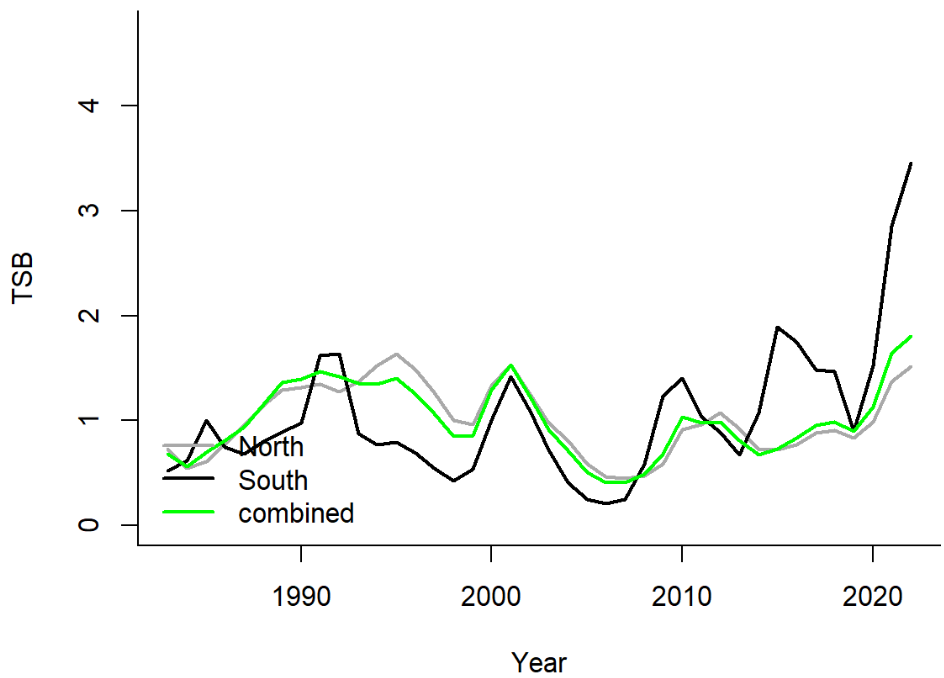
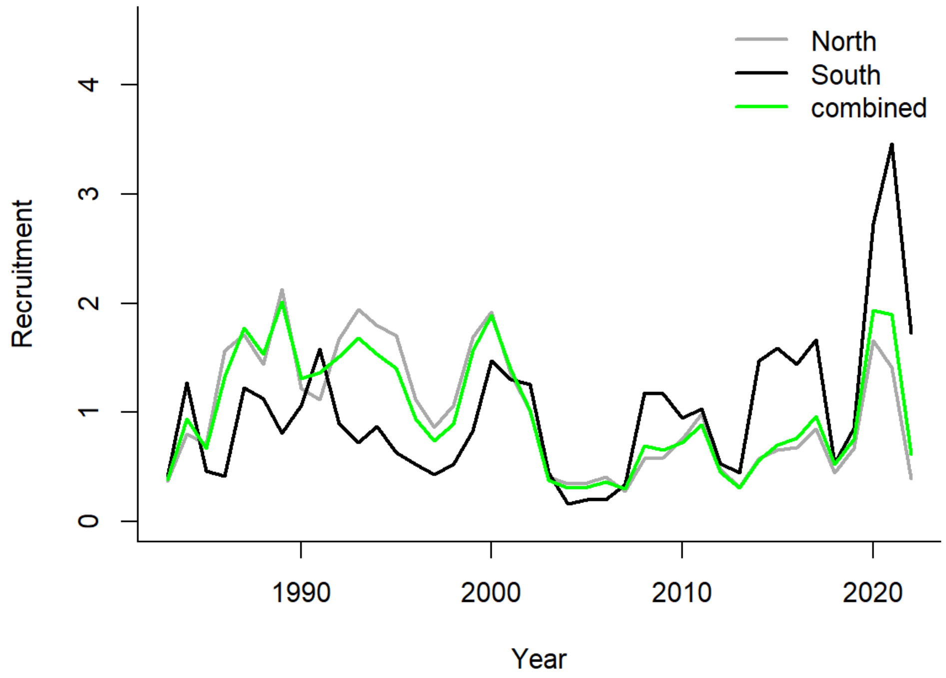


Figure 23.35. Whiting in Subarea 4 and Division 7.d: Components suggested by Holmes *et al*. (2014) to analyse spatial differences in maturation and SURBAR analysis.


SSB
0
1
2
3
4
5
1990
2000
2010
2020
Year
North
South
combined


TSB
0
1
2
3
4
1990
2000
2010
2020
Year
North
South
combined



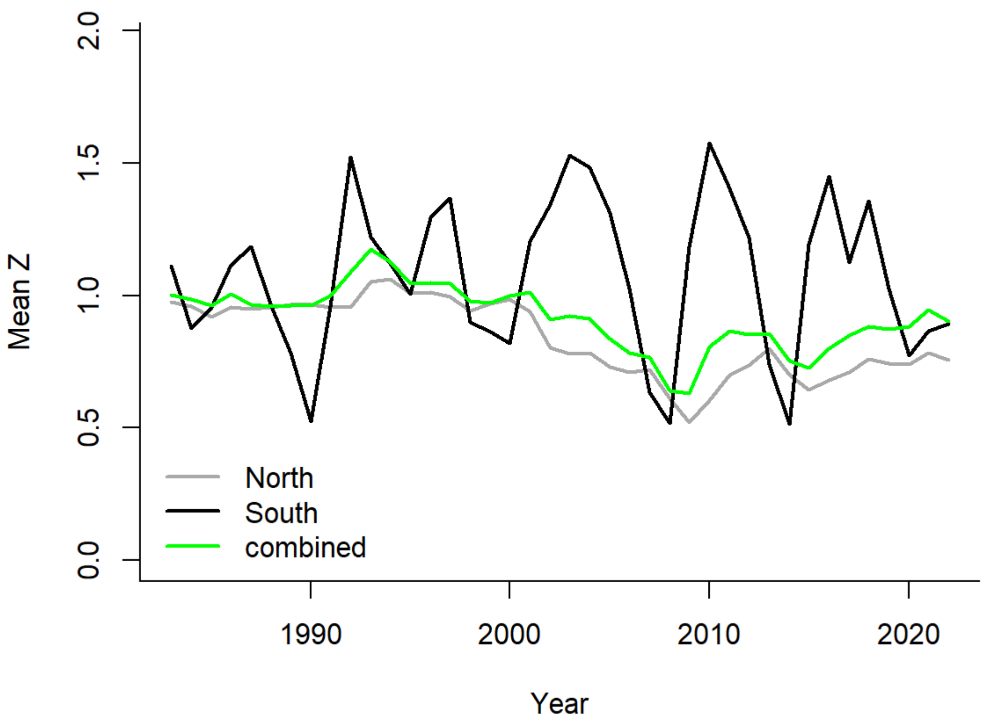


Figure 23.36. Whiting in Subarea 4 and Division 7.d: SURBAR results comparison combined (whg.27.4.47d) and northern and southern component as defined in WKNSEA 2018. Recruitment at age 1, total mortality is mean Z for ages 2–4.

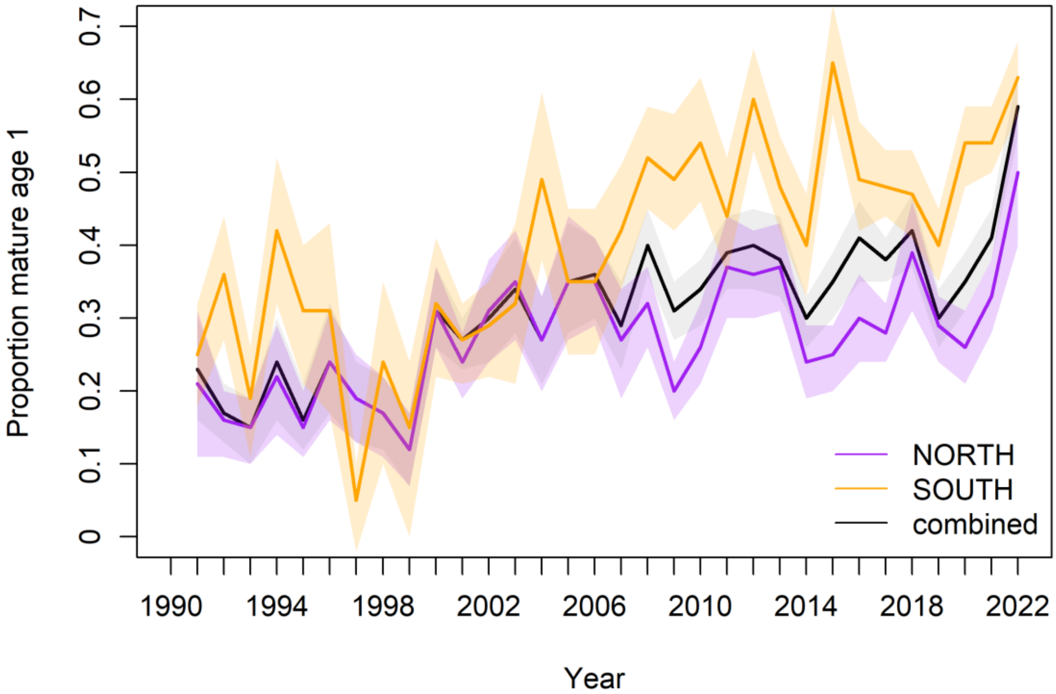


Figure 23.37. Whiting in Subarea 4 and Division 7.d: Trends in proportion mature individuals at age 1 for combined (whg.27.4.47d) and northern and southern component as defined in WKNSEA 2018.

24 Witch in Subarea 4 (North Sea) and Division 3.a (Skagerrak, Kattegat) and 7.d (Eastern Channel)

24.1 General

Witch flounder (*Glyptocephalus cynoglossus*) was assessed, between 2010 and 2013, by the Working Group on Assessment of New MoU Species (WGNEW, ICES 2013a). The main task of WGNEW was to provide information on the new species of the MoU between ICES and the EC. Since 2014 WGNEW was dissolved thus this species was included in the Working Group on the Assessment of Demersal Stocks in the North Sea and Skagerrak (WGNSSK).

Following the ICES guidelines for data limited stocks (ICES, 2012), witch was defined as a category 3 stock as only official landings and survey data were available. The biennial advice, drafted in 2013 (ICES, 2013b), was based on stock size indicators (DATRAS standardized CPUE in number per hour) derived from IBTS (both Q1 and Q3) and exploratory estimates (merely indicative of trends and not used for catch forecast) suggested that fishing mortality was above potential F_{MSY} proxies. In 2015, witch flounder was included in the official data call for the Working Group on the Assessment of Demersal Stocks in the North Sea and Skagerrak (WGNSSK) and the biennial advice was evaluated by this group. The data call for the WGNSSK 2016 included landing and discard data for the years 2012–2015 in order to provide catch advice for this species. The same was done in 2017, with landing and discard data updated up to 2016. The new data-call in 2017 for the Benchmark Workshop (WKNSEA, 2018) included landing and discards data, by age and length, for the years 2002–2016. Following WKNSEA 2018 the stock became category 1. Hence a full analytical assessment was made at WGNSSK 2018 based on data up to 2017. However, being biennial, the advice was not re-opened in 2018. At WGNSSK 2019, the stock assessment was extended in order to include also 2018 data and a new advice was released. From 2019 onwards, the advice is updated on an annual basis.

In 2021, the stock went through an interbenchmark process (IBP) with main aim to establish a new age-specific survey index (IBPWITCH). That was deemed necessary during the WGNSSK 2021 assessment meeting, as ICES did not provide a survey index. Some issues were identified to the previously used survey index; additionally, the previously used index was never tested by relevant ICES working groups. During the IBP, a new index was established based on a Tweedie-GAM approach and the reference points were updated. A few other decisions of the WKNSEA 2018 benchmark were briefly discussed but not changed. Finally, the stock annex was updated to reflect the changes in the survey index calculations and the new reference points.

24.1.1 Biology and ecosystem aspects

The existing knowledge of witch biology is summarized in the Stock Annex.

In 2009, witch flounder has been included as a mandatory species in the EU Data Collection Framework (DCF). Accordingly, Denmark and Sweden started the regular sampling of biological data, i.e. length, weight, maturity status and age, in 3.a and 4 both for discards and landings. Scotland has also been collecting biological samples since 2009 but only from the landings.

Up to 2016, age determination has been conducted by Sweden, also for Scotland and Denmark (only landings). Age readings techniques are now well established but an inter-calibration among readers will be planned at the next WGBIOP (Working Group on Biological parameters) as from 2017; also Scotland has started to read otoliths for age estimation. The macroscopic evaluation of maturity status is still uncertain and gonadal histological analysis is under development. A fixed maturity ogive was employed in the assessment model. Data exploration and reason for the final decision are elucidated in WKNSEA 2018, WD3.

24.1.2 Management regulations

According to EU–Regulations a precautionary TAC is given in EU waters of 2.a and 4 together with lemon sole (*Microstomus kitt*). The TACs have been stable, varying around 6000 tonnes since 2006. There is no official Minimum Landing Size (MLS) specified in EU waters. However, in most of the countries reporting catches, the landing of witch below 28 cm is prohibited. Currently, lemon sole and witch flounder are managed under a combined species TAC, which prevents the effective control of the single species exploitation rates and could potentially lead to the overexploitation of either species. Furthermore, witch flounder is mainly a bycatch species in mixed fisheries (although some limited seasonal target fisheries occurs in 3.a; see Feekings, 2011) thus a TAC alone may not be appropriate as a management tool. Hence, ICES advises that witch should be managed using a single-species TAC covering the stock distribution area, i.e. ICES Division 3.a, Subarea 4, and Division 7.d (ICES, 2018b).

24.2 Data available

24.2.1 Historical landings

North Sea witch flounder landings have declined from a peak in the 1990s to a low at the end of 2000s, but from 2011 a general increasing trend is observed (Figure 24.2.1.1). This species is nowadays mainly landed by Denmark, Norway and Sweden, in both areas (3.a and 4) and UK (Scotland and England) mainly in Subarea 4. In division 3.a, Denmark is landing the largest amount of witch flounder (Figure 24.1, upper plot), while in Subarea 4 it is Scotland having the largest portion of the landings (Figure 24.1, middle plot). A small fraction of the total landings are reported by The Netherlands and Belgium in Subarea 4 and Germany in both areas as this species is mostly discarded (Figure 24.1 upper and middle plots). The landings of witch in Division 7.d reported by France and Belgium are negligible (Figure 24.1, lower plot).

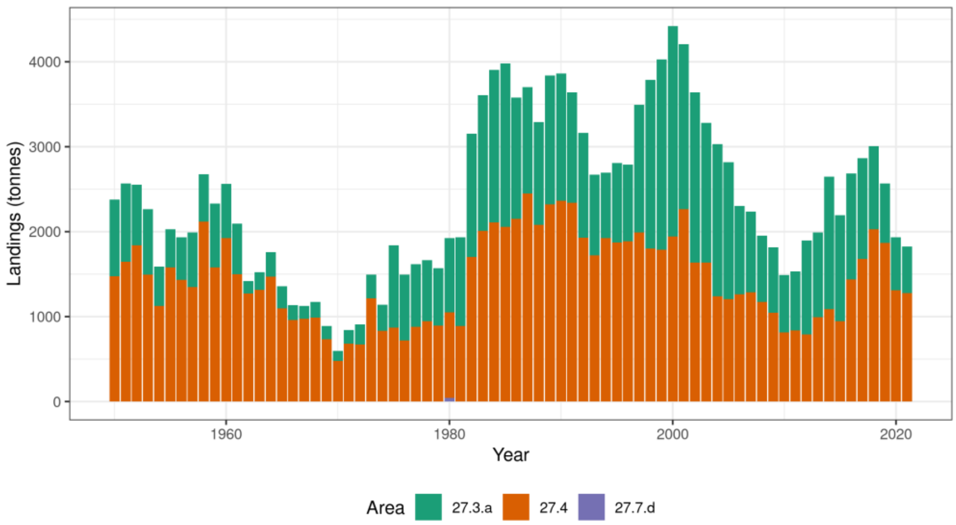


Figure 24.2.1.1. Witch flounder in Subarea 4 and Division 3.a: Total official landings (in tonnes).

24.2.2 Catch

Landings data from human consumption fisheries for recent years as officially reported to ICES together with those estimated by the WG are given in Table 24.1. Official landings data for each area separately are given in Table 24.2.

In preparation for the benchmark (WKNSEA, 2018) InterCatch was used for estimation of both landings and discards numbers, length composition (2002–2016) and age compositions (2009–2016). At WGNSSK 2022, landings, discards and total catch at age and mean weight at age were updated up to 2021.

The ICES estimated catches for 2021 is 2105 tonnes, split as follows for the separate areas and catch categories:

Area	Landings	Discards	BMS landings
3.a	548.61	149.42	0
4	1278.08	129.08	0
7.d	0.15	0.03	0
Total	**1826.84**	**278.53**	**0**

24.2.2.1 Age composition

Age compositions for landings and discards are provided yearly by Denmark, Scotland and Sweden (Tables 24.3a and b).

Total catch numbers-at-age for age groups 0–10+ for the period 2009–2021 are shown in Table 24.4. These data form the basis for the catch-at-age analysis.

24.2.2.2 InterCatch

InterCatch, includes witch flounder data from 2002 and onwards, though biological data only since 2009. InterCatch was used for estimation of landings, discards and total catch at age and mean weight at age in 2021. Data coordinators from each nation uploaded input data into InterCatch, disaggregated to quarter and métier. Allocations of discard ratios and age compositions for unsampled strata were then performed in order to obtain the data required for the assessment.

The proportion of landings with associated discards (same strata) is 84%. The approach used for unmatched discard was to merge all areas (3.a, 4 and 7.d) and treat métiers separately, combined in two categories, i.e. fleets with and without selectivity devices (including passive and active gears). Then, within each of these two categories (ignoring country), where métiers had some samples these were pooled and allocated to unsampled records within that category. Very high discard ratios were excluded from the raising of discards. Quarters were merged for fleets with selectivity gears while kept separate for fleets without selectivity gear. A low amount of industrial bycatch is reported in InterCatch (10.5 tonnes in 2021) and is included in the landings.

The landings and discards imported or raised in InterCatch for 2021 are as follows (weights in tonnes; note any differences in landings and discards values to those given above are due to SOP correction):

Catch Category	Raised or Imported	Catch (tonnes)	%
Landings	Imported Data	1827	100
Discards	Imported Data	217	78
Discards	Raised Discards	61	22
BMS landing	Imported Data	0	0
Logbook Registered Discard	Imported Data	0	0

To allocate age compositions, landings and discards were handled separately; samples from landings were used only for landings and samples from discards were used only for discards. A similar approach to the discards raising was used for allocating age compositions. Quarters were merged for fleets using selectivity gears while treated separately for fleets without selectivity gears.

The landings and discards imported or raised, with age distribution sampled or estimated for 2020 are as follows (tonnes; note any differences in landings and discards values to those given above are due to SOP correction):

Catch Category	Raised or Imported	Sampled or Estimated	Catch (tonnes)	%
Landings	Imported Data	Sampled Distribution	1497	82
Landings	Imported Data	Estimated Distribution	330	18
Discards	Imported Data	Sampled Distribution	197	71
Discards	Raised Discards	Estimated Distribution	61	22
Discards	Imported Data	Estimated Distribution	21	7
BMS landing	Imported Data	Estimated Distribution	0	0
Logbook Registered Discard	Imported Data	Estimated Distribution	0	0

In 2021, the largest amount of landings and discards in Subarea 4 was reported by Scottish métiers OTB_DEF_>=120_0_0_all and the OTB_CRU_70-99_0_0_all, respectively (Figures 24.1 and 24.2 middle plots). In Division 3.a, Denmark had the highest landings and discards, using the OTB_CRU_90-119_0_0_all métier (Figures 24.1 and 24.2, upper plots). The total catch estimated with InterCatch in 2021 was 2105 tonnes, of which 1827 tonnes were landings and 279 tonnes were discards. The unwanted catches were thus 13.3% of the total catch.

Swedish landings in Area 4 for 2019, were not submitted to InterCatch and were made available during the 2020 WGNSSK group meeting. For witch, 2765 tonnes were landed by Sweden in 2019 in Area 4. This corresponds to 0.23 tonnes of discards, assuming the overall discard rate in Area 4 (8.3%). These catches were split to catch at age, assuming the overall catch at age allocation in Area 4 and are included in the assessment.

Norwegian BMS landing was reported very high in 2018, due to a difference in InterCatch submission compared to other years. Therefore, the decision was made for the 2019 assessment to include BMS landing from Norway to landings. The Norwegian data in InterCatch since 2019 show no BMS landing, indicating that the data are submitted in the way it was done in years prior to 2018.

In general, the discard rate is moderately low in the period 2002–2020 where discard information is available in InterCatch, except for 2002 (34%) where further investigation is needed. For the following period, the discard rate has been increasing from almost 10% in 2003 to 27% in 2010 and then decreasing again to 7.8% in 2019 and a slight increase to 9.3% in 2020. However, it should be noted that not all métiers were sampled in every quarter and that raising procedure may not be adequate in all cases. Thus, for some métiers the applied raising procedure might introduce bias to the total discard estimates. Landings (as estimated in InterCatch) showed a decline from 2002 to 2010, decreasing from 3800 to 1531 tonnes followed by an increase to over 3000 in 2018 and a drop to 2580 tonnes in 2019 and further to 1937 tonnes in 2020. In 2021, the ICES estimate of landings is 1827 tonnes.

24.2.3 Weight at age

Mean weight at age data for landings (including Norwegian BMS landings in 2018), discards and catch, are given in Tables 24.5a–c.

The average stock weights at age, estimated using IBTS data from the period 2009–2017 combining quarter 1 and quarter 3, are used for all years in the assessment (Table 24.6).

24.2.4 Maturity and Natural mortality

Constant maturity ogives (Table 24.7), obtained using Swedish commercial samples 2009–2018 all quarters combined are used.

The assessment currently uses a constant natural mortality rate of 0.2 y^{-1} for all ages and years.

24.2.5 Survey data

During the benchmark in 2018, two surveys for demersal fish species in the greater North Sea area were explored, in order to produce potential tuning indices useful for the witch 3a47d stock assessment model. Those surveys are the International Bottom Trawl Survey (IBTS, 1st and 3rd Quarter) and the Beam Trawl Surveys (BTS, 3rd Quarter). While the BTS covers areas 4.b, 4.c and the English Channel (Division 7.d), the IBTS covers area 4.a, the Skagerrak (Division 3.a.20) and Kattegat (Division 3.a.21). The decision of the benchmark group was to include in the assessment total biomass indices for the first part and biomass indices by age for the last part of the time series. Total biomass indices (Table 24.1) were calculated for IBTS Q1 and combined BTS-IBTS Q3 using a delta-GAM approach (Q1: 1983–2008, Q3: 1991–2008). DATRAS-generated IBTS Q1 and Q3 indices by age, provided by the ICES DataCentre, were chosen due to their better internal and external consistencies. Nevertheless, in 2021 ICES DATRAS index was not made available for the assessment, as it was not evaluated from a relevant ICES WG and there were issues with the index calculation procedure. This led to an IBP for the stock with main aim to establish a new age-specific survey index based on a GAM approach. The details of the index calculation are given in the IBPWitch report (ICES, 2021) and in the stock annex.

Witch flounder distribution does not peak at a certain depth range, indicating they are found at depths deeper than the surveys. This species in fact inhabits deep water and the distribution (Figure 24.2.5.1) is not entirely covered by those surveys. The deeper Norwegian Trench is a known habitat for the species and not sampled by the IBTS. The use of the IMR deep-water shrimp survey (held in national database) was mentioned as a potential future data source during the benchmark in 2018, but was not explored.

The length distributions (total number caught by length group overall years divided by total number caught) in the commercial samples and in the survey (Q1 IBTS) are similar so the survey may be regarded as representative of exploitable stock biomass.

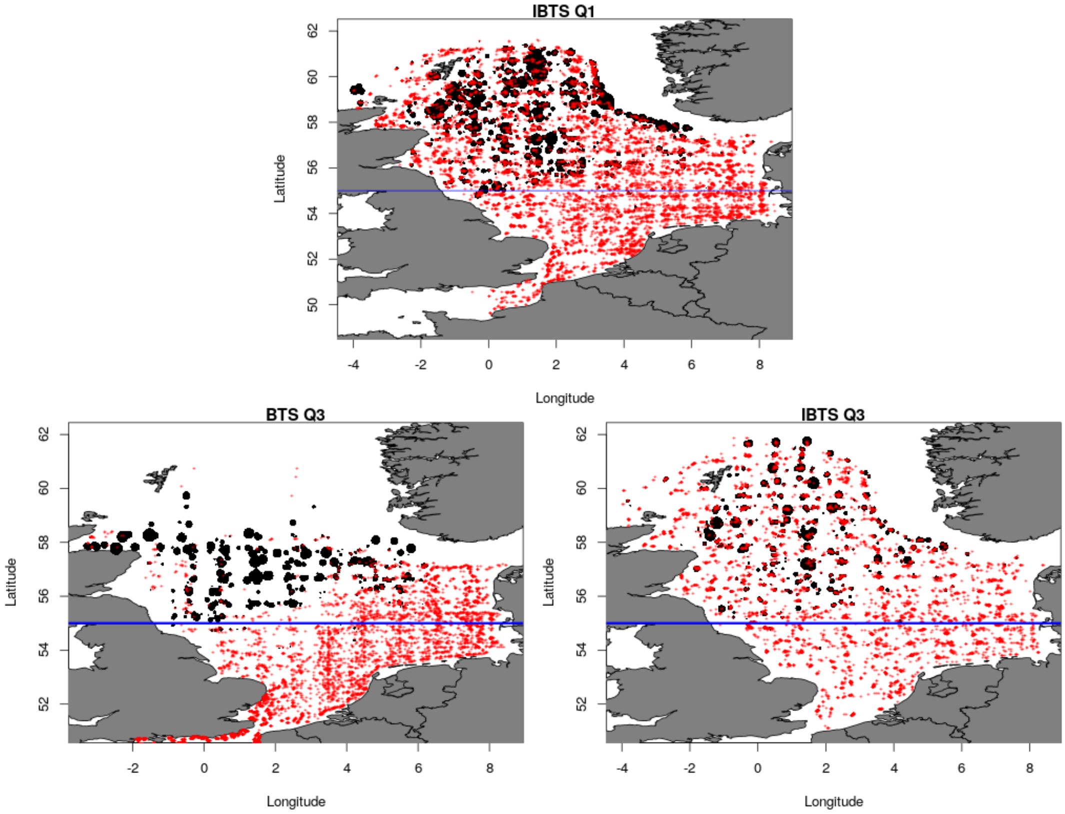


Figure 24.2.5.1. Witch flounder in Subarea 4 and Division 3.a: Aggregated distribution over the period 1983–2017 in the North Sea derived from IBTS–Q1 (upper) and Q3 (lower); data from that period are used to estimate the total biomass indices that are included in the assessment. The sizes of bubbles are proportional to total catch weight. Red crosses represent zero catch hauls. The area above the blue line was used to calculate the survey indices.

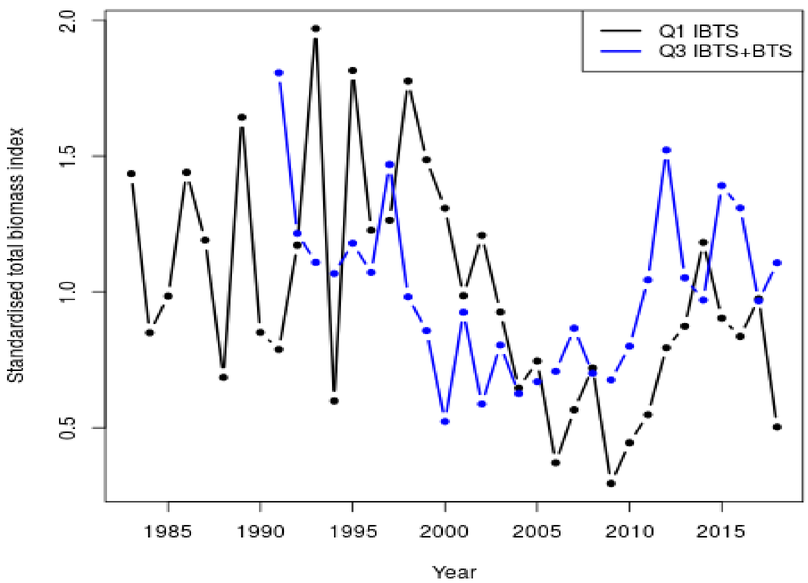


Figure 24.2.5.2. Witch flounder in Subarea 4 and Division 3.a: Q1 and Q3 indices of total biomass (rescaled to mean 1, until 2018). The assessment includes only the time-series up to and including 2008.

24.3 Data Analysis

The accepted assessment model during WKNSEA 2018 is SAM (State–space Assessment Model, WKNSEA 2018, WD 4). A SPiCT (stochastic surplus production model in continuous time) was run in parallel and considered as exploratory (WKNSEA 2018, WD 5). The updated SAM assessment including data up to 2021 is presented in Figures 24.4–24.7. The assessment method was slightly updated during the IBP of the stock, where the index at age includes ages 2–7+ for quarter 1 and 2–6+ for quarter 3. The quarter 3 index includes NS-IBTS and BITS hauls.

24.3.1 Assessment audit

24.3.2 Final assessment

The basic state-space assessment model (SAM) is described in Nielsen and Berg (2014). The current implementation (https://github.com/fishfollower/SAM) is an R-package based on Template Model Builder (TMB) (Kristensen *et al.*, 2016). The dataset used to assess witch uses catches at age and age-specific indices from two scientific surveys from 2009 to 2021. The complete age-specific data set only covers a relative short time period; therefore, the time series is extended using total landings (1950–2008) and fishable stock biomass (FSB) indices (IBTS Q1: 1983–2008, IBTS + BTSQ3: 1991–2008).

The added observation equation for the total landed weight (TLW) was:

$$\log TLW_y = \log\left(\sum_{a=1}^{10^+}\left(\frac{F_{a,y}}{Z_{a,y}}(1-e^{-Z_{a,y}})N_{a,y}\right)\overline{\Psi}_{a,}\overline{W}_{a,}^{(l)}\right)+\varepsilon_y^{(tlw)}$$

where $\epsilon^{(tlw)}$ is normally distributed with mean zero and a standard deviation, which is computed via the delta method from the standard deviation parameters of the age-specific log-catches. No additional model parameters are required.

The observation equation for the fishable stock biomass (FSB) was:

$$logF\,SB_y = logQ^{(s)} + log\widehat{F\,SB}_y + \varepsilon_y{}^{(s)}$$

where $\boldsymbol{Q}^{(s)}$ is the survey specific catchability, $\boldsymbol{s}$ denotes the survey and $\boldsymbol{\epsilon}_{\boldsymbol{y}}^{(s)}$ is normally distributed with mean zero and a standard deviation specific to the survey.

The parameter estimation was done by maximizing the joint likelihood (of random effects and observations and inference was made using the marginal likelihood calculated by integrating out the random effects using the Laplace approximation.

In order to obtain convergence, artificial catch-at-age data were added in the beginning of the time series (1940–1944) and leaving a period of five years without data before the total landings series started in 1950. The artificial catches at age were chosen to be equal to the average of the observed period (2009–2016). Sensitivity analysis showed that there was no influence of the choice of the artificial catches during the assessment period (1950–2016). The sensitivity analysis was repeated during the IBP in 2021 with the same results.

In addition to the observations on catches and surveys a set of biological parameters are available, these include: Mean weight in stock, mean weight in catch, mean weight in landing, proportion mature, and an estimate of natural mortality. The stock weight at age is shown in Table 24.6 and the maturity ogive in Table 24.7. Both are assumed constant for the whole time series. Landing/discard/catch weight at age are shown in Tables 24.5a–c. Natural mortality was assumed to be equal to 0.2 y^{-1} for all ages and years. The spawning stock biomass was calculated in the middle of the year, i.e. the proportion of F and M before spawning were set equal to 0.5.

During the WKNSEA 2018 benchmark an alternative SAM assessment was considered that only used the period where age information was available (2009–2016) termed as "standard". The results of the "standard" assessment were consistent (but more optimistic) with the extended model during the period of the "standard" model.

The assessment estimates are shown in Figure 24.4 and summarized in Table 24.8 that shows the estimated recruitment, SSB, average F (ages 4—8) and total stock biomass. Estimated fishing mortality at age is shown in Table 24.9 and stock numbers at age in Table 24.10. The recruitment against the spawning-stock biomass is shown in Figure 24.5.

Standardized one-observation-ahead residuals are shown in Figure 24.6 (left) for all input time series. Standardized process residuals for the two processes stock numbers per age and fishing mortality at age are shown in Figure 24.6 (right).

The assessment model, input data, results and diagnostics can be found on stockassessment.org with stock name "wit.27.3a47d_2022_ clone". The time series that were used as input and the configuration are shown in Table 24.3.2.1.

Table 24.3.2.1. Input time series used in the assessment.

Series	Years	Notes
Catch at age	2009–2021	ages 1–10+
Survey index IBTS Q1, by age	2009–2021	ages 2–7+
Survey index IBTS+BTS Q3, by age	2009–2021	ages 2–6+
Total landings	1950–2008	
Survey index IBTS Q1, FSB	1983–2008	
Survey index IBTS + BTS Q3, FSB	1991–2008	

Model Configuration:

```
$minAge
# The minimium age class in the assessment
 1

$maxAge
# The maximum age class in the assessment
 10

$maxAgePlusGroup
# Is last age group considered a plus group (1 yes, or 0 no).
1 1 1 0 0 0

$keyLogFsta
# Coupling of the fishing mortality states (nomally only first row is used).
   0   1   2   3   4   5   5   5   5   5
  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1
  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1
  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1
  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1
  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1
```

```
$corFlag
# Correlation of fishing mortality across ages (0 independent, 1 compound symmetry, or 2 AR(1)
 2

$keyLogFpar
# Coupling of the survey catchability parameters (normally first row is not used, as that is covered
by fishing mortality).
  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1
  -1   0   1   2   3   4   4  -1  -1  -1
  -1   5   6   7   8   8  -1  -1  -1  -1
  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1
   9  -1  -1  -1  -1  -1  -1  -1  -1  -1
  10  -1  -1  -1  -1  -1  -1  -1  -1  -1
$keyQpow
# Density dependent catchability power parameters (if any).
  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1
  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1
  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1
  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1
  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1
  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1

$keyVarF
# Coupling of process variance parameters for log(F)-process (normally only first row is used)
   0   0   0   0   0   0   0   0   0   0
  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1
  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1
  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1
  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1
  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1

$keyVarLogN
# Coupling of process variance parameters for log(N)-process
 0 1 1 1 1 1 1 1 1 1

$keyVarObs
# Coupling of the variance parameters for the observations.
   0   0   0   0   0   0   0   0   0   0
  -1   1   1   1   1   1   1  -1  -1  -1
  -1   2   2   2   2   2  -1  -1  -1  -1
  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1
   3  -1  -1  -1  -1  -1  -1  -1  -1  -1
   4  -1  -1  -1  -1  -1  -1  -1  -1  -1

$obsCorStruct
# Covariance structure for each fleet ("ID" independent, "AR" AR(1), or "US" for unstructured). |
Possible values are: "ID" "AR" "US"
 "ID" "ID" "ID" "ID" "ID" "ID"

$keyCorObs
# Coupling of correlation parameters can only be specified if the AR(1) structure is chosen above.
# NA's indicate where correlation parameters can be specified (-1 where they cannot).
#1-2 2-3 3-4 4-5 5-6 6-7 7-8 8-9 9-10
```

```
  NA  NA  NA  NA  NA  NA  NA  NA  NA
  -1  NA  NA  NA  NA  NA  -1  -1  -1
  -1  NA  NA  NA  NA  -1  -1  -1  -1
  -1  -1  -1  -1  -1  -1  -1  -1  -1
  -1  -1  -1  -1  -1  -1  -1  -1  -1
  -1  -1  -1  -1  -1  -1  -1  -1  -1

$stockRecruitmentModelCode
# Stock recruitment code (0 for plain random walk, 1 for Ricker, and 2 for Beverton-Holt).
 0

$noScaledYears
# Number of years where catch scaling is applied.
 0

$keyScaledYears
# A vector of the years where catch scaling is applied.


$keyParScaledYA
# A matrix specifying the couplings of scale parameters (nrow = no scaled years, ncols = no ages).

$fbarRange
# lowest and highest age included in Fbar
4 8

$keyBiomassTreat
# To be defined only if a biomass survey is used (0 SSB index, 1 catch index, and 2 FSB index).
 -1 -1 -1 4 2 2

$obsLikelihoodFlag
# Option for observational likelihood | Possible values are: "LN" "ALN"
 "LN" "LN" "LN" "LN" "LN" "LN"

$fixVarToWeight
# If weight attribute is supplied for observations this option sets the treatment (0 relative weight,
1 fix variance to weight).
 0
```

24.4 Biological reference points

During WKNSEA 2018 EQSIM simulations were conducted using data from the accepted SAM assessment for the witch stock in the Greater North Sea. These followed the ICES advice technical guidelines as published 20 January 2017 (ICES, 2017) for the estimation of the reference points implemented in an R-script by D.C.M. Miller. The reference points were updated following the same procedure during the last interbenchmark process for witch (ICES, 2021). The procedure is described in the IBPWitch report and the reference points are shown in Table 24.12.

24.5 Short-term forecasts

Short-term forecasts were carried out based on the final SAM assessment. Recruitment in the intermediate year (2022) and the following two years was resampled from the recruitment estimates of the years 2009–2021; median was 34 809 thousand individuals (range: 21361–58489 thousand individuals). The fishing mortality in 2022 is assumed to be equal to the last estimate ($F_{2022} = F_{2021} = 0.29\ y^{-1}$) and the corresponding catch was 2506 tonnes. The spawning stock biomass in the intermediate year was 3544 tonnes.

The weight at age in the forecast is assumed to be the average over the years 2019–2021. Natural mortality and maturity ogives were constant and equal to the ones used in the assessment. No TAC constraint is assumed for the intermediate year.

In total, 12 forecast scenarios were run, and the summary of the results is shown in Table 24.11. The estimated SSB in 2022 is below the MSY $B_{trigger}$, therefore, the MSY approach scenario is using a reduced F in the management year 2023 compared to F_{MSY}, according to the advice rule:

$F_{2023} = F_{MSY} \times SSB_{2022}/MSY\ B_{trigger}=0.119y^{-1}$

The short-term forecast of the headline scenario is shown in Figure 24.8.

24.6 Quality of the assessment

There are no signs of problems in the assessment judging from the residuals (One-observation - ahead residuals and process residuals, Figure 24.6) and the retrospective analysis (Figure 24.7). The Mohn's rho values for the recruits, the spawning stock biomass and the fishing pressure are shown in Table 24.6.1.

Table 24.6.1. Mean bias (Mohn's rho) for the recruits (R, age 1), spawning stock biomass (SSB) and fishing pressure ($F_{4\text{-}8}$).

Quantity	Mohn's rho
R(age 1)	-0.3434
SSB	0.0851
$F_{4\text{-}8}$	-0.0942

Age information is only available for the last 13 years of the assessment, i.e. 2009–2021, not allowing for an assessment based solely on age specific information. The estimates during the period prior to 2009 have higher uncertainty. The model is informed only by landings from 1950 to 1983, therefore, the results during that period should be considered with caution. Sensitivity tests during WKNSEA 2018 and repeated during IBPWitch in 2021 showed that there is virtually no effect from the initialisation period (1940–1949) on the estimates during recent years, which are relevant for the management of the stock. As the catch-at-age time series grows over the years, a pure age-based assessment could be considered as the final assessment.

24.7 Status of the stock

Witch is being overfished; the fishing mortality in 2021 was equal to 0.29 y^{-1}, above F_{MSY} (0.147 y^{-1}). The biomass of the stock (3128 tonnes) was below the MSY $B_{trigger}$ (4381 tonnes) and the stock was at full reproductive capacity, i.e. the biomass is above B_{lim} (3077 tonnes). In recent years, the recruitment seems to have an upward trend and the catches have declined from a peak in 2016.

24.8 Management consideration

The advice is based on the assumption that the recruitment will be in the range of the estimated recruitment since 2009, the first year where age-specific information is available. For each simulation the value of the recruitment is sampled randomly from the median recruitment estimates of that period.

Witch and lemon sole are managed using a common TAC. Furthermore, the TAC area (Subarea 4 and Division 2.a) does not coincide with the stock area (Subarea 4 and divisions 3.a and 7.d). This increases the risk of both stocks of being overexploited. ICES advises that management should be implemented at the species level in the entire stock distribution area.

24.9 Issues for future benchmarks

Witch was benchmarked in 2018, implementing a new assessment and raising from category to 3 to category 1 (ICES, 2018a). The available age time series will grow every year and a pure age-based assessment could be basis for advice in the near future.

The choice of proportion of fishing mortality and natural mortality before spawning (F_{prop} and M_{prop}) to be equal to 0.5 should be evaluated for its biological reasoning.

The calculation of reference points is based on the time series since 1950, which excludes the initialisation period before the data start (1940–1949). The adequacy of the assessment to estimate SSB and recruitment during that period should be evaluated.

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Table 24.1. Witch flounder in Subarea 4 and Division 3.a. Landings, discards and catches are in tonnes. The IBTS indices indicate fishable stock biomass in kg/hour, time series from 2009 onwards is not included in the assessment and it is not updated after the last benchmark in 2018.

Year	Official landings	ICES Landings	ICES catches	ICES discards	IBTS–Q1 index	IBTS–Q3 index	Discard rate
1968	1174						
1969	891						
1970	597						
1971	843						
1972	908						
1973	1494						
1974	1138						
1975	1841						
1976	1496						
1977	1618						
1978	1664						
1979	1572						
1980	1883						
1981	1933						
1982	3155						
1983	3606				0.26		
1984	3903				0.16		
1985	3979				0.18		
1986	3579				0.26		
1987	3700				0.22		
1988	3290				0.13		
1989	3841				0.29		
1990	3862				0.15		
1991	3641				0.14	0.25	
1992	3164				0.21	0.17	
1993	2673				0.35	0.15	
1994	2696				0.11	0.15	
1995	2810				0.33	0.17	
1996	2790				0.22	0.15	
1997	3494				0.23	0.22	
1998	3786				0.32	0.14	
1999	4024				0.27	0.12	
2000	4422				0.23	0.07	
2001	4206				0.18	0.13	
2002	3640	3813	5341	1529	0.21	0.08	0.343
2003	3281	3308	3657	349	0.16	0.11	0.095
2004	3029	3059	3428	369	0.12	0.09	0.108
2005	2813	2960	3379	419	0.13	0.09	0.124

Year	Official landings	ICES Landings	ICES catches	ICES discards	IBTS–Q1 index	IBTS–Q3 index	Discard rate
2006	2303	2335	2631	296	0.07	0.1	0.112
2007	2236	2271	2470	199	0.1	0.12	0.081
2008	1953	1999	2317	318	0.13	0.1	0,137
2009	1818	1863	2319	455	0.051	0.09	0.196
2010	1490	1531	2090	559	0.077	0.11	0.268
2011	1530	1567	2114	547	0.094	0.14	0.259
2012	1895	1952	2507	555	0.137	0.21	0.222
2013	1993	2013	2267	254	0.151	0.14	0.112
2014	2646	2685	2992	307	0.2	0.13	0.103
2015	2359	2240	2690	449	0.156	0.19	0.167
2016	2658	2744	3135	390	0.144	0.18	0.125
2017	2855	2850	3086	236	0.168	0.13	0.076
2018	3001	3010*	3209	199	0.087	0.15	0.062
2019	2568	2580*	2797	217	-	-	0.078
2020	1931	1937	2135	198	-	-	0.093
2021	1824	1827	2105	279	-	-	0.133

*** including BMS Landings**

Table 24.2. Witch flounder in Subarea 4 and Division 3.a: Official landings by Subarea 4 and Division 3.a. Landings in 2020 and 2021 are preliminary.

Year	3.a	4	Total
1950	902	1477	2379
1951	923	1645	2568
1952	713	1841	2554
1953	767	1496	2263
1954	463	1127	1590
1955	450	1577	2027
1956	502	1434	1936
1957	643	1348	1991
1958	559	2119	2678
1959	752	1581	2333
1960	640	1923	2563
1961	594	1499	2093
1962	148	1271	1419
1963	209	1314	1523
1964	288	1472	1760
1965	260	1096	1356
1966	175	962	1137
1967	152	973	1125
1968	185	989	1174

Year	3.a	4	Total
1969	156	735	891
1970	118	479	597
1971	162	681	843
1972	235	673	908
1973	277	1217	1494
1974	304	834	1138
1975	972	869	1841
1976	778	718	1496
1977	738	880	1618
1978	719	945	1664
1979	678	894	1572
1980	874	1009	1883
1981	1044	889	1933
1982	1453	1702	3155
1983	1598	2008	3606
1984	1796	2107	3903
1985	1921	2058	3979
1986	1426	2153	3579
1987	1252	2448	3700
1988	1210	2080	3290
1989	1520	2321	3841
1990	1498	2364	3862
1991	1301	2340	3641
1992	1237	1927	3164
1993	950	1723	2673
1994	771	1925	2696
1995	939	1871	2810
1996	902	1888	2790
1997	1502	1992	3494
1998	1986	1800	3786
1999	2239	1785	4024
2000	2477	1945	4422
2001	1939	2267	4206
2002	2006	1634	3640
2003	1646	1635	3281
2004	1788	1241	3029
2005	1605	1208	2813
2006	1043	1260	2303
2007	949	1287	2236
2008	783	1170	1953

Year	3.a	4	Total
2009	773	1045	1818
2010	675	815	1490
2011	693	837	1530
2012	1107	788	1895
2013	1000	993	1993
2014	1562	1085	2647
2015	1282	956	2238
2016	1317	1421	2738
2017	1190	1665	2855
2018	977	2024	3001
2019	698	1869	2567
2020	624	1308	1931
2021	548	1276	1824

Table 24.3a. Witch flounder in Subarea 4 and Division 3.a and 7.d: Number of age measurements and samples by country per year (total for all fleets combined) for the landings.

Year	Number of age measurements			Number of age samples		
	Denmark	Sweden	UK (Scotland)	Denmark	Sweden	UK (Scotland)
2009	397	1224	160	2	5	6
2010	361	511	42	7	5	3
2011	576	661	0	4	4	0
2012	414	983	0	3	7	0
2013	605	491	277	5	4	21
2014	389	821	328	10	11	25
2015	567	454	150	17	7	10
2016	416	622	78	11	8	6
2017	725	320	360	19	7	23
2018	764	747	587	21	12	40
2019	18573	2307	688	88	45	48
2020	18893	1563	3466	84	23	37
2021	31062	1692	8378	145	22	51

Table 24.3b. Witch flounder in Subarea 4 and Division 3.a and 7.d: Number of age measurements and samples by country per year (total for all fleets combined) for the discards.

Year	Number of age measurements		Number of age samples	
	Denmark	Sweden	Denmark	Sweden
2009	93	766	11	44
2010	265	777	17	37
2011	320	665	13	27
2012	187	950	19	30
2013	225	443	30	22
2014	272	451	24	22
2015	269	405	21	27
2016	323	542	36	35
2017	207	182	24	22
2018	268	284	45	20
2019	573	896	110	57
2020	2401	20	56	4
2021	2871	256	51	14

Table 24.4. Witch flounder in Subarea 4 and Division 3.a and 7.d: Catch in numbers at age.

Year/ Age	1	2	3	4	5	6	7	8	9	10+
2009	1880573	2342251	1306459	2533154	1750724	1130623	1428139	1136690	440997	249704
2010	2243128	9205743	3114282	621403	1775664	904293	710391	884118	300687	250464
2011	439853	4200087	4860390	2810639	532899	1247980	378356	417048	187914	133150
2012	434615	1866105	4732981	4966594	1795657	373283	865604	226613	112876	134888
2013	659598	1306878	787294	2404872	3344504	926551	452899	496486	156215	299857
2014	473986	874655	1031433	2044359	3602513	2556211	717811	565648	530939	1038283
2015	438688	1583896	1278428	1895083	1999973	2410283	1360073	407315	178735	402182
2016	131888	592166	1138587	2126914	2315582	2411597	2200081	936330	303633	197312
2017	485269	300963	757597	1949013	3174531	1636402	2034440	1476957	687934	740442
2018	133318	597821	350856	1014348	2886430	1883862	2056046	1353651	488024	652598
2019	690854	605544	1599850	701940	1491371	2286068	1601786	1314229	557135	427225
2020	263420	1630164	702115	1163668	912773	1294094	1594476	945132	366735	562454
2021	853578	1017556	2172115	1121906	1229001	1306442	1245477	773439	378791	294774

Table 24.5a. Witch flounder in Subarea 4 and Division 3.a and 7.d: Landings weights at age (kg). In 2018, the landings include the Norwegian BMS.

Year/Age	1	2	3	4	5	6	7	8	9	10+
2009	0.113	0.122	0.149	0.160	0.20	0.26	0.29	0.34	0.35	0.47
2010	0.000	0.000	0.149	0.163	0.23	0.32	0.35	0.30	0.34	0.45
2011	0.000	0.091	0.161	0.189	0.23	0.30	0.39	0.40	0.47	0.52
2012	0.000	0.000	0.167	0.197	0.25	0.29	0.34	0.41	0.47	0.46
2013	0.000	0.000	0.142	0.197	0.24	0.29	0.32	0.40	0.45	0.44
2014	0.000	0.000	0.140	0.194	0.23	0.30	0.31	0.35	0.33	0.35
2015	0.000	0.000	0.161	0.22	0.27	0.33	0.39	0.41	0.47	0.47
2016	0.000	0.000	0.138	0.24	0.26	0.33	0.39	0.42	0.41	0.54
2017	0.000	0.026	0.188	0.199	0.25	0.33	0.36	0.39	0.37	0.42
2018	0.000	0.128	0.146	0.185	0.25	0.31	0.35	0.41	0.40	0.47
2019	0.000	0.000	0.151	0.22	0.25	0.30	0.38	0.40	0.39	0.44
2020	0.000	0.061	0.138	0.182	0.252	0.28	0.33	0.38	0.41	0.41
2021	0	0	0.146	0.191	0.23	0.27	0.32	0.36	0.41	0.44

Table 24.5b. Witch flounder in Subarea 4 and Division 3.a and 7.d: Discards weights at age (kg).

Year/Age	1	2	3	4	5	6	7	8	9	10+
2009	0.0122	0.035	0.094	0.118	0.129	0.185	0.22	0.31	0.28	0.46
2010	0.0141	0.032	0.064	0.095	0.123	0.113	0.000	0.000	0.000	0.000
2011	0.0129	0.048	0.075	0.105	0.106	0.139	0.000	0.146	0.000	0.000
2012	0.0118	0.036	0.094	0.102	0.122	0.140	0.155	0.116	0.000	0.000
2013	0.031	0.077	0.096	0.114	0.146	0.154	0.143	0.180	0.000	0.000
2014	0.0109	0.032	0.090	0.127	0.148	0.162	0.42	0.20	0.000	0.000
2015	0.0098	0.028	0.081	0.130	0.23	0.25	0.30	0.36	0.000	0.000
2016	0.0120	0.033	0.072	0.113	0.143	0.189	0.158	0.152	0.163	0.135
2017	0.0104	0.024	0.078	0.125	0.028	0.153	0.188	0.36	0.000	0.000
2018	0.0158	0.038	0.085	0.129	0.150	0.185	0.253	0.221	0.178	0.000
2019	0.0115	0.046	0.082	0.107	0.123	0.143	0.157	0.098	0.110	0.125
2020	0.0190	0.043	0.085	0.119	0.158	0.170	0.142	0.140	0.200	0.120
2021	0.01339	0.05975	0.09223	0.10771	0.13938	0.21003	0	0.17395	0	0.4436

Table 24.5c. Witch flounder in Subarea 4 and Division 3.a and 7.d: Catch weights at age (kg).

Year/Age	1	2	3	4	5	6	7	8	9	10+
2009	0.0122	0.035	0.099	0.136	0.197	0.26	0.29	0.34	0.34	0.47
2010	0.0141	0.032	0.071	0.125	0.218	0.32	0.35	0.30	0.34	0.45
2011	0.0129	0.048	0.100	0.171	0.21	0.29	0.39	0.40	0.47	0.52
2012	0.0118	0.036	0.109	0.178	0.24	0.28	0.34	0.40	0.47	0.46
2013	0.031	0.077	0.099	0.188	0.23	0.28	0.32	0.40	0.45	0.44
2014	0.0109	0.032	0.093	0.170	0.21	0.30	0.31	0.35	0.33	0.35
2015	0.0098	0.028	0.084	0.155	0.26	0.33	0.39	0.41	0.47	0.47
2016	0.0120	0.033	0.076	0.158	0.23	0.31	0.39	0.42	0.40	0.53
2017	0.0104	0.024	0.114	0.165	0.090	0.33	0.36	0.39	0.37	0.42
2018	0.0160	0.038	0.093	0.145	0.23	0.29	0.35	0.41	0.39	0.47
2019	0.0115	0.046	0.086	0.182	0.24	0.29	0.37	0.39	0.39	0.43
2020	0.01864	0.04326	0.09023	0.15813	0.24208	0.27124	0.32434	0.37344	0.40981	0.40389
2021	0.0134	0.060	0.103	0.167	0.23	0.27	0.32	0.36	0.41	0.44

Table 24.6. Witch flounder in Subarea 4 and Division 3.a and 7.d: Stock weights at age (kg); constant for all years (2009–2021).

1	2	3	4	5	6	7	8	9	10+
0.00547	0.03279	0.07720	0.15139	0.23394	0.33624	0.37684	0.42882	0.44348	0.49543

Table 24.7. Witch flounder in Subarea 4 and Division 3.a and 7.d: Constant maturity ogive.

1	2	3	4	5	6	7	8	9	10*	11*	12*
0	0	0.114	0.136	0.275	0.376	0.428	0.524	0.631	0.671	0.882	1

*** The assessment uses age 10 as a plus group, therefore maturation of age 10 is the average of ages 10–12, equal to 0.851.**

Table 24.8. Witch flounder in Subarea 4 and Division 3.a and 7.d: Summary of the assessment. Recruitment (R, number of individuals in thousands), spawning stock biomass (SSB, tonnes), and fishing mortality (Fbar, mean of ages 4–8, y^{-1}). Low and high refer to lower and upper 95% confidence bounds. The recruitment and SSB in the last year result from the short-term forecast assuming F = F_{sq}.

Year	R (age 1)			SSB (tonnes)			Fishing pressure			TSB (tonnes)		
	R	Low	High	SSB	Low	High	F(4–8)	Low	High	TSB	Low	High
1950	28595	17440	46886	3857	1794	8291	0.271	0.142	0.518	14689	9484	22750
1951	29433	18240	47494	3751	1730	8131	0.284	0.147	0.546	14169	9083	22104
1952	32027	20142	50925	3578	1610	7949	0.289	0.147	0.569	13494	8482	21469
1953	34935	22261	54825	3408	1483	7832	0.277	0.136	0.563	12916	7949	20986
1954	35867	22689	56698	3336	1420	7836	0.248	0.118	0.52	12729	7777	20834
1955	34152	21070	55356	3345	1418	7887	0.255	0.123	0.53	13060	8100	21059
1956	29813	17958	49494	3392	1459	7889	0.255	0.124	0.523	13402	8498	21135
1957	25522	15159	42968	3464	1532	7832	0.262	0.131	0.525	13643	8845	21044
1958	22685	13695	37576	3462	1569	7635	0.291	0.151	0.563	13529	8890	20589
1959	20977	12847	34252	3346	1530	7317	0.299	0.155	0.577	12788	8388	19495
1960	19336	11627	32157	3131	1411	6948	0.315	0.163	0.611	11762	7625	18142
1961	17494	10345	29583	2874	1256	6575	0.304	0.153	0.604	10547	6717	16559
1962	15715	9339	26444	2669	1139	6257	0.275	0.135	0.559	9520	5991	15129
1963	14228	8414	24061	2490	1048	5916	0.284	0.14	0.575	8792	5535	13966
1964	12840	7380	22339	2266	939	5473	0.308	0.152	0.626	8038	5053	12787
1965	11946	6746	21153	2032	826	5000	0.303	0.146	0.627	7187	4464	11571
1966	12203	7038	21157	1829	730	4585	0.297	0.141	0.626	6473	3951	10607
1967	13993	8390	23339	1644	639	4230	0.306	0.142	0.66	5913	3521	9930
1968	17806	11107	28546	1471	548	3951	0.317	0.142	0.71	5491	3165	9528
1969	22064	13899	35027	1351	482	3793	0.289	0.122	0.681	5304	2975	9457
1970	25380	15779	40824	1334	472	3772	0.247	0.102	0.601	5563	3141	9851
1971	26083	16157	42108	1404	514	3839	0.254	0.108	0.598	6285	3695	10690
1972	26158	15978	42826	1540	599	3960	0.261	0.116	0.588	7167	4392	11695
1973	25973	15843	42580	1710	709	4122	0.289	0.137	0.609	8069	5105	12755
1974	26608	16219	43653	1891	827	4327	0.278	0.134	0.577	8719	5608	13556
1975	28922	17736	47165	2044	920	4540	0.302	0.152	0.6	9290	6024	14327
1976	33556	20950	53748	2152	980	4726	0.292	0.147	0.579	9607	6225	14827
1977	41670	26713	65000	2256	1030	4941	0.289	0.147	0.57	10083	6539	15548
1978	51371	33581	78587	2376	1090	5179	0.283	0.145	0.554	10860	7115	16576
1979	59084	37779	92404	2568	1203	5480	0.27	0.139	0.521	12134	8168	18025
1980	61348	38115	98741	2865	1404	5848	0.269	0.144	0.5	13998	9837	19918
1981	59326	36711	95875	3283	1719	6270	0.269	0.152	0.475	16171	11896	21983
1982	56793	35326	91305	3746	2110	6648	0.301	0.184	0.492	18339	14009	24007
1983	55646	34905	88711	4129	2480	6874	0.323	0.207	0.502	19750	15439	25265
1984	57240	36426	89947	4372	2740	6976	0.336	0.221	0.51	20364	16082	25785
1985	58547	37786	90715	4480	2865	7005	0.337	0.225	0.506	20424	16161	25811
1986	58423	37435	91179	4534	2922	7034	0.327	0.219	0.487	20315	16082	25660
1987	54394	34164	86604	4585	2968	7084	0.322	0.216	0.478	20343	16175	25585

Year	R (age 1)			SSB (tonnes)			Fishing pressure			TSB (tonnes)		
	R	Low	High	SSB	Low	High	F(4–8)	Low	High	TSB	Low	High
1988	49181	30431	79483	4670	3049	7153	0.309	0.21	0.455	20364	16315	25418
1989	45171	28072	72684	4751	3148	7171	0.315	0.218	0.455	20370	16479	25180
1990	44433	28136	70168	4755	3205	7055	0.316	0.222	0.45	19921	16224	24460
1991	45867	29689	70863	4695	3213	6861	0.307	0.218	0.433	19186	15658	23509
1992	49506	32525	75351	4614	3190	6674	0.289	0.205	0.407	18471	15049	22671
1993	52613	34553	80112	4575	3177	6587	0.269	0.19	0.381	18137	14731	22330
1994	54808	35374	84921	4593	3196	6601	0.263	0.185	0.373	18313	14867	22558
1995	55037	35347	85697	4662	3251	6686	0.264	0.186	0.373	18841	15334	23150
1996	54351	35284	83722	4754	3327	6793	0.271	0.192	0.384	19491	15927	23853
1997	51837	33877	79320	4795	3359	6843	0.302	0.214	0.426	20063	16452	24466
1998	48415	31419	74605	4700	3271	6752	0.337	0.236	0.48	20070	16479	24442
1999	44566	28674	69266	4460	3057	6507	0.375	0.261	0.54	19472	16013	23679
2000	42423	27331	65849	4090	2759	6062	0.417	0.289	0.602	18330	15156	22169
2001	43719	29211	65432	3661	2461	5445	0.443	0.311	0.631	16834	14085	20120
2002	43514	29978	63161	3247	2217	4757	0.458	0.327	0.641	15391	13107	18074
2003	39139	27504	55697	2914	2062	4118	0.457	0.337	0.62	14233	12340	16416
2004	28955	20728	40447	2681	1998	3599	0.453	0.347	0.592	13370	11748	15215
2005	24561	17941	33625	2554	2010	3244	0.437	0.348	0.548	12566	11120	14200
2006	27857	21146	36696	2497	2054	3035	0.395	0.324	0.482	11722	10416	13192
2007	23363	17083	31951	2448	2074	2888	0.374	0.312	0.449	10973	9787	12303
2008	37075	29660	46343	2341	2017	2716	0.366	0.306	0.438	10246	9174	11444
2009	58569	47402	72368	2159	1867	2497	0.377	0.313	0.454	9981	8986	11086
2010	51564	41755	63676	2128	1837	2466	0.329	0.27	0.402	10481	9444	11632
2011	34809	27448	44145	2357	2038	2726	0.26	0.21	0.323	11865	10609	13270
2012	32684	25973	41128	2799	2432	3222	0.231	0.185	0.289	13668	12182	15336
2013	36134	28893	45189	3406	2960	3919	0.24	0.195	0.295	15303	13593	17228
2014	32489	25718	41043	3834	3311	4440	0.284	0.232	0.348	16270	14366	18427
2015	23474	18219	30244	3959	3382	4634	0.27	0.22	0.331	16021	14076	18234
2016	19841	14658	26857	3951	3334	4682	0.275	0.224	0.338	15484	13496	17766
2017	29242	21404	39951	3843	3178	4647	0.312	0.249	0.389	14730	12637	17170
2018	34483	23716	50137	3612	2883	4527	0.317	0.244	0.411	13664	11454	16302
2019	53782	35374	81771	3288	2489	4344	0.322	0.237	0.437	12966	10484	16036
2020	54869	33209	90656	3030	2152	4266	0.302	0.209	0.437	13188	10166	17110
2021	67729	35350	129765	3128	2109	4639	0.29	0.189	0.445	14761	10774	20223
2022	34809			3544								

Table 24.9. Witch flounder in Subarea 4 and Division 3.a and 7.d: Estimated fishing mortality at age. The assessment is using age information only for the years 2009–2021.

Year	1	2	3	4	5	6	7	8	9	10+
1950	0.023	0.086	0.107	0.154	0.224	0.326	0.326	0.326	0.326	0.326
1951	0.023	0.088	0.111	0.161	0.234	0.341	0.341	0.341	0.341	0.341
1952	0.024	0.090	0.113	0.164	0.239	0.348	0.348	0.348	0.348	0.348
1953	0.023	0.088	0.111	0.159	0.229	0.332	0.332	0.332	0.332	0.332
1954	0.023	0.084	0.104	0.147	0.206	0.296	0.296	0.296	0.296	0.296
1955	0.023	0.086	0.106	0.150	0.212	0.305	0.305	0.305	0.305	0.305
1956	0.023	0.086	0.107	0.151	0.212	0.304	0.304	0.304	0.304	0.304
1957	0.024	0.088	0.110	0.155	0.218	0.313	0.313	0.313	0.313	0.313
1958	0.025	0.094	0.119	0.170	0.241	0.348	0.348	0.348	0.348	0.348
1959	0.025	0.096	0.122	0.176	0.248	0.358	0.358	0.358	0.358	0.358
1960	0.026	0.099	0.127	0.184	0.261	0.377	0.377	0.377	0.377	0.377
1961	0.026	0.098	0.126	0.180	0.252	0.362	0.362	0.362	0.362	0.362
1962	0.025	0.095	0.119	0.168	0.230	0.326	0.326	0.326	0.326	0.326
1963	0.026	0.097	0.123	0.173	0.237	0.336	0.336	0.336	0.336	0.336
1964	0.027	0.102	0.130	0.185	0.257	0.367	0.367	0.367	0.367	0.367
1965	0.027	0.102	0.130	0.184	0.252	0.359	0.359	0.359	0.359	0.359
1966	0.027	0.102	0.129	0.182	0.248	0.351	0.351	0.351	0.351	0.351
1967	0.027	0.104	0.132	0.187	0.255	0.363	0.363	0.363	0.363	0.363
1968	0.027	0.105	0.135	0.191	0.263	0.377	0.377	0.377	0.377	0.377
1969	0.026	0.100	0.126	0.177	0.240	0.342	0.342	0.342	0.342	0.342
1970	0.025	0.092	0.114	0.155	0.207	0.291	0.291	0.291	0.291	0.291
1971	0.025	0.093	0.116	0.159	0.212	0.300	0.300	0.300	0.300	0.300
1972	0.025	0.094	0.118	0.163	0.218	0.309	0.309	0.309	0.309	0.309
1973	0.026	0.100	0.127	0.178	0.240	0.342	0.342	0.342	0.342	0.342
1974	0.026	0.098	0.125	0.173	0.231	0.329	0.329	0.329	0.329	0.329
1975	0.027	0.103	0.132	0.186	0.251	0.358	0.358	0.358	0.358	0.358
1976	0.027	0.101	0.130	0.181	0.242	0.345	0.345	0.345	0.345	0.345
1977	0.026	0.101	0.129	0.180	0.240	0.343	0.343	0.343	0.343	0.343
1978	0.026	0.099	0.126	0.176	0.234	0.335	0.335	0.335	0.335	0.335
1979	0.026	0.096	0.122	0.168	0.222	0.319	0.319	0.319	0.319	0.319
1980	0.025	0.095	0.121	0.167	0.221	0.319	0.319	0.319	0.319	0.319
1981	0.025	0.095	0.121	0.167	0.220	0.319	0.319	0.319	0.319	0.319
1982	0.027	0.101	0.131	0.185	0.247	0.358	0.358	0.358	0.358	0.358
1983	0.028	0.105	0.138	0.197	0.264	0.384	0.384	0.384	0.384	0.384
1984	0.028	0.107	0.142	0.203	0.273	0.401	0.401	0.401	0.401	0.401
1985	0.028	0.108	0.142	0.204	0.275	0.403	0.403	0.403	0.403	0.403
1986	0.028	0.106	0.140	0.199	0.266	0.389	0.389	0.389	0.389	0.389
1987	0.028	0.106	0.139	0.197	0.262	0.383	0.383	0.383	0.383	0.383
1988	0.027	0.104	0.135	0.190	0.252	0.367	0.367	0.367	0.367	0.367

Year	1	2	3	4	5	6	7	8	9	10+
1989	0.028	0.106	0.139	0.196	0.258	0.373	0.373	0.373	0.373	0.373
1990	0.028	0.107	0.140	0.198	0.260	0.374	0.374	0.374	0.374	0.374
1991	0.028	0.107	0.139	0.195	0.254	0.362	0.362	0.362	0.362	0.362
1992	0.027	0.104	0.135	0.187	0.241	0.339	0.339	0.339	0.339	0.339
1993	0.027	0.100	0.129	0.176	0.225	0.315	0.315	0.315	0.315	0.315
1994	0.026	0.098	0.126	0.171	0.219	0.308	0.308	0.308	0.308	0.308
1995	0.026	0.099	0.126	0.172	0.220	0.309	0.309	0.309	0.309	0.309
1996	0.027	0.099	0.127	0.175	0.225	0.319	0.319	0.319	0.319	0.319
1997	0.028	0.104	0.136	0.190	0.248	0.357	0.357	0.357	0.357	0.357
1998	0.029	0.109	0.144	0.205	0.274	0.402	0.402	0.402	0.402	0.402
1999	0.030	0.114	0.152	0.220	0.301	0.452	0.452	0.452	0.452	0.452
2000	0.031	0.119	0.160	0.237	0.331	0.507	0.507	0.507	0.507	0.507
2001	0.031	0.122	0.167	0.249	0.350	0.539	0.539	0.539	0.539	0.539
2002	0.032	0.124	0.169	0.254	0.361	0.558	0.558	0.558	0.558	0.558
2003	0.032	0.124	0.169	0.254	0.361	0.558	0.558	0.558	0.558	0.558
2004	0.032	0.123	0.166	0.249	0.357	0.554	0.554	0.554	0.554	0.554
2005	0.031	0.121	0.163	0.242	0.344	0.532	0.532	0.532	0.532	0.532
2006	0.031	0.117	0.155	0.225	0.314	0.479	0.479	0.479	0.479	0.479
2007	0.030	0.116	0.153	0.220	0.302	0.449	0.449	0.449	0.449	0.449
2008	0.030	0.115	0.151	0.219	0.300	0.437	0.437	0.437	0.437	0.437
2009	0.030	0.114	0.152	0.221	0.309	0.452	0.452	0.452	0.452	0.452
2010	0.029	0.109	0.142	0.201	0.273	0.390	0.390	0.390	0.390	0.390
2011	0.023	0.088	0.118	0.171	0.224	0.302	0.302	0.302	0.302	0.302
2012	0.020	0.072	0.099	0.152	0.204	0.267	0.267	0.267	0.267	0.267
2013	0.017	0.058	0.081	0.136	0.204	0.286	0.286	0.286	0.286	0.286
2014	0.015	0.052	0.076	0.137	0.226	0.352	0.352	0.352	0.352	0.352
2015	0.014	0.046	0.069	0.126	0.212	0.337	0.337	0.337	0.337	0.337
2016	0.012	0.039	0.061	0.118	0.210	0.350	0.350	0.350	0.350	0.350
2017	0.011	0.036	0.059	0.118	0.226	0.405	0.405	0.405	0.405	0.405
2018	0.010	0.031	0.053	0.108	0.218	0.419	0.419	0.419	0.419	0.419
2019	0.010	0.032	0.055	0.106	0.214	0.430	0.430	0.430	0.430	0.430
2020	0.009	0.030	0.051	0.097	0.196	0.406	0.406	0.406	0.406	0.406
2021	0.010	0.031	0.051	0.094	0.187	0.389	0.389	0.389	0.389	0.389

Table 24.10. Witch flounder in Subarea 4 and Division 3.a and 7.d: Estimated stock numbers (in thousand individuals) at age. The assessment is using age information only for the years 2009–2021.

Year	1	2	3	4	5	6	7	8	9	10+
1950	28595	23637	19353	15454	11381	7600	4539	2689	1589	2296
1951	29433	22863	17750	14239	10852	7454	4494	2683	1590	2297
1952	32027	23522	17122	12996	9925	7034	4340	2616	1562	2263
1953	34935	25605	17593	12506	9019	6397	4064	2508	1512	2210
1954	35867	27961	19193	12884	8722	5864	3752	2385	1472	2184
1955	34152	28736	21063	14166	9112	5811	3573	2286	1453	2228
1956	29813	27357	21617	15516	9978	6035	3508	2157	1380	2222
1957	25522	23856	20572	15919	10935	6614	3648	2120	1304	2177
1958	22685	20398	17886	15107	11174	7213	3966	2186	1271	2086
1959	20977	18110	15198	13005	10437	7192	4171	2293	1264	1941
1960	19336	16748	13461	11005	8933	6673	4119	2388	1313	1835
1961	17494	15431	12416	9697	7487	5632	3746	2312	1341	1767
1962	15715	13960	11452	8966	6627	4759	3207	2133	1317	1770
1963	14228	12546	10395	8324	6213	4313	2814	1896	1261	1825
1964	12840	11355	9318	7526	5736	4017	2524	1647	1109	1807
1965	11946	10233	8396	6695	5116	3632	2279	1432	934	1654
1966	12203	9512	7563	6037	4560	3254	2076	1302	818	1479
1967	13993	9714	7026	5439	4122	2915	1875	1196	750	1324
1968	17806	11137	7160	5033	3693	2616	1660	1068	681	1181
1969	22064	14193	8200	5114	3396	2321	1467	931	599	1045
1970	25380	17616	10523	5908	3502	2183	1348	852	541	954
1971	26083	20304	13169	7695	4142	2333	1336	825	522	915
1972	26158	20837	15169	9610	5378	2743	1415	810	500	872
1973	25973	20886	15527	11051	6694	3548	1651	851	487	825
1974	26608	20705	15477	11192	7570	4308	2062	960	495	763
1975	28922	21209	15357	11190	7713	4926	2540	1215	565	741
1976	33556	23031	15655	11007	7599	4912	2818	1453	695	748
1977	41670	26728	17026	11250	7515	4884	2847	1633	842	836
1978	51371	33227	19772	12243	7688	4840	2838	1655	949	976
1979	59084	41010	24646	14252	8398	4978	2832	1661	969	1127
1980	61348	47216	30537	17871	9858	5503	2961	1685	988	1247
1981	59326	49010	35193	22173	12383	6468	3275	1763	1003	1330
1982	56793	47357	36519	25578	15395	8145	3855	1951	1050	1390
1983	55646	45257	35043	26244	17425	9859	4665	2207	1117	1397
1984	57240	44291	33337	24989	17653	10957	5498	2601	1231	1402
1985	58547	45574	32552	23686	16704	10996	6009	3015	1427	1444
1986	58423	46622	33504	23105	15811	10391	6019	3289	1650	1571
1987	54394	46561	34327	23852	15491	9914	5765	3340	1825	1788
1988	49181	43332	34328	24473	16039	9749	5530	3216	1864	2016

Year	1	2	3	4	5	6	7	8	9	10+
1989	45171	39169	31992	24583	16586	10220	5534	3138	1825	2201
1990	44433	35932	28830	22802	16560	10494	5763	3120	1769	2270
1991	45867	35347	26405	20507	15323	10463	5916	3248	1758	2277
1992	49506	36493	25993	18783	13799	9723	5966	3374	1852	2301
1993	52613	39441	26913	18584	12743	8874	5668	3479	1967	2422
1994	54808	41948	29213	19359	12748	8325	5300	3386	2079	2622
1995	55037	43725	31140	21106	13355	8389	5011	3190	2038	2829
1996	54351	43892	32449	22481	14552	8776	5042	3012	1917	2925
1997	51837	43347	32542	23404	15468	9526	5227	3002	1793	2884
1998	48415	41292	31981	23258	15846	9880	5459	2995	1720	2680
1999	44566	38526	30320	22685	15513	9865	5412	2991	1641	2411
2000	42423	35406	28155	21336	14911	9401	5141	2820	1558	2111
2001	43719	33649	25731	19646	13797	8780	4641	2537	1392	1811
2002	43514	34703	24348	17825	12546	7958	4194	2216	1212	1530
2003	39139	34560	25114	16812	11314	7161	3732	1966	1039	1285
2004	28955	31124	25038	17375	10667	6450	3356	1749	922	1090
2005	24561	22929	22603	17382	11093	6107	3034	1579	823	947
2006	27857	19413	16595	15756	11180	6436	2931	1457	759	850
2007	23363	22209	14084	11616	10334	6702	3269	1485	739	816
2008	37075	18402	16262	9860	7615	6272	3509	1710	775	811
2009	58569	29455	13317	11487	6458	4608	3327	1859	906	837
2010	51564	46833	21523	9264	7586	3863	2402	1736	966	905
2011	34809	41011	34500	15287	6156	4760	2135	1332	959	1031
2012	32684	27829	30766	25096	10496	4003	2903	1293	805	1202
2013	36134	26237	21245	22751	17574	6942	2504	1829	812	1265
2014	32489	29128	20303	16174	16247	11674	4240	1538	1129	1286
2015	23474	26260	22704	15495	11650	10594	6693	2432	883	1389
2016	19841	18858	20553	17398	11236	7786	6190	3901	1420	1323
2017	29242	15992	14803	15864	12675	7489	4528	3565	2247	1586
2018	34483	23659	12601	11399	11564	8279	4117	2486	1940	2089
2019	53782	28027	18743	9796	8371	7624	4469	2224	1340	2158
2020	54869	43727	22245	14458	7218	5530	4069	2383	1183	1858
2021	67729	44579	34787	17300	10693	4862	3024	2223	1300	1653

Table 24.11. Witch flounder in Subarea 4 and Division 3.a and 7.d: Short-term forecasting scenarios and results.

Basis	Total catch (2022) ^^	Projected landings (2022)	Projected discards * (2022)	F_{total} ages 4–8 (2022 & 2023)	SSB ^ (2023)	SSB ^ (2024)	% SSB change **	% advice change ***
ICES advice basis								
MSY approach: F_{MSY} × SSB(2022)/MSY $B_{trigger}$	1313	1215	98	0.119	4543	5948	28	8.9
Other scenarios ^^								
$F_{MSY\ lower}$ × SSB(2022)/MSY $B_{trigger}$	954	882	72	0.085	4620	6218	30	-21
F = 0	0	0	0	0.00	4814	6942	36	-100
F_{pa}	2871	2644	227	0.28	4206	4848	18.7	138
F_{lim}	3228	2968	260	0.32	4132	4612	16.6	168
F_{sq}	2961	2726	235	0.29	4187	4788	18.1	146
SSB (2024) = B_{lim}	5916	5379	537	0.68	3505	3077	-1.10	390
SSB (2024) = B_{pa}	3595	3307	288	0.36	4051	4381	14.3	198
SSB (2024) = MSY $B_{trigger}$	3595	3307	288	0.36	4051	4381	14.3	198
Rollover advice	1206	1115	91	0.109	4567	6124	29	0
F_{MSY}	1601	1483	118	0.147	4482	5732	26	33
$F_{MSY\ lower}$	1168	1080	88	0.105	4575	6054	29	-3.2

*** Including BMS landings, assuming recent discard rate (average of 2018–2021).**
**** SSB in 2023 relative to SSB in 2022 (3 544 tonnes).**
***** Advice value for 2023 relative to advice value for 2022 (1206 tonnes).**
^ SSB is estimated at spawning time (1 July).
^^ Other scenarios do not include $F_{MSY\ upper}$ because SSB(2022) < MSY $B_{trigger}$

Table 24.12 Witch flounder in Subarea 4 and Divisions 3.a and 7.d: Reference points estimated using EQSIM during the IBPWitch2021.

Reference Point	Estimate
MSY $B_{trigger}$	4381 tonnes
B_{lim}	3077 tonnes
B_{pa}	4381 tonnes
F_{MSY}	0.147 y^{-1}
$F_{MSY\ upper}$	0.20 y^{-1}
$F_{MSY\ lower}$	0.105 y^{-1}
F_{lim}	0.32 y^{-1}
F_{pa}*	0.28 y^{-1}
$F_{P0.5}$ (with AR)	0.28 y^{-1}
$F_{P0.5}$ (without AR)	0.22 y^{-1}

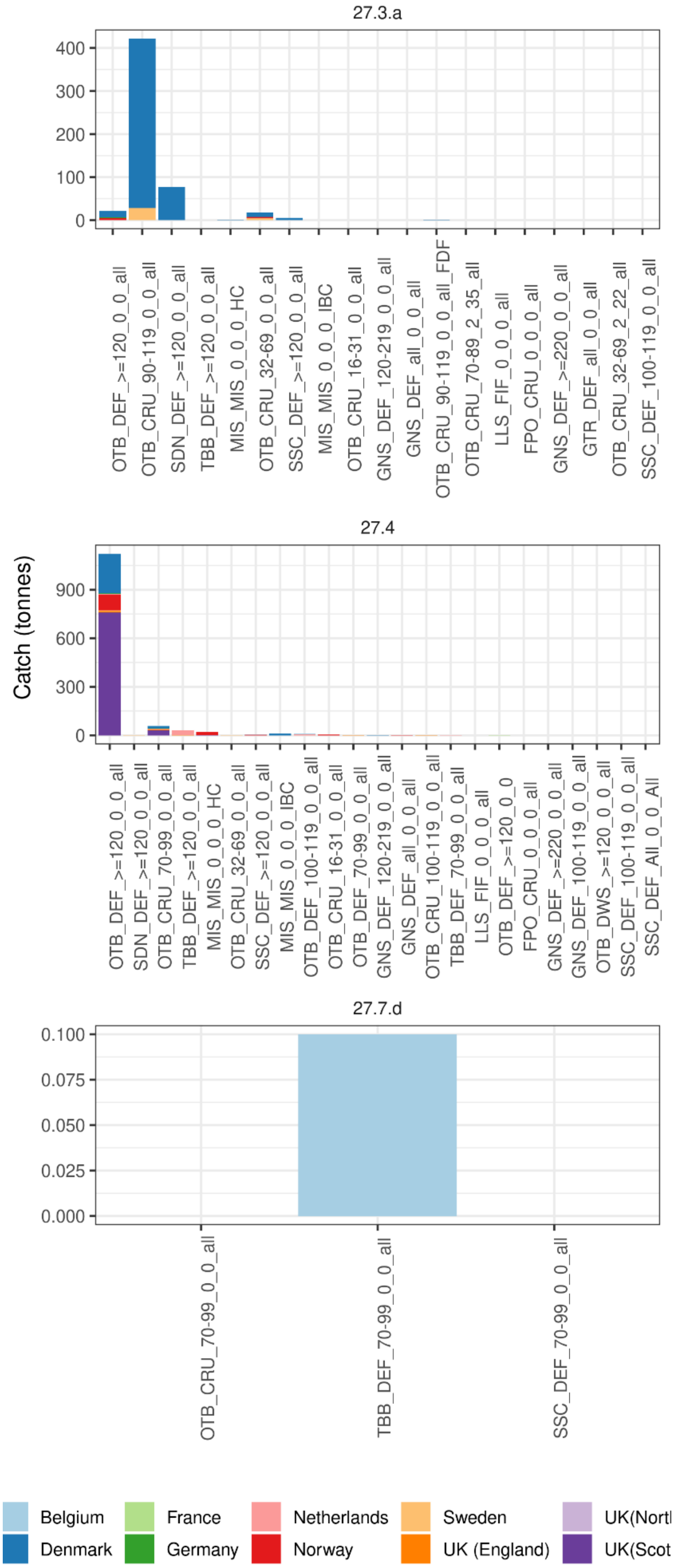

Figure 24.1. Witch flounder Division 3.a (upper plot), in Subarea 4 (middle plot) and Division 7.d (lower plot): Landings in tonnes by métier and country in 2021.

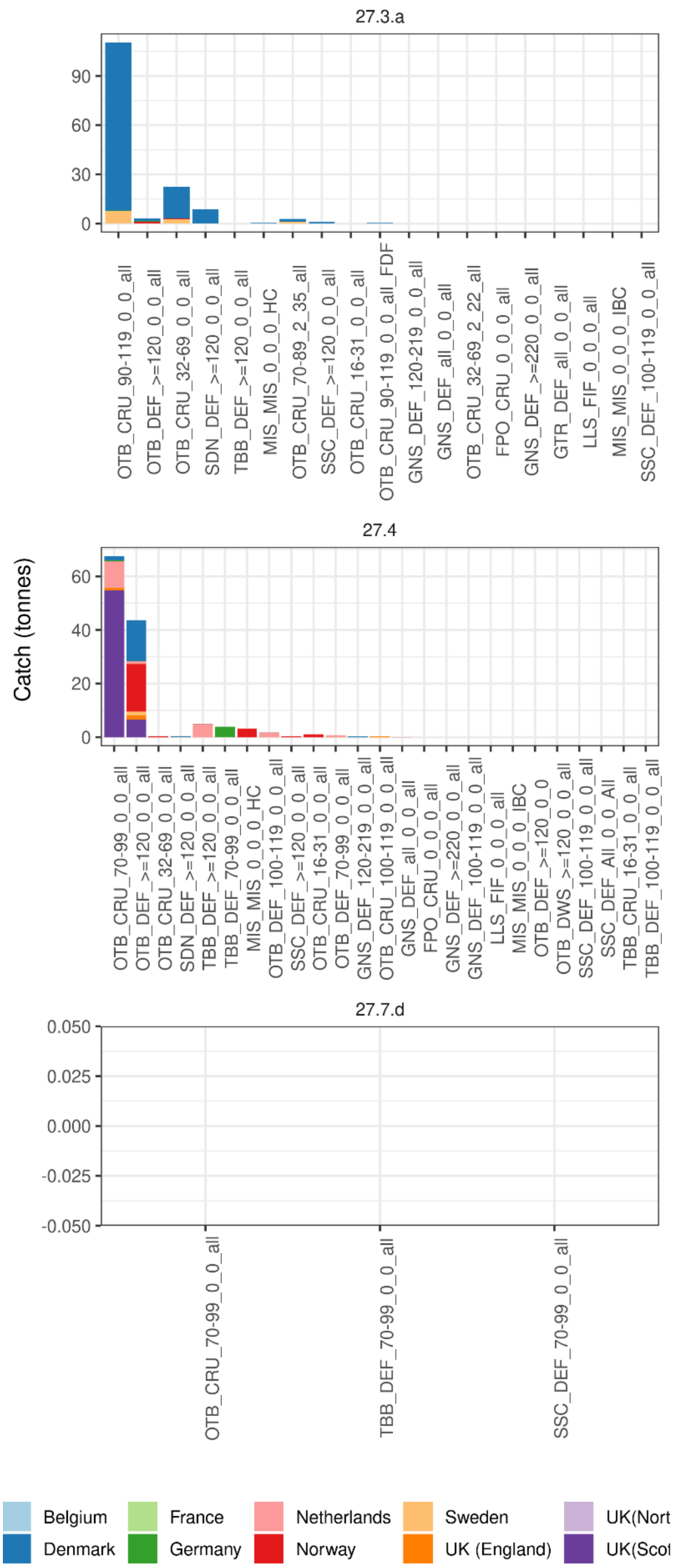

Figure 24.2. Witch flounder in Division 3.a (upper plot), Subarea 4 (middle plot) and Division 7.d (lower plot): Discards by métier and country in 2021.

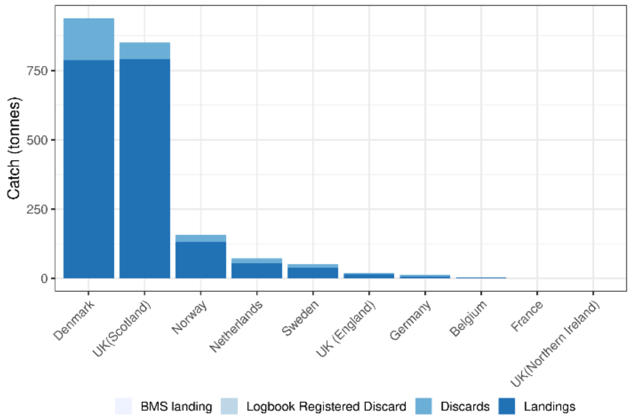

Figure 24.3. Witch flounder in Subarea 4 and Division 3.a: Estimated catch categories by countries in 2021.

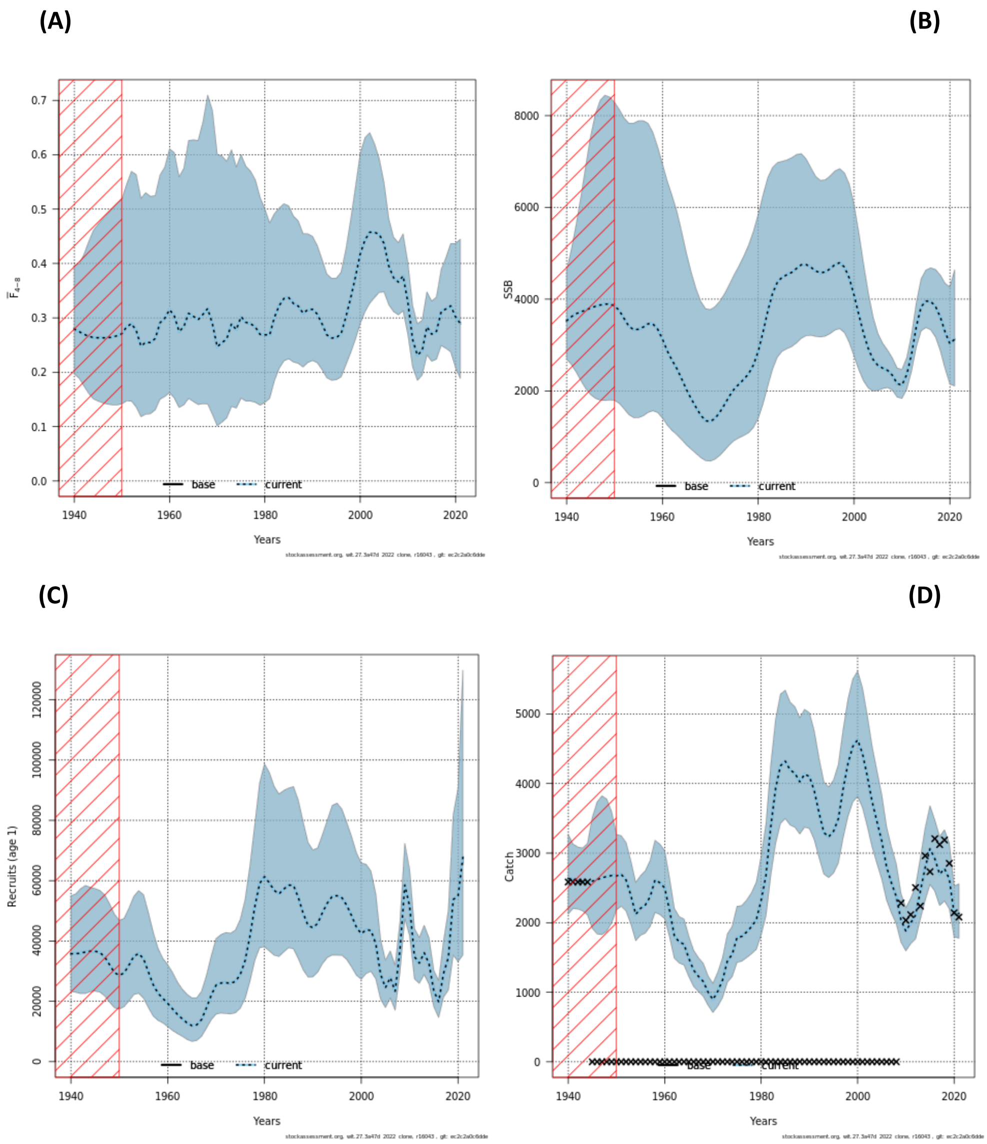

Figure 24.4. Witch flounder in Subarea 4 and Divisions 3.a and 7.d: Results of the SAM model, fishing mortality (A), SSB (B), Recruits (C) and Catch (D). Median estimates (dashed lines) and point wise 95% confidence intervals (shaded area). The red line shaded area shaded is the period prior to the observations, used for initialization.

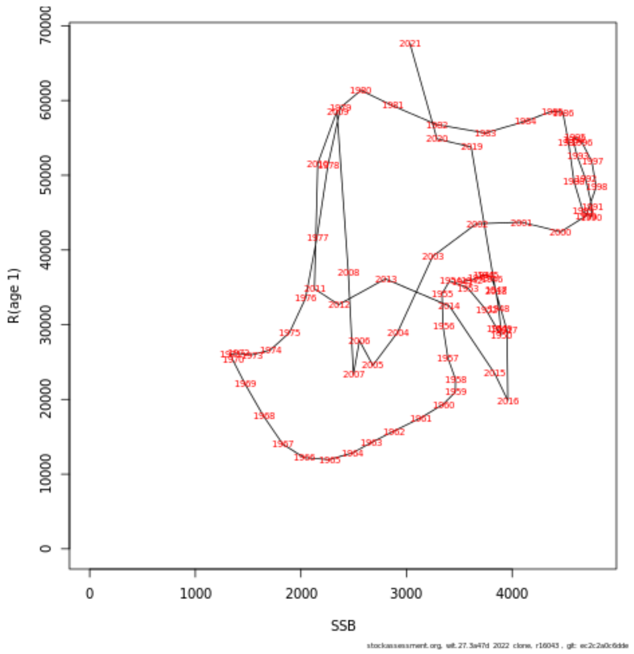

Figure 24.5. Witch flounder in Subarea 4 and Divisions 3.a and 7.d: Results of the SAM model. Recruits over spawning stock biomass (SSB).

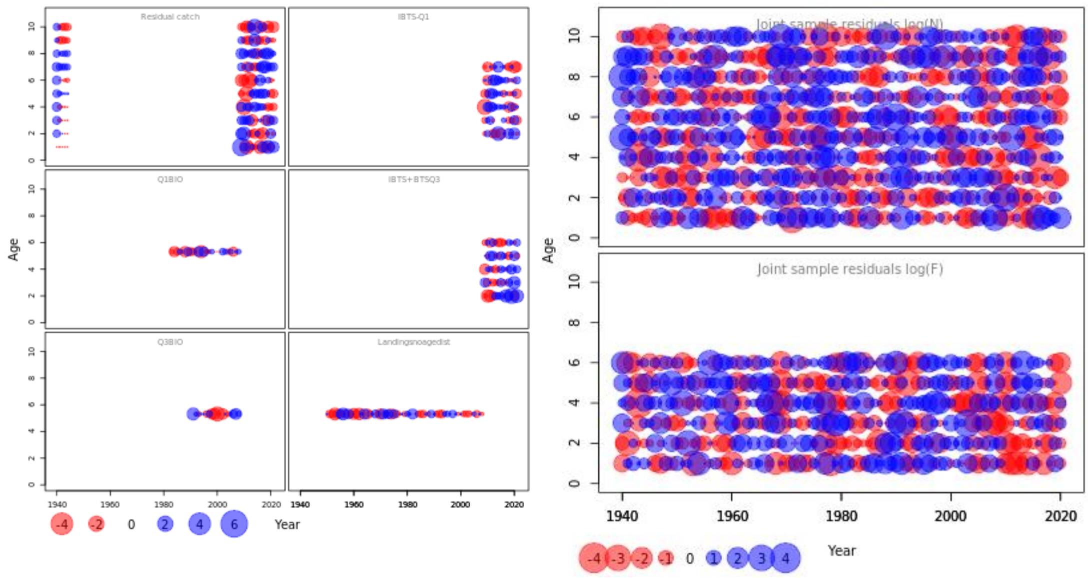

Figure 24.6. Witch flounder in Subarea 4 and Divisions 3.a and 7.d: Results of the SAM model. Residual plots, standardized one-observation-ahead residuals (left) and standardized single-joint-sample residuals of process increments (right).

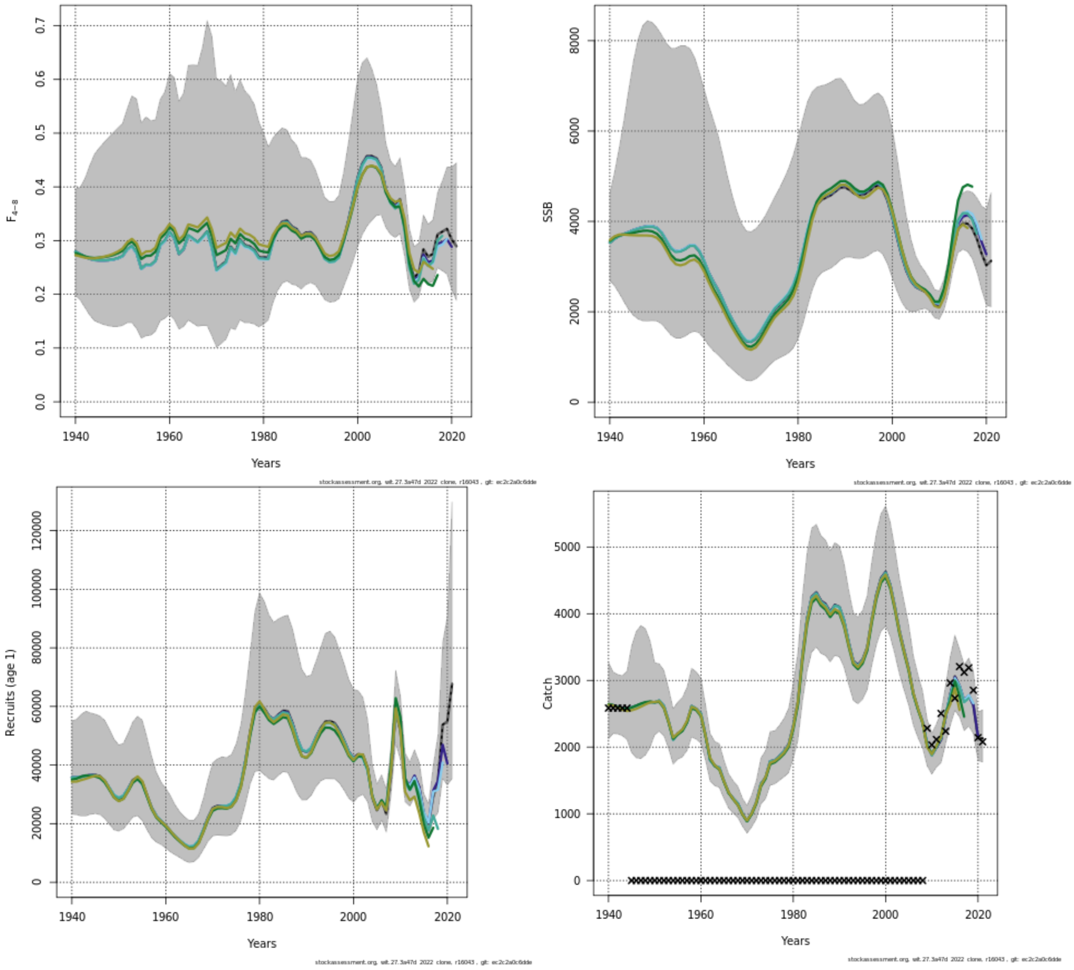

Figure 24.7. Witch flounder in Subarea 4 and Divisions 3.a and 7.d: Results of the SAM model. Retrospective analysis, for fishing mortality (top left), spawning stock biomass (SSB, top right), recruits (bottom left) and catch (bottom right).

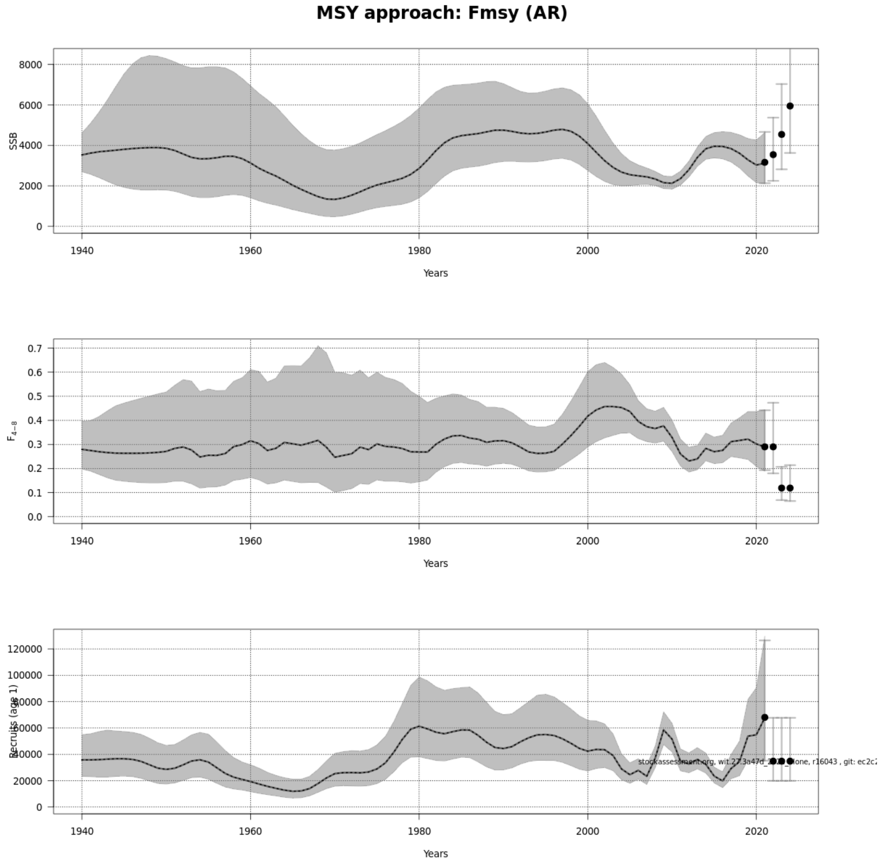

Figure 24.8. Witch flounder in Subarea 4 and Division 3.a: Short-term forecast under the MSY approach scenario ($F_{2023} = F_{MSY} \times SSB(2022)/MSY\ B_{trigger} = 0.119\ y^{-1}$) of the spawning stock biomass (SSB, in tonnes, top), the fishing pressure (F_{4-8}, middle) and recruits (bottom).

Annex 1: List of participants

Name	Country
Anja Helene Alvestad	Norway
Jurgen Batsleer	Netherlands
Alan Baudron	United Kingdom
Casper Berg	Denmark
Chun Chen	Netherlands
Harriet Cole	United Kingdom
José De Oliveira	United Kingdom
Côme Denechaud	Norway
Elise Eidset	Norway
Raphaël Girardin	France
Jette Fredslund	Denmark
Ghassen Halouani	France
Holger Haslob	Germany
Alexander Neil Holdgate	United Kingdom
Nis Sand Jacobsen	Denmark
Alexander Kempf	Germany
Alexandros Kokkalis	Denmark
Tiago Veiga Malta	Denmark
Carlos Mesquita	United Kingdom
Tanja Miethe	United Kingdom
Sarah Millar	Denmark
Iago Mosqueira	Netherlands
Nikolai Nawri	United Kingdom
Coby Needle	United Kingdom
Anders Nielsen	Denmark
J. Rasmus Nielsen	Denmark
Alessandro Orio	Sweden

Name	Country
Yves Reecht	Norway
Jon Egil Skjæraasen	Norway
Andreas Sundelöf	Sweden
Klaas Sys	Belgium
Guldborg Søvik	Norway
Marc Taylor	Germany
Mikael van Deurs	Denmark
Lies Vansteenbrugge	Belgium
Francesca Vitale	Sweden
Kathrin Vossen	United Kingdom
Nicola Walker	United Kingdom
Fabian Zimmermann	Norway

Annex 2: Resolutions

WGNSSK – Working Group on the Assessment of Demersal Stocks in the North Sea and Skagerrak

2021/2/FRSG19 The **Working Group on the Assessment of Demersal Stocks in the North Sea and Skagerrak** (WGNSSK), chaired by Tanja Miethe, UK, and Raphaël Girardin, France, will meet in ICES HQ, Copenhagen, Denmark, 20–29 April 2022 and by correspondence in September 2022 to:

a) Address generic ToRs for Regional and Species Working Groups.
b) Assess Norway pout assessments by correspondence.
c) Report on reopened advice as appropriate;

The assessments will be carried out on the basis of the stock annex. The assessments must be available for audit on the first day of the meeting.

Material and data relevant for the meeting must be available to the group on the dates specified in the 2022 ICES data call.

WGNSSK will report by 13 May 2022, and by 21 September 2022 (Norway pout) for the attention of ACOM.

Only experts appointed by national Delegates or appointed in consultation with the national Delegates of the expert's country can attend this Expert Group

Generic ToRs for Regional and Species Working Groups

2021/2/FRSG01 The following ToRs apply to: AFWG, HAWG, NWWG, NIPAG, WGWIDE, WGBAST, WGBFAS, WGNSSK, WGCSE, WGDEEP, WGBIE, WGEEL, WGEF, WGHANSA and WGNAS.

The working group should focus on:

a) Consider and comment on Ecosystem and Fisheries overviews where available;

b) For the aim of providing input for the Fisheries Overviews, consider and comment on the following for the fisheries relevant to the working group:

   i) descriptions of ecosystem impacts on fisheries

   ii) descriptions of developments and recent changes to the fisheries

   iii) mixed fisheries considerations, and

   iv) emerging issues of relevance for management of the fisheries;

c) Conduct an assessment on the stock(s) to be addressed in 2022 using the method (assessment, forecast or trends indicators) as described in the stock annex; - complete and document an audit of the calculations and results; and produce a **brief** report of the work carried out regarding the stock, providing summaries of the following where relevant:

   i) Input data and examination of data quality; in the event of missing or inconsistent survey or catch information refer to the ACOM document for dealing with COVID-

19 pandemic disruption and the linked template that formulates how deviations from the stock annex are to be reported.

ii) Where misreporting of catches is significant, provide qualitative and where possible quantitative information and describe the methods used to obtain the information;

iii) For relevant stocks (i.e., all stocks with catches in the NEAFC Regulatory Area), estimate the percentage of the total catch that has been taken in the NEAFC Regulatory Area in 2021.

iv) For category 3 and 4 stocks requiring new advice in 2022, implement the methods recommended by WKLIFE X (e.g. SPiCT, rfb, chr, rb rules) to replace the former 2 over 3 advice rule (2 over 5 for elasmobranchs). MSY reference points or proxies for the category 3 and 4 stocks

v) Evaluate spawning stock biomass, total stock biomass, fishing mortality, catches (projected landings and discards) using the method described in the stock annex;

1) for category 1 and 2 stocks, in addition to the other relevant model diagnostics, the recommendations and decision tree formulated by WKFORBIAS (see Annex 2 of https://www.ices.dk/sites/pub/Publication%20Reports/Expert%20Group%20Report/Fisheries%20Resources%20Steering%20Group/2020/WKFORBIAS_2019.pdf) should be considered as guidance to determine whether an assessment remains sufficiently robust for providing advice.

2) If the assessment is deemed no longer suitable as basis for advice, consider whether it is possible and feasible to resolve the issue through an interbenchmark. If this is not possible, consider providing advice using an appropriate Category 2 to 5 approach.;

vi) The state of the stocks against relevant reference points;

Consistent with ACOM's 2020 decision, the basis for Fpa should be Fp.05.

1) 1. Where Fp.05 for the current set of reference points is reported in the relevant benchmark report, replace the value and basis of Fpa with the information relevant for Fp.05

2) 2. Where Fp.05 for the current set of reference points is not reported in the relevant benchmark report, compute the Fp.05 that is consistent with the current set of reference points and use as Fpa. A review/audit of the computations will be organized.

3) 3. Where Fp.05 for the current set of reference points is not reported and cannot be computed, retain the existing basis for Fpa.

vii) Catch scenarios for the year(s) beyond the terminal year of the data for the stocks for which ICES has been requested to provide advice on fishing opportunities;

viii) Historical and analytical performance of the assessment and catch options with a succinct description of associated quality issues. For the analytical performance of category 1 and 2 age-structured assessments, report the mean Mohn's rho (assessment retrospective bias analysis) values for time series of recruitment, spawning stock biomass, and fishing mortality rate. The WG report should include a plot of this retrospective analysis. The values should be calculated in accordance with the "Guidance for completing ToR viii) of the Generic ToRs for Regional and Species

Working Groups - Retrospective bias in assessment" and reported using the ICES application for this purpose.

d) Produce a first draft of the advice on the stocks under considerations according to ACOM guidelines.

   i. In the section 'Basis for the assessment' under input data match the survey names with the relevant "SurveyCode" listed ICES survey naming convention *(restricted access)* and add the "SurveyCode" to the advice sheet.

e) Review progress on benchmark issues and processes of relevance to the Expert Group.
   i) update the benchmark issues lists for the individual stocks in SID;
   ii) review progress on benchmark issues and identify potential benchmarks to be initiated in 2023 for conclusion in 2024;
   iii) determine the prioritization score for benchmarks proposed for 2023–2024;
   iv) as necessary, document generic issues to be addressed by the Benchmark Oversight Group (BOG)

f) Prepare the data calls for the next year's update assessment and for planned data evaluation workshops;

g) Identify research needs of relevance to the work of the Expert Group.

h) Review and update information regarding operational issues and research priorities on the Fisheries Resources Steering Group SharePoint site.

i) If not completed in 2020, complete the audit spread sheet 'Monitor and alert for changes in ecosystem/fisheries productivity' for the new assessments and data used for the stocks. Also note in the benchmark report how productivity, species interactions, habitat and distributional changes, including those related to climate-change, could be considered in the advice.

Information of the stocks to be considered by each Expert Group is available here.

Annex 4: Audit reports

Audits for stocks for which advice sheets were produced were conducted during and immediately following the WGNSSK 2022 meeting. The audits were made available to the stock assessors, who had the opportunity to adjust their reports and advice sheets if any problems were detected in the audit. The audits were also made available to the relevant advice-drafting group.

Audits for spring assessments

bll.27.3a47de (brill)

General

Brill is managed under a combined TAC with turbot. Given the lack of catch and landings data as well as survey-information brill is assessed as a Category 3 stock. This year the new chr rule was used to provide advice. The index used is a commercial LPUE of the Dutch large beam trawl fleet. LBI method is used to determine the state of the stock in relation to fishing mortality reference point proxy for brill.

For single-stock summary sheet advice

Stock **Bll.27.3a47de**

Short description of the assessment as follows (examples in grey text):

1) Assessment type: update
2) Assessment: accepted
3) Forecast: not presented
4) Assessment model: *chr* rule
5) Consistency: first year application of the *chr* rule
6) Stock status: F is above F_{MSY} proxy (LBI), the stock size is above $I_{trigger}$.
7) Management plan: No management plan.

General comments

This was a well documented, well ordered and considered section. The assessment is easy to follow and interpret. Input and output data were correct.

Technical comments

Few inconsistencies were reported to the assessor and have already been fixed in both the advice sheet and report.

The assessment relies solely on a biomass index derived from a the standardized LPUE from the Dutch beam-trawl fleet for vessels > 221 kW. Considering the changes in the fleet related to technological creep, and potential issues with the calculation of the index, a benchmark to improve this index is quite urgent.

The Dutch industry survey seems to be a promising survey that could be used in the future to assess the status of the brill stock.

Conclusions

The assessment has been performed correctly.

cod.27.47d20 (cod, spring)

General

The stock has been benchmarked in 2021 with several changes made to the assessment and reference point calculations. Among other changes, emigration from the North Sea to area 6a is now taken into account via increased natural mortality rates for ages 3 and above. The assessment in 2022 was a normal update assessment from 2021.

For single-stock summary sheet advice

Stock Cod 27.47d20

Short description of the assessment as follows (examples in grey text):

1) Assessment type: Update
2) Assessment: analytical
3) Forecast: presented
4) Assessment model: SAM assessment accepted by external reviewers during and after the 2021 benchmark - tuning by two scientific surveys (IBTS q1 and IBTS q3) and one additional recruitment index derived from the IBTS q3 survey (age 0)
5) Consistency: consistent with 2021 assessment (only maturity at age updated because of new maturity keys used by some countries in ICES Datras since 2020)
6) Stock status: $B < B_{lim}$, $F < F_{MSY}$
7) Management plan: EU MAP accepted only by EU. Shared stock ➔ Headline advice based on ICES MSY approach

General comments

To have the assessment in TAF is a large improvement. Even data and scripts to derive input data like the Delta Gam indices or maturity at age have been added this year.

Overall, the report is very well written. It mentions the most important developments. It gives a clear overview over the most important results and issues relevant for the assessment, forecast and management.

Technical comments

According to the ICES estimated catch, the TAC in 2021 has been overshot. This could be mentioned explicitly in the report.

Remedial measures could be mentioned in the report as they likely have contributed to the decline in F over the last years.

The landings and discard fraction used for the forecast could be described a bit better by adding the information that it are the landings and discard fractions at age from 2021 and not just discard or landing/total catch by weight.

The numbers in the report and in the advice sheet are consistent. Rerunning the code from TAF leads to the same numbers as reported.

The model settings used are identical to the ones listed in the stock annex.

For small issues, comments were added directly to the report and advice sheet.

Conclusions

The assessment and forecasts have been carried out correctly.

dab.27.3a4 (dab)

General

Dab is assessed as a Category 3 stock. This year the new *chr* rule was used to provide advice. The index used Survey biomass index (based on SURBAR assessment). LBI method is used to determine the state of the stock in relation to fishing mortality reference point proxy.

For single-stock summary sheet advice

Stock **dab.27.3a4**

Short description of the assessment as follows (examples in grey text):

1) Assessment type: update
2) Assessment: accepted
3) Forecast: not presented
4) Assessment model: *chr* rule
5) Consistency: first year application of the *chr* rule
6) Stock status: F is below F_{MSY} proxy (LBI), the stock size is above $I_{trigger}$.
7) Management plan: The EU multiannual plan (MAP) for stocks in the North Sea (EU, 2018) and adjacent waters applies to catches of this stock.

General comments

This was a well documented, well ordered and considered section. The assessment is easy to follow and interpret. Input and output data were correct.

Technical comments

Few inconsistencies were reported directly to the assessor and will be fixed in both the advice sheet and report.

Conclusions

The assessment has been performed correctly.

gug.27.3a47d (grey gurnard)

General

The Gug43a7d stock is a data limited DLS Category 3.2 stock where only survey data (IBTS Q1 and Q3) and limited catch data are available. ICES has not been requested to provide advice on fishing opportunities for the stock for the years 2019-2022, where it has been a non-targeted stock with no TAC advice. ICES produces a biennial advice sheet for the stock, and in 2021 it was a rollover advice. However, a new catch advice was requested for the years 2023 and 2024 based on the 2022 assessment. It is a mixed fishery stock, and there are very high discard rates among the commercial fisheries harvesting the stock.

For single stock summary sheet advice:

Short description of the assessment: extremely useful for reference of ACOM.

1) **Assessment type:** Update (every second year; biennial advice);
2) **Assessment**: Trends-based assessment applying the rb rule. To analyse stock trends, a mature biomass index was calculated applying a length weight relationship and a maturity ogive which were obtained from available NS-IBTS CA (DATRAS) records with a length-weight relationship from NS-IBTS Q1 and IBTS Q3 and a maturity ogive from NS-IBTS Q1. Trends and stock status was checked according to MSY Proxies using a Length Based Index (LBI) for mature stock biomass using InterCatch data for all commercial fleets and fisheries from 2015-2021 and applying IBTS Q1+Q3 based condition (length-weight) factor and applying IBTS Q1 maturity ogive. Thus, input from several commercial fleets and 2 research surveys are used. The used survey indices are considered well suitable for this stock as the IBTS covers most of the stock distribution area and shows a good catchability for this species.
3) **Forecast**: The advice for 2023 and 2024 is based on the empirical rb rule which was applied for the first time as the basis for the catch advice. The ICES framework for category 3 stocks was applied. The advice is based on the rb rule to provide precautionary advice. A survey combined biomass index was used as an indicator of stock development. The advice is based on the ratio of the mean of the last two index values (index A) and the mean of the three preceding values (index B), multiplied by the recent catches, a biomass safeguard, and a precautionary multiplier. The stability clause was considered and applied (-30%). The discard rate (average 2019-2021) was 81% of the total catch.
4) **Assessment model**: Trends-based assessment applying the rb rule.
5) **Data issues:** Data are available. Updated data up to 2021 have been used. Data have been presented in the WGNSSK report and WGNSSK presentation. See specific technical comments below in relation to the input data.
6) **Consistency:** This assessment is consistent with the last assessment conducted for the stock, but the advice for 2023 and 2024 is based on the empirical rb rule which was applied for the first time as the basis for the catch advice.
7) **Stock status**: The stock size index is above I-trigger. No reference points for fishing pressure have been defined for this stock.
8) **Management Plan**: There is no management plan agreed. ICES has not been requested to provide advice for the stock in 2019-2022, however a new catch advice was requested for the years 2023 and 2024. It is a non-targeted stock with most catches consisting of discard.

General comments

This is a well documented, well ordered and considered assessment and advice (and section). The assessment is easy to follow and interpret.

Technical comments

Comment 1: Data issues (landings, discards, catches)

Traditionally the quality of landings data has been poor for this species. It is in accordance with the issues list of the assessment working group report noted that there are some issues with the reporting of grey gurnard for some nations (e.g. Germany, and maybe UK England), where for example Germany does not officially report grey gurnard but only a generic gurnard group in which also other gurnard species are included. This is usually not corrected for when uploading data to InterCatch. This is similar to the UK data for which a ratio from survey data typically has been used to correct for the proportion of other gurnard species. However, also this method will introduce a bias in the final estimates because the survey abundance does not necessarily reflect what is landed or discarded in the fishery, and the species and size selectivity is different between surveys and the different commercial fishery fleets. Further, this species is highly discarded and discard data are only available for the recent years (2012–2021).

Furthermore, it should also in accordance with the issues list of the assessment working group report be noted that for some fleets zero landings are reported, but at the same time no discards are reported. For these cases it is not possible to raise any discards in InterCatch, although high discards may occur in these fleets. It is not known how this affects the estimation of the total catch within InterCatch. It should in future benchmark be investigated to what extent on-board-observer monitoring information and data actually exist (are available) for these fleets and fisheries. This could maybe give indication of catch/discard-ratios for these fleets/fisheries. It should also in benchmarks be investigated if catch data time series could possibly be extended to cover more years in the past.

It should be emphasized that the discards estimates will given the above most often be based on observer on board monitoring where specific species are identified, while in the landings there occur the above described grouping. Furthermore, there may be different targeting between species in the combined species group among other because of price differences, and there is also different selectivity according to the different species in the commercial fishery (and its different fleets/metiérs), and also in relation to selectivity in the survey trawls. This may result in, that the survey species ratios (and biological data) are not representative for the landing species ratios (and biological data and parameters).

Comment 2: Data Issues (Requirements on biological information and ecosystem considerations)

As noted under data requirements in the working group report: For a better understanding of this species an increase in our knowledge of biological parameters is required, especially of growth parameters with respect to the application of the *rb* rule or other empirical rules developed for data limited stocks.

Grey gurnard is an important predator in the North Sea. In the context of ecosystem considerations, it would be useful to obtain more information on age composition of the stock and its diet composition.

Comment 3: Advice

The empirical *rb* rule was applied for the first time as the basis of the catch advice. The approach follows the ICES WKLIFE X report and flow chart. Here a m value of 0.5 is recommended “if no case-specific tuning” is performed which has not been done here. This is meant to be an extra precautionary buffer similar to that what there was in the two over three (2:3) rule before. The LBI method showed that the F is above FMSY proxy, although this is just on the edge: the ratio Lm / LF=M is 0.99, but this is still below 1. The survey indices are still on a comparable high level and above I-trigger, but decreasing quite drastically after 2017. The landings is likely not a good indicator in this case (see also comments on the data quality of landings above), but have also decreased to around 1100 tonnes. In this context it should also be considered, that the used survey indices are well suitable for this stock as the NS-IBTS covers most of the stock distribution area and shows a good catchability for this species. As such I agree with the assessor that the rb rule is the best ad hoc approach to the new empirical rules and it is difficult to find good arguments here to increase the m value. The advice will result in nearly the same amount of landings as reported for 2021. As pointed out in the assessment report and in the presentation of the assessment, the main reason to fall back to the rb rule is that the von Bertalanffy parameters, and here including the k values, are not reliable. Before using the k-values a thorough benchmark analysis of the quality of the von Bertalanffy parameters are needed (see also comments below). The old 2:3 rule would result in an even slightly lower catch advice, because also here one would apply the precautionary buffer.

The *rb* rule is based on the ratio (r) of the mean of the last two biomass index values (index A) and the mean of the three preceding values (index B), multiplied by recent catches or previous advised catches (A_y), and additionally a biomass safeguard (b), and a precautionary multiplier (m):

$$C_{y+1} = A_y \times r \times b \times m$$

The biomass safeguard b is determined by the relation of the most recent index value to $I_{trigger}$ (with $I_{trigger}$ = 1.4 x I_{loss}; I_{loss} = defined as lowest observed index value). When the most recent index value is greater than $I_{trigger}$, b is set to 1. The precautionary multiplier m is applied with the *rb* rule to maintain the probability of the biomass declining below B_{lim} to less than 5%. Following the guidelines for single stock advice (ICES, 2022), this precautionary multiplier should be set to 0.5 when applying the *rb* rule.

I** **loss**, **I** **trigger

I_{loss} is generally defined as the lowest observed index value. The lowest index value of the NS-IBTS Q1 mature biomass index (Figure 14) is I_{loss} = 2.355 kg/hour. This results in $I_{trigger}$ = 3.296 kg/hour.

Comment 4: Stock Annex

The Stock Annex has been updated.

Minor technical and editorial comments in relation to working group report and draft advice sheet:

a) Working Group Report section 7.4: It is stated that "A maturity ogive based on all available grey gurnard maturity data from NS-IBTS Q1 was used to calculate this mature biomass index." Which year range of IBTS Q1 data does that cover?
b) Working Group Report section 7.5: For the survey indices there is referred to Table 7.7, but Table 7.7 presents official landings.

Conclusions
The assessment has been performed correctly.

had.27.46a20 (haddock)

General

The stock was benchmarked in early 2022. Assessment model was changed from TSA to SAM and the reference points were re-estimated. Several input datasets were also updated, the most significant being changes to the maturity ogives and survey indices.

A new maturity scale was introduced in 2021, but was unfortunately not being adapted during the benchmark. An update was then made to the maturity ogive calculation made at the recent benchmark. The maturity ogives derived at the benchmark were updated. Overall, very little difference was seen compared to the benchmark assessment results and so the conclusions of the benchmark remain unaffected.

WGNSSK 2022 decided to use the coefficients of variation of Q1 survey as an extra parameter in the SAM assessment to adjust the increased uncertainty caused by the lowered sampling coverage of the NS-IBTS Q1 survey. This also adds as a permanent change to the assessment model inputs as agreed at the benchmark.

For single-stock summary sheet advice

Stock: had.27.46a20

Short description of the assessment as follows (examples in grey text):

8) Assessment type: Update (benchmarked in early 2022)
9) Assessment: accepted
10) Forecast: accepted
11) Assessment model: SAM, Age based analytical assessment using a Q1 and a Q3+Q3 survey indices, both extracted using delta-GAM approach
12) Consistency: just after benchmark, assessment cannot be compared to previous years
13) Stock status: Fishing pressure on the stock is below F_{MSY} and spawning-stock size is above MSY $B_{trigger}$, B_{pa}, and B_{lim}.
14) Management plan: EU multiannual management plan (MAP) plan for the Western Waters (EU, 2019)

General comments

The report was well written. Report and assessments covers a wide range of aspects: Impact of covid 19 in fishing efforts, sampling coverage and data quality was assessed. Changes in discards rate and biological parameters such as mean weight, maturity were well discussed. Exploratory assessments using SURBAR was conducted and the consistent result to SAM further insure the quality of the current assessment.

The audit was based on the presentations to the WG, stock annex, advice sheet, report and assessment and forecast files on SharePoint.

Technical comments

- The role of Q1 survey intermediate year indices is not clearly described. The indices for intermediate year is included, but not used in the estimation of the intermediate year recruitment, nor forecast. Maybe add some description in the stock annex.
- The F in references points were not estimated till last 3 digits. Since it was finalized in benchmark and it is very likely that it is no longer a request, it is not necessary to modify anymore.

Sock annex:

- Maybe add a brief description of the stratification strategy in raising discards and age allocation for catch data in Intercatch
- Add information about which survey (and period) are used to provide the catch to stock weight conversion factor
- Is there any extra SAM parameter configurations changed/added with the introduction of Q1 CV adjustment? If so, can you add to the SAM parameter config table

The advice sheets and reports are well- written. Some figure numbers in the report needs to be adjusted. Other minor comments were directly added in the documents.

Conclusions

Assessment was done consistently, and report was well written

lem.27.3a47d (lemon sole)

General

Audit based on the stock annex, benchmark report, presentations, advice sheet and the report section. Overall, the presented assessment appears sound and conform to the stock annex (which was updated to match the new DLS advice rules recommended after WKLIFE X).

For single-stock summary sheet advice

Stock lem.27.3a47d

Short description of the assessment as follows:

1) **Assessment type:** Updated assessment and advice according to the [2018 WKNSEA benchmark, with further adaptation to, and implementation of, new DLS rules (ICES, 2021).]
2) **Assessment:** accepted. Lemon sole has been defined as a category 3 species according to the ICES guidelines.
3) **Forecast:** No forecast.
4) **Assessment model:** no consistently reliable age structured data is available for commercial catches and the assessment and advice therefore follow a data limited approach:
    - Exploratory model: SSB index from a SURBAR model (using *ad-hoc* catchability corrections for age 1 and 2). The model uses age-structured GAM indices in Q1 (IBTS) and Q3 (combined IBTS+BTS).
    - Advice formulated using the "constant harvest rate" (chr) rule (following WKLIFE X recommendations, and subsequent new DLS approach adopted by ICES), based on an empirical IBTS Q1 survey index (age 2-5), with m = 0.5 (based on estimated K = 0.407).
    - Stock exploitation status evaluated using length-based indicators (LBIs), here in relation to the F_{MSY} proxy L_{mean} = $L_{F=M}$ (with assumption M/k = 1.5).
5) **Data:** data limitations such as noisiness of the survey index, partly due to low catchability of younger classes, are well documented and believed to have little influence on the advice. The Q1 index, in particular, shows a poorer internal consistency and seems to be given a lower weight by the SURBAR model, as suggested by larger residuals.
   Poor IBTS coverage in Q1 2022 believed not to hinder the index quality dramatically.
6) **Consistency:** Consistent with the benchmark. No inconsistency over time revealed; annual advice issued since 2019, every second year before. In 2022, a new advice rule was introduced, but the basis of the assessment remains mostly unchanged.
7) **Stock status:** relative SSB increasing in 2022, following an overall decline over the former 10 years. L_{mean} > $L_{F=M}$ indicates a stock exploited below $F_{MSY\ proxy}$. Relative stock size is over $I_{trigger}$ (I_{loss}). Recruitment exhibited an

upward trend since 2017 (but with high uncertainty around the estimate).

8) **Management plan:** none.

General comments

Assessment and advice in line with the stock annex and benchmark decisions, further adapted to match the WKLIFE X (ICES, 2021) recommendation on new advice rules.

I have been lacking time for a thorough proof-reading, but here are some minor comments/suggestions:

- 9.3.3: **delta**-GAM, to match changes in the stock annex. Few more occurrences throughout the text.
- Figure 9.5.7: the left vertical dashed line representing L_{max} (used to estimate L_∞) seems at a suspiciously low value to represent the 99th percentile, if based on the same distribution as represented on the graphic. This may need verification or clarification.
- WKLIFE X report referenced in advice sheet as ICES 2020 (should be 2021).

Technical comments

No new technical comment, but I leave the one stressed last year, because – and this is new development – L_∞ is used to estimate $L_{F=M}$, and may therefore influence the $F_{proxy,MSY}$ used in the chr rule (and maybe $I_{trigger}$ too). This may be a consideration for future benchmark:

The range of possible estimates considered for L_∞, during the benchmark, appears very wide. The choice of the method is therefore expected to have a considerable impact on the estimates for L_{opt} and $L_{F=M}$, and for comparison with $L_{max5\%}$. It is moreover noticed that the option based on survey data (which was disregarded because deemed not representative of the stock size composition):

- did not include a correction for biases induced by length-stratified age sampling (which to the best of my knowledge is standard on IBTS surveys), while fitting the growth function.
- forced the t_0 of the Von Bertalanffy growth function to zero, which, by experience, may have a sizeable impact on the L_∞ estimate.

It may therefore be advisable to reconsider the option based on survey data using an alternative method (such as the one proposed by Perreault *et al.*, 2019) in a future benchmark. Although the method chosen to estimate L_∞ appears sound, it is based on a meta-analysis, and therefore need to be considered with caution as it could provide misleading perspective on the exploitation level. A method based on data from the stock itself may provide more accurate estimates, although the issue of the representativeness of course has to be addressed.

If not suitable alternative was found, it may be recommendable to at least document the sensitivity of the reference points and advice rule to such uncertainty.

Conclusions

The assessment has been performed correctly and reporting is adequate.

WGNSSK reiterate the advice that management should be implemented at the species level (currently managed under a combined species TAC with witch).

References

ICES. 2021. Tenth Workshop on the Development of Quantitative Assessment Methodologies based on LIFE-history traits, exploitation characteristics, and other relevant parameters for data-limited stocks (WKLIFE X). ICES Scientific Reports. 2:98. 72 pp. http://doi.org/10.17895/ices.pub.5985

Perreault, A. M. J., Zheng, N., and Cadigan, N. G. 2019. Estimation of growth parameters based on length-stratified age samples. Canadian Journal of Fisheries and Aquatic Sciences. http://dx.doi.org/10.1139/cjfas-2019-0129.

ple.27.420 (plaice in the North Sea)

General

The stock was benchmarked in 2022. The main changes were to re-estimate a time-invariant natural mortality based on the Peterson–Wroblewski estimator, to combine the BTS and IBTS-Q3 indices and to change the assessment model from AAP to SAM. Reference points were re-estimated although perception of stock status has not changed ($B>B_{trigger}$ and $F<F_{MSY}$), despite changes to the SSB, fishing mortality and recruitment trajectories.

For single-stock summary sheet advice

Stock: Ple.27.420

Short description of the assessment as follows (examples in grey text):

1) Assessment type: update (benchmarked in 2022)

2) Assessment: accepted

3) Forecast: accepted

4) Assessment model: SAM assessment – tuning with 5 survey indices (BTS+IBTS Q3 and IBTSQ1 both derived using delta-GAM, BTS-ISIS and SNS split into two time-series).

5) Consistency: 2022 benchmark, therefore not consistent with 2021 assessment.

6) Stock status: $B>B_{trigger}$ & B_{pa}; $F<F_{MSY}$.

7) Management plan: Advice is based on the MSY approach. The EU management plan (MAP) is not adopted by Norway and is given only as a catch option.

General comments

Overall, well documented, and consistent with the stock annex.

The 2022 assessment is not yet in TAF or on stockassessment.org. This could be considered for future assessments to facilitate the audit process. The audit was based on the presentations to the WG, stock annex, advice sheet, report and assessment and forecast files on SharePoint.

Technical comments

Some descriptions of the survey indices remain to be updated in Section B.3 (pages 9–10) of the stock annex: (1) the description of the GAM model refers to the BTS and IBTS Q3 surveys separately; (2) five different survey indices are used in the assessment; and (3) the RCT3 analysis is no longer used to estimate recruitment. It would be useful to include specifications of the delta-GAM models in the stock annex and/or report.

Year ranges in the assessment data table of the stock annex (page 11) could be misinterpreted because intermediate year data for the IBTS-Q1 are available at the time of the WGNSSK assessment. This could instead be described as 'last data year'.

Forecasted recruitments are resampled from the recent 10 years, excluding the last data year if uncertainty is high. The inclusion or not of the last data year seems somewhat subjective but presented to and agreed by the WG.

The %TAC change column in the forecast options is based on the TAC for 4 and 20 while the rollover forecast option includes a proportion of the 7.d TAC in the catch target. The stock assessor explained that this addition corresponds to the part of the North Sea stock caught in 7.d (consistent with the stock definition) which is subsequently removed to give the catch for the North Sea.

The order of figures does not follow the order they are mentioned in the text, which makes it more difficult for the reader to follow. Furthermore, some figures are not referred to in the main text.

Minor comments have been added directly to the report section and the advice sheet.

Conclusions

The assessment and forecasts have been done correctly and carried out in accordance with the stock annex.

ple.27.7d (plaice in the eastern English Channel)

General

The stock is classified as category 1 and uses the “Aarts and Poos” model. The FR-CGFS survey index at age has been derived using a delta-GAMM model, to cope with the 2020 missing stations in the UK EEZ and improving the internal consistency of the survey index compared to the stratified mean approach as was used in previous plaice 7.d stock assessment. With the new survey index the reference points were recalculated and reviewed during the group.

For single-stock summary sheet advice

Stock Plaice 27.7.d

Short description of the assessment as follows:

1) Assessment type: Update.
2) Assessment: analytical.
3) Forecast: presented.
4) Assessment model: Aarts and Poos model, which is an age-based analytical assessment that uses catches in the model and forecast. Age-based natural mortality estimated with Peterson and Wroblewski’s estimator (weight), and two surveys : UK BTS and FR GFS.
5) Consistency: The assessment is largely consist. However the FR-CGFS survey index is now derived using a delta-GAMM approach. Working document is provided on the SharePoint and added to the stock annex.
6) Stock status: $B > B_{pa,}$ $F < F_{MSY}$
7) Management plan: In 2021 the advice was based on the management plan. In 2022, the advice is based on the MSY approach.

General comments

Overall, the report is well written and covers all major topics. The report, however, would benefit by discussing the change in survey index a bit more. I think the report, in contrast to the stock annex, should not go into the technical details, but would benefit by showing the difference in the index resulting from the delta-GAMM versus the index from the stratified mean. The description of the delta-GAMM in the stock annex is a bit too brief. I think some parts of the WD could be added so the process of the methodology is more clear.

Because of the new index, reference points where recalculated and reviewed during the 2022 working group. While the new reference points are shown in the stock annex, these should also be added to the report to facilitate the readers outside of ICES.

Technical comments

Please check the Stock Annex. The text describes the use of a Delta GAMM index for the FR-CGFS, but it is not clear how the model is constructed. Additionally, no information on the changes in the survey index are mentioned. A WD is available which nicely takes the reader through the different approaches explored and evaluated. While the WD is available on the 2022 Sharepoint, I do think the Stock Annex should contain a more elaborate paragraph on the chosen method, e.g. explains the formula and show the change in internal consistency. By doing so you document everything for the person who potentially in the future may take over the assessment.

Similary, the report would benefit from a graph showing the differences in survey indices used in the previous assessment and current assessment.

The numbers in the report and in the advice sheet appear to be consistent.

The stock annex has been update with the new reference points. The model settings used are identical to the ones listed in the stock annex. It could help to add the new reference points in the report as well. Some editorial comments were added directly to the report and stock annex.

Conclusions

The assessment and forecasts have been carried out correctly. With the new survey method and thus index at age for the FR-CGFS new reference points had to be calculated during the WG. These were reviewed and accepted by the group.

pok.27.3a46 (saithe)

Stock: Saithe in areas 3.a, 4 and 6

1) Assessment type: update

2) Assessment: accepted

3) Forecast: accepted

4) Assessment model: Age-based analytical assessment SAM (ICES, 2022) that uses catches in the model and in the forecast, tuned by one survey index and one combined commercial index scaled to the exploitable biomass.

5) Consistency: both this year's and last year's assessments accepted.

6) Stock status: B has just fallen below MSY $B_{trigger}$ for the first time since the mid-1990s; $F_{MSY} < F < F_{pa}$; long-term downwards trend in R.

7) Management plan: an EU multiannual management plan (MAP) has been developed by the EU for this stock, although it is not been agreed by Norway. Before Brexit, there was a new EU-Norway management plan in development, but that has since stalled. The UK are in the process of developing a management plan for saithe in UK waters. There is no widely-agreed management plan that can be used by ICES as the basis for advice, which is therefore based on the ICES MSY approach.

General comments

- The report mentions that the Stock Annex of 2019 was followed, but the stock annex itself was updated in 2021. It would be helpful to explain in the Introduction what the change was in 2021 (presumably this refers to updates to reference points).
- At some future point, the Stock Annex could be updated – it refers to several management measures that are out of date as being current, for example, and the industry Stock Survey is mentioned as still being current. Probably a suitable task for a future benchmark.
- Section 16.1.3, 2nd paragraph – the last line here is very specific to 2017. Is this still the case? Similarly in the 4th paragraph, did Scottish discarding also continue into 2021 (presumably)?
- Section 16.2 – this could also mention the EU MAP, as that is what is highlighted in the advice sheet.
- Table 16.3.1 – the caption should be corrected to read "2005-2021".
- Tables 16.3.2, 16.3.4, 16.5.1 – the captions should be corrected to read "2021".
- Figure 16.4.1 – can you check that the bottom-right subplot is actually "commercial CPUE", as the caption suggests? The figure labels indicate this is exploitable biomass from the Q3 survey, which would make more sense for this figure (which should be all about the Q3 survey). If it is the commercial CPUE, then it might be better to remove it from this plot (you have it in Figure 16.4.3 anyway) and include instead the negative gradients from the catch curves in Figure 16.4.1.
- Section 16.4.4, final paragraph – the final assessment results are in Figure 16.5.1, not Figure 16.4.10 (or at least, they are presented more clearly in Figure 16.5.1, so I think that would be the better reference).
- Section 16.9.1, fourth paragraph – this could be updated, as I think the retrospective pattern is now quite small.

Technical comments

- The general approach now is that F_{MSY} is defined as $F_{p.05}$, while the stock annex (and Table 16.7.2) still has F_{MSY} from an "EQsim analysis based on the recruitment period 1998–2017." Was there any consideration during the meeting about updating this?

- The text notes that covid-19-related sampling problems are unlikely to have adversely affected the quality or utility of catch estimates.

Conclusions

I have relatively minor comments only – the assessment and advice looks to have been prepared correctly according to the Stock Annex.

sol.27.4 (sole in the North Sea)

General

The stock was benchmarked in 2020 (additional survey data were used). However, the 2022 assessment presents:

- a strong retrospective pattern for SSB and F
- high residuals for landings age 1 and SNS survey ages (4-6)

Several tests have been carried out during WGNSSK meeting (test runs with SAM, JABBA, alternative M) but no clear explanation has yet been found. Some hypothesis could explain the large retrospective pattern:

- Selectivity changes with switch TBB - pulse - TBB.
- Misspecification of natural mortality in the younger ages
- BTS selectivity at age given changes in length.
- Possible underestimation of discards in recent years.
- Loss of information in SNS in the recent years.

For single-stock summary sheet advice

Stock **sol.27.4**

Short description of the assessment as follows:

8) Assessment type: update
9) Assessment: accepted
10) Forecast: accepted
11) Assessment model: Art and Poos statistical catch-at-age model – tuning by two survey indices (BTS combined [NL, DE, BE] Q3 [B2453] and SNS Q3 [B3499])
12) Consistency: consistent with 2021 assessment. (The stock was benchmarked in 2020)
13) Stock status: Fishing pressure on the stock is at F_{MSY} and below F_{pa} and F_{lim}; spawning-stock size is below MSY $B_{trigger}$ but above B_{pa} and B_{lim}.
14) Management plan: ICES advises that when the MSY approach is applied, catches in 2023 should be no more than 9152 tonnes.

General comments

The sol.27.4 assessment is clear, well documented and easy to follow. It states clearly the problem of the large retrospective pattern of SSB and F, and follows the recommendation of WKFORBIAS decision tree. Input data, source code and output of the index standardization are available in a TAF repository (https://github.com/ices-taf/2022_sol.27.4_survey/).
Overall, consistent with the stock annex and the advice sheet.

Technical comments

This issue of large retrospective patterns was investigated during the meeting, and it was decided to give an advice as usual since the F_{target} was assumed to be sufficiently precautionary.

- It would be interesting to mention in the report the different tests carried out to find an explanation to the issue of retrospective patterns.

- In the table 2 of the advice sheet, F total is not equal to the sum of F projected discards and F projected landings.
- if possible, it would be better to show recent years in the x-axis label in the advice sheet graphs (SSB, rec, F and catches), similar to the last year advice in order to make the graphs easier to read (it was difficult to check if 2022 biomass is added or not to the graph).

- The rounding need to be checked in the advice sheet for F= $F_{msy\ lower}$ scenario
- The standardGraph (.xlsm file) need to be added to the assessment and forecast folder
- Some minor editorial comments were added to the stock annex and the report.

Conclusions

The assessment has been performed correctly.

tur.27.3a (turbot in Skagerrak and Kattegat)

General
Turbot is not managed under a TAC and regarded as a bycatch species. Denmark is responsible for approximately ¾ of the turbot landings in 3a and also provides most of the sample data. Issues concerning stock identity were raised during the benchmark in 2020. A SPiCT assessment and forecast are used to provide advice. Catches in 2021 were lower than the year before and also the discard rate was lower.

For single-stock summary sheet advice

Stock **Tur.27.3a**
Short description of the assessment as follows:

1) Assessment type: update
2) Assessment: accepted
3) Forecast: accepted (SPiCT forecast -> 35% fractile rule)
4) Assessment model: SPiCT, including a catch series from 1975-2021 and a combined survey index from 1983-2021.
5) Consistency: The stock was benchmarked in 2020, this is the second assessment after that benchmark.
6) Stock status: F is below F_{MSY} (SPiCT) and the stock size is above MSY $B_{trigger}$ (SPiCT).
7) Management plan: The EU multiannual plan (MAP) for stocks in the North Sea (EU, 2018) and adjacent waters applies to bycatches of this stock.

General comments
The turbot 3a section of the report is well-written and well-documented. Both assessment and forecast are well-explained. Values provided in the report match with those in the advice sheet (e.g. advice, landings and discards 2021, discard rates, official landings and summary tables).

Technical comments
Few inconsistencies were reported to the stock assessor and have been fixed in both the advice sheet and report.

All diagnostics are satisfactory, except for some autocorrelation related to the survey index being included as a smoothed biomass index in the SPiCT assessment. This issue was investigated during the benchmark, but it was decided to move forward with this smoothed index.
Retrospective patterns were acceptable.

Conclusions
The assessment has been performed correctly.

tur.27.4 (turbot in the North Sea)

General

The stock has been classified as category 1 since the 2018 inter-benchmark, which improved the previous application of the state-space assessment model SAM, and estimated reference points for the stock. The assessment in 2022 was a normal update assessment from 2021.

For single-stock summary sheet advice

Stock Turbot 27.4

Short description of the assessment as follows (examples in grey text):

15) Assessment type: Update.
16) Assessment: analytical.
17) Forecast: presented.
18) Assessment model: SAM assessment accepted by external reviewers during and after the 2018 inter-benchmark - tuning by two scientific surveys (SNS and BTS Q3) and a standardised commercial LPUE biomass abundance index based on the Dutch 80 mm beam trawl fleet (BT2).
19) Consistency: consistent with 2021 assessment.
20) Stock status: $B > B_{pa,}$ $F < F_{MSY}$
21) Management plan: TAC is set combined with brill. EU MAP accepted only by EU. Includes FMSY ranges. Headline advice based on ICES MSY approach.

General comments

The assessment appears robust despite the limitations in the information on abundance available from the indices used. The two scientirfic surveys do not particularly well traget turbot, so the model depends greatly on the LPUE series. Issues have been raised on the exact procedure employed for standardizing this index, which should be reviewed.

The model will be pushed into TAF. If possible, the repository should also include the LPUE standardization code.

The report is very well written, detailed, and states clearly the identified problems with the data. The document provides sufficient information to evaluate the strength of the advice provided making use of the assessment model and forecast.

Technical comments

The stochastic forecast could be added.
The numbers in the report and in the advice sheet appeasr to be consistent.
The model settings used are identical to the ones listed in the stock annex.
Some editorial comments were added directly to the report.

Conclusions

The assessment and forecasts have been carried out correctly.

whg.27.3a (whiting in Skagerrak and Kattegat)

General

The current advice is for years 2023-2024 with the previous TAC agreed in 2020 for 2021-2022. The new advice is based on a new harvest control rule (rb) causing a decrease in the advice despite an increase in survey index trend.

For single-stock summary sheet advice

whg.27.3a

Short description of the assessment as follows (examples in grey text):

1) Assessment type: update. Benchmarked in 2020.
2) Assessment: accepted
3) Forecast: not presented
4) Assessment model: Index trend. One catch time series and one combined tuning time series, 2:3 rule applied.
5) Consistency: A decrease in advice following a new precautionary approach multiplier
6) Stock status: No reference points available.
7) Management plan: No management plan. TAC advice produced every 2 years.

General comments

Some minor comments were adjusted in the advice sheet by the stock assessor.

Technical comments

An exploratory SPiCT model was presented, but very high uncertainty and an unrealistic production curve caused the model to not be further investigated.

Conclusions

The TAC advice decreased despite increases in biomass index due to implementation of the rb rule. No further comments to the assessment.

whg.27.47d (whiting in the North Sea)

General

For single-stock summary sheet advice

Whiting in 4 and 7d

Short description of the assessment as follows:

1) Assessment type: update
2) Assessment: accepted in WGNSSK with external review pending
3) Forecast: accepted in WGNSSK with external review pending
4) Assessment model: SAM, 2 survey tuning indices (IBTS q1 and q3). SURBAR is used for comparison to SAM. SURBAR is used to ensure consistent survey patterns between northern and southern areas, and continued justification for a single stock assessment.
5) Consistency: The original assessment was consistent with the agreed procedure defined by the IBP in 2021, but issues were noted regarding the sensitivity of the current assessment configuration to small changes in catch numbers in late age classes (ages 0-8+ considered). These changes are due to uncertainties in aging of those age classes due to low numbers, with consequences on the stability of Fbar (ages 2-6) between assessments. Based on these sensitivities (with consequences in retrospective patterns), additional explorations looked at lowering the plus group to 6+ and using Fbar ages 2-5. In additional, the SAM model configuration was adjusted to have a separate catch variance parameter for the new plus group (6+). The results were deemed to be much robust, as reflected by the retrospective patterns; however, reference points required re-calculation and forecasts were conducted during the meeting using these new values in the updated harvest control rule. The assessment and forecast were accepted within the group but changes will need to be subjected to external review before advice can be published.
6) Stock status: Fishing pressure on the stock is below FMSY and spawning-stock size is above MSY Btrigger, Bpa, and Blim. Revision of the assessment procedure increased biomass reference points slightly, as well as Fmsy (from 0.371 to 0.393).
7) Management plan: Part of the EU plan. Shared stock with Norway → Advice based on the MSY approach.

General comments

Overall, well documented and conclusions are substantiated. One omission was the rationale for the use of a separate variance parameter for the observations of the plus group in the SAM configuration. I believe this was also a change from the previous assessment configuration, but have missed the justification, other than it improved the fit and retrospective pattern.

Technical comments

Fig 2 seems to have several errors. 1) Are 5 lines supposed to be shown? 2) SSB plot does not display MSY Btrigger blue line – This is probably because this is equivalent to Bpa, but Fig. 1 shows both correctly. 3) Orange line in Fishing pressure plot is the current assessment? Not mentioned. Can this be adjusted or is a note possibly needed? 4) Recruitment plot only shows a single line.

For future consideration: Smoothing of natural mortality and maturity through time might benefit from a more standardized approach than the currently used GAM (e.g. where number of knots used is dependent on the number of data points), such as a moving average with a predefined number of years is specified. As is, the addition of new data may cause undesired fluctuations from year to year.

Assessment and forecast code have been uploaded to the Sharepoint, but not to TAF. I realize this is no easy task, but the assessors may find that a direct R workflow (using the "stockassessment" package, as opposed to reliance on stockassessment.org) may help streamline many aspects.

Conclusions

The assessment has been done correctly.

wit.27.3a47d (witch)

For single stock summary sheet advice:

9) **Assessment type:** update assessment
10) **Assessment:** analytical
11) **Forecast:** presented
12) **Assessment model:** SAM – tuning by 2 age indices and 2 biomass indices
13) **Data issues:** data available are as described in stock annex.
14) **Consistency:** An inter-benchmark was needed in 2021 to derive replacement survey indices previously provided by ICES. Stock was benchmarked in 2018.
15) **Stock status**: Blim<B<MSY Btrigger and has been for a few years, F> Fmsy but relatively constant. R has increased since 2016 while catches have decreased.
16) **Management Plan**: The EU MAP for the North Sea and adjacent waters applied to bycatches of this stock. This stock had a joint TAC with lemon sole (SubArea 27.4 and Division 27.2.a)

General comments

- The report section is well written and easy to follow and interpret.
- All input data described in the stock annex were available and used in the assessment.
- The model settings/configuration used are as described in the stock annex and the report.
- The input data and outputs from the assessment are consistently reported across the stock annex, presentations, data files, report section, stockassessment.org and the advice sheet.
- The forecast settings used are as described in the report.
- The advice sheet is consistent with the assessment and forecast results presented in the report section. The correct basis for advice has been used.

Technical comments

- Stock annex
  - The stock annex does not list all model setting listed in the report or on stockassessment.org
  - Forecast settings for mean weights-at-age, maturity and natural mortality are not listed
- Report
  - A few typos were found (see the "tracked changes" in the report section.
- Advice sheet
  - The official landings for witch listed for 2017 in table 6 (2811 t) do not match the official landings listed in table 24.1 of the report section (2855 t).

Conclusions

The assessment has been performed correctly.

Audits for delayed advice for sole 7.d, re-opening of advice for cod and autumn update assessments (Norway pout and *Nephrops*)

These audits were added in autumn 2022

sol.27.7d (sole in the eastern English Channel)

General

Audit based on the report section, advice sheet, stock annex, 2021 WKNSEA benchmark report, 2022 IBPSOL7D interbenchmark report, and data available on the SharePoint. Overall, the presented assessment appears sound.

For single-stock summary sheet advice

Stock: Sole in Division 27.7.d

Short description of the assessment as follows (examples in grey text):

1) Assessment type: update
2) Assessment: accepted
3) Forecast: accepted
4) Assessment model: SAM, 3 survey age-structured indices (UK (E&W) BTS, France YFS and UK YFS), 3 commercial tuning series (FRA-COTB, UK (E&W)-CBT and BE-CBT).
5) Consistency: In 2019 and 2020, category 3 advice was provided for this stock. In 2021 this stock was benchmarked during WKNSEA to address data issues. During WGNSSK 2021, the new assessment performed with SAM was accepted and category 1 advice was provided. During WGNSSK 2022 the SAM assessment model was rejected due to poor fit to observed catches caused by trend sin survey catchability of the UK beam trawl survey. An interbenchmark was carried out to address the issue and a new SAM model was accepted. New reference points were calculated as a result. The short-term forecast methodology was also updated at the same time.
6) Stock status: ICES assesses that fishing pressure on the stock is just below F_{MSY} (although about half of the F confidence interval is over) and below F_{pa} and F_{lim}; spawning-stock size is below MSY $B_{trigger}$ and between B_{pa} and B_{lim}.
7) Management plan: EU multiannual management plan (MAP) for the Western Waters.

General comments

Overall, the sol.27.7d section of the report is very well written and thoroughly documented. It is easy to follow and interpret. This year's changes to the assessment model following the 2022 interbenchmark are clearly laid out. The steps taken for the short-term forecast and resulting advice are well explained. The catch advice given in the report section matches with the values given in the advice sheet, and so do the reported landings and stock summary tables. The values in the advice sheet also match with the data available on the SharePoint. I made some very minor edits and comments throughout the report.

Technical comments

1. In the advice sheet, the SAG plot for recruitment is missing the peels for comparison with previous assessment and needs updated.

2. As mentioned above, I made a couple of comments in track changes.

Conclusions

Following an interbenchmark to tackle model issues, the 2022 assessment of sol.27.7d has been performed correctly, and all the diagnostics are satisfactory. This stock has been through an extensive benchmark and a thorough review of the data input in 2021. In 2022, the stock further went through an interbenchmark to review input data and the SAM model parameterisation. I have no concerns about the assessment of this stock.

cod.27.47d20 (cod, autumn)

General

The stock has been benchmarked in 2021 with several changes made to the assessment and reference point calculations. Among other changes, emigration from the North Sea to area 6a is now taken into account via increased natural mortality rates for ages 3 and above. The assessment in 2022 was a normal update assessment from 2021. In autumn 2022 reopening was triggered and the assessment and forecast has been rerun with additional information from the 2022 quarter 3 IBTS. In addition, in year information on landings from North Sea cod were made available and extrapolated based on linear relationships to get an updated value for the intermediate year catch.

For single-stock summary sheet advice

Stock Cod 27.47d20

Short description of the assessment as follows (examples in grey text):

1) Assessment type: Update
2) Assessment: analytical
3) Forecast: presented
4) Assessment model: SAM assessment accepted by external reviewers during and after the 2021 benchmark - tuning by two scientific surveys (IBTS q1 and IBTS q3) and one additional recruitment index derived from the IBTS q3 survey (age 0). For the reopening the q3 survey time series were extended with values from 2022.
5) Assessment run with same settings as for the advice in June 2022, but with additional 2022 data points from q3 IBTS index. This also includes the Q3 age 0 recruitment index forward shifted to age 1 to let SAM estimate the recruitment in 2023 (Tac year). In addition, in-year information on North Sea cod landings were used to update the intermediate catch value in the forecast based on relationships from WKNSROP.
6) Stock status: $B < B_{lim}$, $F < F_{MSY}$
7) Management plan: EU MAP accepted only by EU. Shared stock ➔ Headline advice based on ICES MSY approach

General comments

The reopening protocol is not 100% clear for the situation where reopening is triggered by new information on recruitment in the intermediate year, but D from RCT3 for the recruitment in the TAC year is <1. Experts involved interpreted point 4b of the protocol (“Populate and rerun the forecast procedure with the resulting assessment estimates, and updated intermediate year F assumption (step 3a) if available“) and agreed that the estimate for the recruitment in 2023 (Tac year) is a resulting assessment estimate (based on the 2022 age 0 Q3 survey index) and therefore has to be updated also in cases where D is <1.

The intermediate year catch assumption is based on landings information from quarters 1 to 2 extrapolated by a linear relationship to get expected annual landings. The shortcoming of this approach is that sudden changes in seasonal fishing patterns or changes in discard rates are still unknown for 2022 and cannot be taken into account. This shortcoming of the approach could be mentioned in the report. Overall, the extrapolations lead to a total catch lower than ever observed despite the stock is assessed/predicted to increase in 2022 from the low levels observed in 2020 and 2021.

Technical comments

The RCT3 analyses have been carried with the settings and for the age groups agreed in the reopening protocol.

The assessment has been rerun with additional q3 survey data from 2022. This required "padding" of data for 2023 (to some extent dependent on the R version). Running forecasts with recruitment in the TAC year estimated by SAM also required a custom function developed during the last benchmark. The custom function seems to be incompatible with newer versions of package "stockassessment" and therefore the version of "stockassessment" from the benchmark was used together with R version 3.5.1 (also used during the benchmark) by the stock assessor. Overall, the assessment needs a very specific combination of R, TMB and stockassessment package versions to run without error messages. This is not an optimal situation and during the next benchmark this may be improved.

The reopening report only provides the summary of the autumn assessment. No diagnostics are presented. However, changes between the May assessment and the autumn assessment are very minor.

The numbers in the report, generated by report_tbales.r and in the advice sheet regarding catch options are consistent. However, table 9 (summary of the assessment) in the advice sheet was not yet available during the audit.

For small issues, comments were added directly to the report and advice sheet.

Conclusions

The reopening assessment and forecast have been carried in accordance with the reopening protocol.

nop.27.3a4 (Norway pout)

General

Assessment and forecast completed under severe time pressure and according the specifications of the Stock Annex following the 2016 benchmark, updated with 2020 reference points. The audit was also completed under severe time pressure.

For single stock summary sheet advice:

17) **Assessment type:** update assessment
18) **Assessment**: analytical
19) **Forecast**: Stochastic forecast
20) **Assessment model**: Quarterly SESAM model
21) **Data issues:** Q3 English and Scottish survey data available in time for assessment schedule. IBTS data were revised following automation of age allocation procedures, which caused a re-scaling of the assessment (SSB increase, F decrease).
22) **Consistency**: Update assessment, following specifications in the Stock Annex, but with revised reference points following the rescaling in the assessments.
23) **Stock status**: Above B_{lim} and B_{pa}, no F reference points except for F_{cap} (F_{bar}(1-2));
24) **Management Plan**: No management plan, but ICES has evaluated long-term management strategies for Norway Pout following an EU-Norway request

General comments

Given the rapid turnaround for the audit (just a few hours), the auditor only focused on the advice sheet and the relevant inputs from the report, WGNSSK sharepoint, and stockassessment.org (NP_Sep2022_v2) to the advice sheet, and could not check Tables 6-9 of the advice sheet. The stock assessor is to be commended for a rapid turn-around from provision of data to completion of report and advice.

Only minor errors detected, and a potential problem in the advice sheet was cleared up and highlighted as a typo.

Technical comments (advice sheet version 18.0 under released advice on the advice sharepoint, as per 29/09/2022)

- Advice sheet, Table 1 – when taking the observed values in Table 12.2.3a of the report and summing 4th quarter 2021 to 3rd quarter 2022 (this is what was done last year for the corresponding quarters), then the total catch value is 43701 (=30767+743+3650+8541). I could not reproduce 44851, and this has implications for Table 2 and he headline advice. [Subsequently confirmed to be a typo, and the correct value was indeed 43701.]
- Advice sheet, Table 2 and footnote *** – the % catch change column is calculated relative to 44851, and this would need to be rectified (and the footnote changed) if 43701 is the correct value. [Subsequently corrected.]

The following are very minor and could be ignored unless the stock assessor is bothered by it:

- Report section, Table 12.2.11 versus input data from stockassessment.org (NP_Sep2022_v2): very minor discrepancy for the 2-group value in 2020 for IBTS Q3.
- Report section, Table 12.2.4 versus input data from stockassessment.org (NP_Sep2022_v2): very minor discrepancy (but bigger than would be caused by rounding) for the Q4 age 3-group value in 2009.

Conclusions

The assessment has been performed correctly.

Nep.4outFU (*Nephrops*)

General

This stock comprises any ICES rectangles in Area 4 that are not included in other Functional Units. There is no assessment for this area. Landings have been consistently reported since 2011 for this area, while discards have been reported since 2016 but are not considered representative. No new information has emerged that would warrant a change to the previous advice in 2020, thus the same advice was kept for the next two years (2023-2024).

For single-stock summary sheet advice

Stock **nep.27.4outFU**

Short description of the assessment as follows:

22) Assessment type: No assessment (ICES Category 5 stock)
23) Assessment: NA
24) Forecast: not presented
25) Assessment model: NA
26) Consistency: consistent
27) Stock status:
- Landings since 2015 have been consistently higher than the total landings adviced for the area.
- There are no reference points estimated for this stock
28) Management plan: No management plan.

General comments

No discard data is available prior to 2016. Recent data show variable (and probably incomplete) discard rates but relatively high in particular those coming from the Netherlands fleet.

Technical comments

Few inconsistencies were reported to the assessor and have already been fixed in both the advice sheet and report.

Conclusions

The decision to maintain the advice for total landings (301 tonnes) for the next two years was done correctly in accordance with the ICES precautionary approach.

nep.fu.5

General

For single stock summary sheet advice:

1) **Assessment type:** Category 4 with biennial advice (October advice)
2) **Assessment**: Data-limited approach, Method 4.1.4 for Nephrops
3) **Forecast**: A short-term forecast for 2023 and 2024 was presented. Forecast based on latest UWTV survey (2012), mean weights (2018, 2019 and 2021), discard rate (50.5%), assuming zero discard survival.
4) **Assessment model**: None
5) **Data issues:** No issues
6) **Consistency**: No issues
7) **Stock status**:
   - Assuming the current burrow density is the same as 2012, most catch options provided result in a harvest rate below 7.5%. The 2020 advice results in a harvest rate of 3.5%. Therefore, a 20% increase in the 2020 advice is recommended (corresponding to a 4.6% harvest rate). The PA buffer was applied to this stock in the 2020 advice.
8) **Management Plan**: There is no agreement with UK regarding the EU multiannual plan (MAP), and this it is not used as the basis of the advice for this stock. There are no FMSY reference points estimated for this stock. The WG, ACOM and STECF have repeatedly advised that management should be at a smaller scale (FU level) than the ICES subarea level.

General comments

There are catch sampling data available for FU 5 from Dutch fleets since 2015. Due to interruption during the Covid pandemic there were no landings samples for 2020 and the mean individual weights in landings for this advice are calculated from 2018, 2019 and 2021 values.

Technical comments

The advice given in 2020 for 2021 and 2022 was 1570 tonnes. In the advice sheet the value given is 1578 tonnes.

The numbering of tables in the advice sheet jumped from table 5 to table 8, and then table 6 and 7 – numbering needs correction.

There is a small discrepancy in the landings reported in tables for 2015 (1516 vs 1517)

Conclusions

The forecast has been performed correctly with no deviations from the standard procedure for this stock.

nep.fu.6

General

For single stock summary sheet advice:

9) **Assessment type:** Category 1 with annual advice (October advice)
10) **Assessment**: UWTV survey
11) **Forecast**: An updated short-term forecast for 2022 was presented. Forecast based on latest UWTV survey (2022), mean weights (2019-2021), discard rate (26.7%), discard survival (15%) and MSY harvest rates.
12) **Assessment model**: None
13) **Data issues:** No data issues
14) **Consistency**: This stock has been benchmarked by ICES in 2013 (WKNEPH, 2013) and the stock annex was updated.
15) **Stock status**:
    - The 2022 burrow abundance estimate decreased 12% in relation to 2022 but remains just above the Btrigger. The harvest rate increased in 2021 to 11.9% and remains above Fmsy.
16) **Management Plan**: EU multiannual plan (MAP). There is no agreement with the UK regarding the EU multiannual plan (MAP) and it is not used as the basis of the advice for this stock. The WG, ACOM and STECF have repeatedly advised that management should be at a smaller scale (FU level) than the ICES subarea level.

General comments

Technical comments

None

Conclusions

The forecast has been performed correctly with no deviations from the standard procedure for this stock.

nep.fu.7

General

- ICES has been giving catch advice for this stock since 2016.
- It was decided by ICES prior to the 2022 WGNSSK meeting that the advice for North Sea *Nephrops* stocks would be delayed until autumn after the summer surveys. The advice in September 2022 is as such the only advice given this year.
- The abundance in 2022 decreased 12% from 2021, but the stock is above the average abundance over the time series and is well above the biomass trigger (lowest observed absolute UWTV abundance, 1992–2010).
- The harvest ratio in 2021 (4.7%, calculated as dead removals/TV abundance) is below the F_{MSY} proxy (7.5%).
- The 7.6% reduction in the catch advice from 2021 is mainly a result of the decrease in the abundance observed between the 2021 and 2022 UWTV surveys, as well as updated mean weights and discard rates.

For single stock summary sheet advice:

1. **Assessment type:** Annual. Underwater TV survey linked to yield-per-recruit analysis from length data.
2. **Assessment**: Analytical.
3. **Forecast**: A table with catch scenarios for 2023 is included in the advice, assuming recent discard rates.
4. **Assessment model**: Catch options are provided for a range of harvest rates associated with potential Fmsy proxies which are obtained from per-recruit analysis. The survey index is multiplied by the harvest rates to give the number of total removals. Catch biomass is produced by applying mean weight (recent three years).
5. **Data issues:** Input data are of good quality. Sampling of landings and catches is good. The quality of landings (and catch) data is likely to have improved in recent years following the implementation of 'the registration of buyers and sellers' legislation in the UK in 2006. Discard sampling was impacted by the COVID-19 situation in 2020 and 2021; however, sampling in 2021 (quarters 2 and 4) was considered sufficient (coverage 71% of the landings in 2021) to be used for the discard estimates. A continuous annual time series of Underwater TV surveys is available since 1997. The UWTV survey is conducted over the main part of the ground. The FU contains several patches of mud to the north of the ground which are fished, but not surveyed. The absolute abundance estimate for this ground is therefore likely to be somewhat underestimated by the current methodology.
6. **Consistency**: No issues.
7. **Stock status**: The stock abundance is well above the MSY $B_{trigger}$. Landings taken from this FU in 2021 (9559 tonnes) were lower than the 2020 total catch advice (for 2021) of 9579 tonnes. The harvest rate increased in 2021 (in relation to 2020) to 4.7% but remains below F_{MSY}.
8. **Management Plan**: The EU multiannual management plan (MAP) has been agreed for this stock (EU, 2018). There is, however, no agreement with UK regarding this plan, and it is not used as the basis of the advice for this stock.

General comments

This was a well documented, well ordered and structured section. The report section and advice were easy to follow and interpret. Numbers in the advice are correct.

Technical comments

- The Stock annex was last updated in 2015 and could use an update.
- Report:
    - Table 11.5.1: remove “na = not available” beneath table as there are no “na” listed in the table.

Conclusions

The assessment has been performed correctly.

nep.fu.8

General

For single stock summary sheet advice:

1) **Assessment type:** Category 1
2) **Assessment**: UWTV survey, dropped in 2022
3) **Forecast**: An updated short-term forecast for 2022 was presented. Forecast based on latest UWTV survey (2021), mean weights (2019-2021), discard rate (2019-2021), discard survival (25%) and MSY harvest rates.
4) **Assessment model**: None
5) **Data issues:** UWTV not performed in 2022.
6) **Consistency**: In 2020, only commercial catch samples from quarter 1 were available, as a result of the COVID-19 pandemic. As observed discard rates in quarter 1 were lower than average, it was decided to calculate averages for the reference period 2017—2019 and scale to quarter 1 values in 2020. There was no seasonal pattern in discard rate in the past, so the approach was considered appropriate.
7) **Stock status**: The 2021 burrow abundance estimate decreased by 25% in relation to 2020. The harvest rate increased a little but is well below Fmsy. Since the 2022 index was not updated it was assumed equal to 2021.
8) **Management Plan**: Since 2021, ICES MSY approach; previously EU multiannual plan (MAP). There is no agreement with the UK regarding the EU MAP and it is not used as the basis of the advice for this stock. The WG, ACOM and STECF have repeatedly advised that management should be at a smaller scale (FU level) than the ICES subarea level.

General comments

TR2 main gear. Very little discarding the last years, remains unclear why (reporting or change in fishery/landing pattern)

Reduction in stock size 2020 to 2021, But stock size on a high level and fishery below sustainable harvest level.

Size sampling of landings mainly, only little discard sampling. Using last UWTV, Same approach as for FU9 in 2020

Technical comments

As with every other Category 1 functional unit in the NSSK assessment area, advice for FU 8 has been impacted by the ongoing COVID-19 pandemic. However, with the resumption of UWTV surveys in 2021, the assessment could be carried out as normal, and there is no immediate need to reclassify the category of this stock.

Conclusions

The forecast has been performed correctly with the deviations from the standard procedure for this stock mentioned above.

nep.fu.9

For single-stock summary sheet advice

Stock: nep.fu.9

General

FU 9 (Moray Firth) is one of nine Norway Lobster stock units in the North Sea (plus the area outside FUs). ICES advice is given specifically for each individual FU, however EU fishery management uses a combined stock TAC covering FUs 5, 6, 7, 8, 9, 10, 32, 33, 34, as well as regions of Subarea 4 that are outside FUs. FU 9 is a Category 1 (Nephrops) stock: the assessment uses an underwater video survey (UWTV) to estimate absolute abundance.

Short description of the assessment

1) Assessment type: Category 1 (UWTV survey) with annual advice
2) Assessment: Absolute abundance from UWTV survey
3) Forecast: An updated short-term forecast for 2023 was presented. It is based on the latest UWTV survey (2022), mean weights (2019-2021), discard rate (2019-2021), discard survival (25%) and MSY harvest rates.
4) Assessment model: None
5) Data issues: None
6) Consistency: The 2020 UWTV survey was not deemed robust enough for the assessment, because of the reduced number of stations completed due to the COVID-19 disruption on the survey schedule. As such, the stock size for 2020 is unknown. The UWTV survey was resumed in 2021 and has been carried out as normal since then. The harvest rate in 2020 was calculated using an interpolated value for abundance (average of 2019 and 2021).
7) Stock status: F is below the F_{MSY} proxy, and stock size is above the MSY $B_{trigger}$ proxy.
8) Management plan: Since 2021, ICES MSY approach; previously EU multi-annual plan

General comments

This Norway lobster functional unit is generally well documented, and there were no general issues with either the advice sheet or the report section.

Technical comments

None

Conclusions

The assessment has been performed correctly in line with the stock annexe.

nep.fu.10

General

- It was decided by ICES prior to the 2022 WGNSSK meeting that the advice for North Sea *Nephrops* stocks would be delayed until autumn after the summer surveys. The advice in September 2022 is as such the only advice given this year.
- ICES has been giving catch advice for this stock since 2015.
- The most recent UWTV survey was carried out in 2019. The abundance in 2019 was not significantly higher than the abundance in 2014 (second last survey).
- Stock size in relation to reference points is unknown.
- As the stock appears to be very lightly exploited, the advice may be increased to a level corresponding to an acceptable harvest rate (HR), applying an uncertainty cap to restrict annual change to less than 20%. The same advice as given in 2020 + 20% corresponds to a potential HR of 2.3%, which is well below the range of maximum sustainable yield (MSY) harvest rates in the North Sea (7.5%-16%).

For single stock summary sheet advice:

1) **Assessment type:** Biennual. ICES framework for category 4 *Nephrops* stocks.
2) **Assessment**: Precautionary approach.
3) **Forecast**: One table with catch scenarios for 2023 and 2024 is included in the advice, assuming recent discard rates.
4) **Assessment model**: Catch options are provided for a range of harvest rates following the procedure for data poor *Nephrops* stocks. The catch options are based on a calculation of potential landing options and harvest rates, given the known surface area of *Nephrops* habitat and observed densities of the functional unit. Discard percentages and mean weights have been taken from the closest inshore functional unit (FU 9) (Moray Firth).
5) **Data issues:** Levels of market sampling are low and discard sampling is not available. There were no sampling data available for 2015, 2018 and 2020, two sampling trips in 2016, and one trip in each of 2017, 2019 and 2021. The low levels of sampling for this fishery mean it is not realistic to draw conclusions from changes in size composition or sex ratio. An underwater TV (UWTV) survey of this FU has been conducted sporadically (1994, 1999, 2006, 2007, 2014 and 2019). For the 2022 advice, UWTV survey information on the mean density of *Nephrops* (0.22 *Nephrops*/m^2), from the 2019 survey, was used together with discard percentages, and mean weights taken from FU 9.
6) **Consistency**: No issues.
7) **Stock status**: The current state of the stock is unknown.
8) **Management Plan**: The EU multiannual management plan (MAP) has been agreed for this stock (EU, 2018). There is, however, no agreement with UK regarding this plan, and it is not used as the basis of the advice for this stock.

General comments

This was a well documented, well ordered and structured section. The report section and advice were easy to follow and interpret. Numbers in the advice are correct.

Technical comments

- The Stock annex was last updated in 2018 and could use an update:
    - Two different numbers for the spatial extent of the *Nephrops* stock in Noup are provided (409 and 339 km^2).
    - Some figures need to be correctly labelled.
    - Figures and table should be updated.

  - Information on numbers of UWTV surveys conducted in Noup needs to be updated.
  - MLS should be stated in the SA
  - In C. Assessment: data and method: it would be informative to know that the landings mean weight and discard rate borrowed from FU9 are the means of the last three years. Under "Discard survival": delete "25% (from Fladen)" as a discard survival of 0% is used.
- The report chapter
  - "Data available" should be a numbered section (i.e. 11.8.4), now it is included in the Advice in 2020-section.
  - Consider including a "Issues for future benchmarks" section in the report chapter

Conclusions

The assessment has been performed correctly.

nep.fu.32

General

FU32 (Norwegian Deep) *Nephrops* is one of the 9 stock units in the North sea (plus landings outside the FUs). ICES advice is given for the FU with management in place specifically for this FU (unlike the other FUs in the North Sea). This is a category 4 stock where the average landings are looked at in relation to possible reference points.

For single-stock summary sheet advice

Stock **nep.FU32**

Short description of the assessment as follows:

1) Assessment type: No assessment (ICES Category 4 stock)
2) Assessment: NA
3) Forecast: NA
4) Assessment model: NA
5) Consistency: consistent
6) Stock status: Fishing pressure is below possible reference points
7) Management plan: No management plan.

General comments

This was a well documented, well ordered and considered section. The advice procedure is easy to follow and interpret. Input and output data were correct.

Technical comments

Draft advice sheet follows the same process as the previous published advice.

Conclusions

The decision to increase the advice for total catch of 20% (457 tonnes) for the next two years was done correctly in accordance with the ICES precautionary approach.

nep.fu.33

General

- It was decided by ICES prior to the 2022 WGNSSK meeting that the advice for North Sea *Nephrops* stocks would be delayed until autumn after the summer surveys. The advice in September 2022 is as such the only advice given this year.
- ICES has been giving landings advice for this stock since 1992 due to lack of discard data.
- Discards are known to take place for the entire fishery, but discard data are scarce. Estimates are only available from the Netherlands and Denmark, where large differences in discard rates are observed. The data are not believed to be representative for the entire fishery and have not been used to calculate the values (basis) for the catch scenario table.
- The most recent UWTV survey was carried out in 2021. The estimated 2021-density of 0.22 burrows per m^2 is three times higher than the two previous estimates (2018 and 2019), but the number of stations was only 28. The 95% CI reflects the lower sample size, but its lower bound is around 0.2 burrows per m^2, supporting the conclusion of an increase in abundance for FU 33 in 2021.
- Stock size in relation to reference ponts is unknown.
- As long as the harvest rate is less than or equal to 7.5%, the default basis for advice is that catches can be increased from the previous advice, within the 20% uncertainty cap. The precautionary buffer was last applied in 2019 and therefore has been applied this year.

For single stock summary sheet advice:

9) **Assessment type:** Biennial. ICES framework for category 4 *Nephrops* stocks.
10) **Assessment**: Precautionary approach. Data-limited approach for *Nephrops.*
11) **Forecast**: One table with landings scenarios for 2023 and 2024 is included in the advice.
12) **Assessment model:** Data limited approach for *Nephrops* calculates harvest rate (HR) based on ratio of dead removals to population numbers (i.e. individuals). Population numbers are calculated from an observed density estimate for this functional unit (FU) derived from an UWTV survey conducted in 2021 (0.22 ind m^{-2}), multiplied by FU 33 habitat area (5737 km^2). Mean weight in landings (40.57 g) is a Danish value from this FU from 2015. An assumed mean discard weight of 17.2 g (Danish value from 2015) and an assumed maximum 25% discard rate is used for calculation of the harvest rates.
13) **Data issues:** Discard data exist, but are not considered representative and are not used to formulate catch advice. It is currently not possible to update mean weight estimates for landings because current sampling levels are too low. No length data were available from Denmark from 2017–2021. Between 2016 and 2021, Dutch discards included length information. Due to a National minimum landing size, a large majority of the Dutch discards are above the MCS of 25 mm set for the North Sea and, thus, not considered representative for the other countries.
14) **Consistency**: No issues
15) **Stock status**: Stock and exploitation status is unknown. The most recent TV survey estimate from 2021 suggests that the population density has increased recently.
16) **Management Plan**: The EU multiannual plan (MAP) for stocks in the North Sea and adjacent waters applies to catches of this stock. The MAP stipulates that when the FMSY ranges are not available, fishing opportunities should be based on the best available scientific advice

General comments

The advice and assessment were well documented.

Technical comments

- The Stock annex needs to be updated (last updated in 2016).
- The report chapter:
  - Insert numbered headings for the first sections of the report chapter
  - Figure 11.10.1 The figure caption should state from what country/countries the mean size values come from. Perhaps comment on the low mean size also in 2020 in this figure (not just 2005 and 2011), as the 2020-value is the lowest in the time-series
  - The HR table in the report is not updated
  - Consider including a "Issues for future benchmarks" section in the report chapter
- Advice
  - All comments in advice need to be considered
  - Table 8: harvest rates are calculated using the landings, not total catch. The table needs to be corrected with harvest rates based on catch.
  - The same applies to values in the % harvest rate column in Table 2

Conclusions

The assessment has been performed correctly with no deviations from the standard procedure for this stock.

nep.fu.34

General

For single stock summary sheet advice:

1) **Assessment type:** Category 4
2) **Assessment**: ICES precautionary approach.
3) **Forecast**: An updated short-term forecast for 2022 was presented. Forecast based on latest UWTV survey (2021), mean weights (average for landings 2007-2010 from benchmark, and discards for 2019-2021 from FU7), discard rate (2008-2011 from benchmark), discard survival (0%) and MSY harvest rates.
4) **Assessment model**: None. UWTV survey usually performed for relative estimation, but dropped in 2022
5) **Data issues:** Sizes in Landings from 2007-2010 benchmark and discards from FU7. UWTV not performed.
6) **Consistency**:
7) **Stock status**: The 2019 and 2021 stock estimates were higher than average with little change between the years. Since the 2022 index was not updated and exploitation rate was considered quite high in the area some caution was issued.
8) **Management Plan**: ICES is aware of the EU multiannual management plan (MAP) that has been agreed for this stock and considers it to be precautionary when implemented at the functional unit level. There is no agreement with UK regarding this plan, and it is not used as the basis of the advice for this stock. For this stock it is not possible to estimate FMSY ranges, therefore ICES continues to give advice based on the ICES precautionary approach

General comments

Data for this FU have diverse origins. Landings data and UWTV are usually taken from FU 34. Size information and discard rates are from other FU's or benchmark estimates. A quantitative evaluation is difficult, and the advice relies on relative measures.

The last years the catch has dramatically exceeded the TAC-advice. Implementation of TAC on FU-level is needed to reach sustainable catch levels in several FUs, and particularly FU 34.

Technical comments

Conclusions

The forecast has been performed correctly with no deviations from the standard procedure for this stock.

nep.fu.3-4

Stock: nep.fu.3-4

General
The advice for FU 3-4 combines the two functional units in Division 3.a: FU 3 (Skagerrak in 3.a.20) and FU 4 (Kattegat in 3.a.21). FU 3-4 is a Category 1 (Nephrops) stock: the assessment uses an underwater video survey (UWTV) to estimate absolute abundance.

Short description of the assessment

1) Assessment type: Category 1 (UWTV survey) with annual advice
2) Assessment: Absolute abundance from UWTV survey
3) Forecast: An updated short-term forecast for 2023 was presented. It is based on the latest UWTV survey (2021), mean weights (2019-2021), discard rate (2019-2021), discard survival (25%) and MSY harvest rates.
4) Assessment model: None
5) Data issues: None
6) Consistency: This stock has been benchmarked by ICES in 2016 (WKNEPH, 2016). The area covered by the UWTV survey was gradually expanded between 2008 and 2017. Since 2017, the surveyed area has been consistent. No UWTV survey was carried out in 2022. The advice for 2023 is therefore based on the 2021 abundance estimate.
7) Stock status: F is below the F_{MSY} proxy, and has been since at least 2017. The abundance since 2017 has steadily declined; no reference points for stock size have been defined for this stock.
8) Management plan: EU multiannual plan (MAP) for the North Sea (EU, 2016)

General comments
This Norway lobster functional unit is generally well documented, and there were no general issues with either the advice sheet or the report section.

Technical comments
Some discrepancies were flagged up between tables on the advice sheet and in the report section. These did not affect the advice and have been corrected.

Conclusions
The assessment has been performed correctly in line with the stock annex.

Annex 5: Benchmarks and prioritisation

This section was updated in October 2022

Benchmarks

A.1.1 Executive Summaries of recent benchmarks

Two benchmarks that involved WGNSSK stocks were organised in 2021–2022. The WKNSEA benchmark was convened to evaluate the appropriateness of data and methods to determine stock status for Northern Shelf haddock (had.27.46a20) and plaice in the North Sea (ple.27.420). Furthermore, an interbenchmark workshop (IBP) was convened in 2022 for Eastern Channel sole (sol.27.7d) to adjust assessment model configuration and tuning indices.

A.1.1.1 Haddock in 4, 7.d and 20 (WKNSCS 2022)

The primary reason for this benchmark was that support for the assessment model, TSA, would soon be unavailable due to the imminent retirement of the model developer. The assessment model was updated to SAM. Additionally, several updates were made to the input datasets:

- Update of catch data and natural mortality estimates from the latest WGSAM key run.
- Change from constant knife-edged maturity estimates to an age and time-varying maturity ogive.
- Update of the estimation of stock weights at age at the beginning of the year using annual commercial catch weights at age and correction factors based on Q1 survey data.
- The use of modelled survey indices, including both the North Sea and West of Scotland.

The fishing mortality was correspondingly estimated to be higher whereas the more recent peaks in recruitment were estimated to be lower. These changes were primarily driven by the new abundance indices. New reference points were calculated, assuming a stock type 1 (with spasmodic recruitment) and the inputs to the short term forecast were updated in line with the new assessment model software. Due to the low amount in catches, industrial bycatch is not treated as a separate fleet in the forecast anymore.

A.1.1.2 Plaice in 4 and 20 (WKNSCS 2022)

The benchmark was required to address residual patterns of the model and issues with the plusgroup which tends to accumulate a large proportion of the SSB. At the benchmark meeting the assessment model was updated from AAP to SAM. Additionally, several updates were made to the input data sets:

- Age-specific time-invariant natural mortality estimates following of Peterson- Wroblewski method were used.
- Combined BTS+IBTS Q3 indices were included.

The benchmark update led to changes in the fishing mortality, recruitment and SSB. Now, the plusgroup is estimated to contain a relatively lower proportion of the stock. New reference points were calculated based on a type 5 S–R plot.

A.1.1.3 Sole in 7.d (IBPSol7d 2022)

The Interbenchmark protocol on eastern English Channel sole (IBPSOL7d) was convened because the Working Group on the Assessment of Demersal Stocks in the North Sea and Skagerrak (WGNSSK) rejected the 2022 stock assessment due to a likely trend in survey catchability of the UK beam trawl survey (UK BTS) index and poor fit of the State-space Assessment Model (SAM) to observed catches. IBPSOL7d was primarily tasked with adapting the method of the calculation of the Belgian commercial beam trawl tuning fleet (BEL CBT), adapting the configuration of SAM, and updating the reference points. During this IBP, the calculation of the BEL CBT index was slightly modified to allow for a more robust index over time. More specifically, the threshold on the rectangles included in the calculation was removed. The possibility of allowing trends in the catchability of the UK BTS survey index in the SAM model was explored but was eventually rejected because similar model outcomes could be achieved with alternative model parameterisation and concerns about the appropriateness of this feature. In the final SAM model agreed at the IBP, the revised BEL CBT index was included, the auto-regressive correlation structure for catches at age (“obsCorStruct”) was removed to allow for more flexibility of the modelled catches to better match observations, and UK BTS data for ages 1–3 in 2010–2021 were removed because the inclusion of these data resulted in a deterioration of cohort tracking, possibly caused by ageing problems or changes in the survey catchability. These changes improved the model fit compared to the previous model and model diagnostics were appropriate. The calculation of the reference points was conducted with Eqsim and following the ICES technical guidelines. The stock-recruitment relationship was evaluated as type 5, showing a stock with no evidence that recruitment has been impaired or with no clear relation between stock and recruitment. The short-term forecast methodology was modified to provide a more consistent estimation of recruitment. In particular, forecast recruitment is now the median value from resampling over the period 2012–2020. This shorter time period was chosen because of the lower recruitment regime in the most recent years. The last data year is not considered as uncertainty is larger.

A.1.2 Benchmarks for 2023

A.1.2.1 Striped red mullet

Data available/needed

Current assessment issues

Proposed working papers/analyses

Work plan for benchmark

The issue list for Striped red mullet (mur.27.3a47d) is given below.

Issue	Problem/Aim	Work needed / possible direction of solution	Data needed to be able to do this: are these available / where should these come from?	External expertise needed at benchmark type of expertise / proposed names
(New) data to be Considered and/or	Even if discards are expected to be very low (no minimum landing size, high price), discards data	Review data available in Intercatch once more.	Review data available in Intercatch once more.	Data analysis

quantified	should be re-investigated.			
	Age and length sampling coverage for that stock remain to low (usually around 20% in 2021 only 8.7%). All of the sampling come from FR fleets for age and FR-UK and a bit NL for length. Most of the sample are collected in 7d.	Sampling strategy needs to be revised at national/EU levels to allow better coverage at least for length. The use of RDBES could allow the use of age-length-key from France sampling to allocate age to other country	Commercial landings and discards age and/or length data covering 3a, 4 and 7d area for all main fishing fleets (FR,UK, NL and BE) from 2003 onwards	Data analysis
Tuning series	The survey index currently used only covers area 7d and not the all stock area. Other survey data should be investigated again.	Analyse IBTS, and BTS surveys data in area 3a 4 and 7d to derive a age/length based abundance index or a non-structured abundance index.	DATRAS survey data for all relevant surveys.	GAM or GLMM expertise to derive several or a combine abundance index.
	CGFS survey data issue in index calculation needs to be fixed, as well as the lack of sampling in UK water in 2020.	GAM or GLMM methods such as the method developped by Berg et al. or Thorston et al. should be explored to account for missing data UK haul in 2020 and also better account for the change in vessel in 2014 if needed.	DATRAS survey data	GAM or GLMM expertise
Biological parameters	Update growth, maturity and natural mortality	Fit VB growth curve and calculate maturity ogive. Analysis have been already carried on for growth curves and partly for maturity at age	Data from French commercial and survey sampling	
Assessment method	Assessment model was rejected by WGNSSK 2021 and a	Explore new a4a model formulation to try to fix	tuning series, commercial catches by age	a4a & two stage biomass (bbm) expertise

	category 5 advice is given for this stock	the current issue or new model such as two-stage biomass model.		
		Explore the use of surplus production model (SPiCT)	tuning series, commercial catches, official landings	SPiCT expertise
Biological Reference Points	Stock status is assessed using length based methods only.	Explore possibility to use SPiCT to assess stock status	tuning series, commercial catches, official landings	SPiCT expertise
		If age based model applied try to derive reference points from it	tuning series, commercial catches by age	a4a & two stage biomass (bbm) expertise
		If none of the above methods are applicable derive references points proxies from the new length based empirical approach	tuning series, commercial catches by length	WKLIFE X methodologies expertise
Forecast	No forecast is provided for this stock	Depending on the assessment model used and the data available, explore the possibility to provide forecast.		
Other				

A.1.3 Benchmarks for 2024 and beyond

There remain a few Category 3+ stocks that have not yet been benchmarked, namely bll.27.3a47de (brill), pol.27.3a4 (pollack) and gug.27.3a47d (grey gurnard).

At an upcoming WKMSYSPiCT meeting to develop SPiCT assessments, flounder (fle.27.3a4), lemon sole (lem.27.3a47d), brill (bll.27.3a47de) and whiting (whg.27.3a) should be considered.

The stock already selected for benchmark in 2024 are pok.27.3a46 (saithe) to improve data input and account for the recent low productivity regime in the forecast. The group recommends including also pollack (pol.27.3a4) and sole (sol.27.4) in a benchmark in 2024 with high priority. In case, further stocks can be included in a benchmark, brill (bll.27.3a47de), plaice (ple.27.d), grey gurnard (gug.27.3a47d) and Norway pout (nop.27.3a4) could be considered.

Full benchmark issue lists for these stocks will be developed in the coming year.

A.2 Benchmark prioritisation

Benchmark prioritisation was conducted according to the scheme described in Table A2.1. Table A2.2 provides a summarised list of benchmark issues for each stock, and applies the scoring scheme to each stock. The finfish stocks listed in Table A2.2 have been ordered from highest to lowest score.

Table A2.1. Prioritisation scoring used in Table A2.2.

Category	1. assessment quality	2. Opportunity to improve	3. Management importance	4. Perceived stock status	5. Time since last benchmark
Scoring / weight	0.4	0.3	0.1	0.1	0.1
5	Assessment judged to be inadequate to provide advice (e.g., bias, stock id, unreliable catches, major change in biological processes/productivity)	New approaches <u>and</u> new data sources will be available for the stock, and these are likely to address issues or change perception of stock dynamics	All 4 attributes: a) Advice on fishing opportunities is requested for the stock. b) Stock is the object of an agreed management plan. c) Stock is the object of a directed fishery. d) Stock is included in a mixed fishery analysis, is a likely choke stock, or the object of a pelagic fishery (meets 1 of the 3)	Most likely below B_{lim}, or stock is in rapid decline, or state of the stock unknown	Stock has never been benchmarked
4	Assessment has high potential & priority to be upgraded to Cat. 1 from Cat. 3 or to Cat. 3 from Cat. 5 and 6	New data sources or corrections in data, <u>or</u> new methods will be available for the stock, and these are likely to address issues or change perception of stock dynamics	3 attributes	Between B_{lim} and MSY $B_{trigger}$	Stock has been benchmarked 10 years or more ago
3	Assessment judged to have substantial deficiencies (models and/or data) but considered acceptable	Some improvement in data /modelling approaches will be available, and unclear whether they will address issues or change perceptions	2 attributes	About MSY $B_{trigger}$	Stock has been benchmarked between 5 and <10 years ago
2	Assessment has no substantial or only minor issues	Minor improvement in data or methods will be available	1 attribute	Above MSY $B_{trigger}$	Stock has been benchmarked between 1 and < 5 years ago
1	Assessment has no obvious issues	No change in data or models will be available	No attributes	Near highest on record	Stock was benchmarked in the last year

Table A2.2. Benchmark prioritisation scoring for WGNSSK finfish stocks along with issues. The weighting for the scoring categories is according to Table A2.1. Stocks have been ordered from highest to lowest total score.

stock	Type	Benchmark Issues			Scoring Categories					Total
		data and stock ID	assessment	forecast and reference points	1	2	3	4	5	(weighted)
mur.27.3a47d	Cat 3 No TAC	- Age data from other countries than France need to be provided as everything is actually raised using the French catches in the Eastern Channel and few sample from the North Sea. - Length data is mainly provided by France and a also UK with recently some submission from Netherlands, however the sampling coverage remain to low and further sampling is required. - No survey is available in the North Sea; IBTS/UK BTS should be investigated again. So work was done to assess the representativeness of the Eastern Channel data compared to the stock, but these should be investigated further - CGFS survey data issue in index calculation needs to be fixed. GAM or GLMM methods such as the method developped by Berg et al. or Thorston et al. should be explored to account for missing data UK haul in 2020 and also better account for the change in vessel in 2014.	- Assessment model was rejected by WGNSSK 2021 and a category 5 advice is given for this stock. - With so few age classes exploited the a4a model formulation used needs revision as it is no longer fit to give advice. - Explore other models (SAM, SURBAR, length-based model…) - Explore methods applied to "short lived species" (two stages model)? - SPiCT should be explore again either as basis for advice or to estimate the stock status.	- This stock was downgraded to category 5, so no forecast is done currently. This should be investigated if the assessment method is improved. However, there is no TAC for that stock so Forecast is not a priority, although reference points are still important.	5	4	2	5	3	**4.2**

stock	Type	Benchmark Issues			Scoring Categories					Total
		data and stock ID	assessment	forecast and reference points	1	2	3	4	5	(weighted)
		- Even if discards are expected to be very low (no minimum landing size, high price), discards data should be re-investigated - Based on the recent WD presented at WGNSSK2020 stock ID should be reinvestigated								
tur.27.3a	Cat 2 No TAC	- review of knowledge, including genetic findings, and turbot migrations and spawning grounds - Stock definition - dealing with the missing Swedish catches - overview of recreational catches - dealing with a reduction in sampling for length - survey data to be investigated and mapped in more detail (including options for a combined Delta-GAM index for the entire stock area) - update of Cardinale et al (2009) survey time series	-advance assessment (SPiCT)	-develop reference points	5	5	2	2	1	**4**
pol.27.3a4	Cat 5 No TAC	- Examine if data exist that allows the determination of age and size of maturity ; - Explore the potential availability of data that would allow the determination of size/age in catches and	-develop an assessment if possible	-develop reference points if possible	5	3	1	5	5	**4**

stock	Type	Benchmark Issues			Scoring Categories					Total
		data and stock ID	assessment	forecast and reference points	1	2	3	4	5	(weighted)
		the possibility to determine reference points								
cod.27.47d20	Cat 1 shared	-develop spatial approaches to better account for stock structure and linkages to 6a -investigate the significance of spawner age on reproductive potential -investigate perceived catchability problems in IBTS surveys (age reading issues as well as emmigration?) -investigate the possibility of including recreational catches	- combine the North Sea and West of Scotland assessments '-develop spatial assessment approaches to account for sub-stock structure	-explore potential biases in the forecast and how to deal with these	3	5	5	5	2	**3.9**
whg.27.3a	Cat 3 PA	-explore stock ID	-develop assessment (SPiCT)	-develop reference points -develop advice based on short term forecast	4	4	3	5	1	**3.7**
nep.fu.32	Cat 4 PA	Sampling of trawl catches by the Norwegian coast guard should be improved by sexing individuals and sampling discards and landings components separately to enable discards estimations. An UWTV survey should be carried out to explore and map distribution and density	Assessment methods for data poor stocks should be explored		3	4	3	5	5	**3.7**
pok.27.3a46	Cat 1 shared	Stock definition – The North Sea saithe stock is influenced by migrations to and from the North Sea. This can potentially lead to the observed year effects in survey	Variance by age – The last inter-benchmark for saithe in 2019 revealed that uncoupling of the variance parameters for the observations by age (i.e. age 3 receiving a	The effect of the current low productivity regime of the stock (i.e. lower recruitment) on reference points should be investigated.	3	4	5	4	3	**3.6**

stock	Type	Benchmark Issues			Scoring Categories					Total
		data and stock ID	assessment	forecast and reference points	1	2	3	4	5	(weighted)
		indices. It needs to be analysed if the inclusion of spawning grounds north of 62°N could improve the assessment. Planned tagging studies may also aid in this. Recreational catches, to inform quality of the assessment (likely not a big deal in NS, but possible influence from the Norwegian Sea recreational fishery if connected populations). New survey indices – IMR-Norway has set-up a new hydro-acoustic survey targeting spawning aggregations in Quarter 1. Germany has also participated in this survey in recent years. The inclusion of this survey in the assessment should be evaluated once a sufficiently long time series has been developed. The use of the Norwegian summer accoustic survey (NORACU) - formerly dissmissed during the 2016 benchmark on the ground of (now corrected) inconsistencies - should also be re-evaluated. Catch-per-effort index – The	separate parameter) could improve the model fit statistics (e.g. log-likelihood, AIC). This should be investigated further. CPUE index - issues exist on the calculation method / model. Improved methods exist for deriving yearly indices in the CPUE model. The fix maturity ogive assumption should be re-evaluated, especially in the light of improved sampling during the spawning season (Q1 acoustic survey). Survey Index - time series has been updated using new ALK-matching methodology	Recruitment forecast: downward trend in the recruitment has proven problematic. Options to account for auto-correlation (both in model and forecast) should be considered.						

stock	Type	Benchmark Issues			Scoring Categories					Total
		data and stock ID	assessment	forecast and reference points	1	2	3	4	5	(weighted)
		current commercial CPUE index is standardized for area and engine power effects and is not able to account for spatial and temporal effects interactions. The inclusion of alternative explanatory variables (e.g. vessel effect) and spatio-temporal effects should be evaluated. Obsolescence of DATRAS products: the phasing out of IBTS DATRAS indices (Q3 used in the current assessment), together with future phasing in of a new IBTS trawl (IBTSWG 2022), entails consideration of alternative index modelling approaches, such as the popular delta-GAM approach, in case IBTS series were to be kept in the assessment (to be evaluated too).								
pol.27.3a4		- Examine if data exist that allows the determination of age and size of maturity; - Explore the potential availability of data that would allow the determination of size/age in catches and the possibility to determine reference points most likely through the use of data limited approaches	-develop an assessment if possible	-develop reference points if possible	4	3	1	5	5	**3.6**

stock	Type	Benchmark Issues			Scoring Categories					Total
		data and stock ID	assessment	forecast and reference points	1	2	3	4	5	(weighted)
sol.27.4	Cat 1 EU	- Explore data giving rise to larger discards estimates for fish aged 6+	- Evaluate alternative natural mortality at age vectors. Current low values at younger ages appear to be behind model misspecification and retrospective pattern. - Consider changes in time in natural mortality given the trends in mean weight and length at age. Could a larger M in recent years for smaller younger fish be behind the overestimate of the effect of the 2018 cohort on SSB? - Consider what the effect of the 1963 larger M is on the model estimation. Such a shock at the start of the series appears to create great difficulties. - Incorporation of age 0 could allow more [precise information on recruitment and cohort strength to be used 9(SNS, DFYS)	-Use of age 0 information from SNS and DYFS to get earlier information on recruitment strength	3	4	4	4	2	**3.4**
nop.27.3a4	Cat 1 shared	- Investigate size-at-age and derived weight-at-age in how it affects model estimation in terms of sampling accuracy and precision achieved under the current design and the most statistically rigorous	- Investigate retrospective patterns in the assessment among other in relation to the Mohn´s Rho values for recruitment, SSB and F. - Introduce procedure in SESAM to	- The consumption amount of Norway pout by its main predators should be evaluated in relation to production amount in the Norway pout stock under consideration of consumption	3	4	3	2	3	**3.2**

stock	Type	Benchmark Issues			Scoring Categories					Total
		data and stock ID	assessment	forecast and reference points	1	2	3	4	5	(weighted)
		way to impute values for years where these data are missing or in question. - There are currently two recruit indices (age 0 from SGFS and EGFS) being used in model parameter estimation. To avoid duplicative information being introduced into the assessment, a method should be developed that combines the Scottish and the English indices into a single robust index. In general GAMM analyses should be conducted to explore further integration of survey time series. - Investigate error variances of the data that concerns sampling mechanics, sampling theoretics and sampling designs for both fishery-independent data, and for those obtained from the fleets.	make one-out-standard analyses of tuning time series. - Develop additional standard diagnostic tools for performance for the new SESAM model: (i) a better format for displaying and interpreting standardized model residuals over time (the bubble plots are horizontally compressed and very difficult to read and interpret); (ii) performance statistics based on prediction skill (e.g., how well does the model predict when a data point is removed?); (iii) likelihood profiles (if there is tension in the model, where does it occur?); (iv) some depictions of any gradient problems that may exist; (v) summary tables with AIC/BIC values for models using the same data (i.e., documentation of all intermediate models tested before arriving at the final choice of parameter coupling); (vi) statistics for model goodness-of-fit.	and production of other prey species for those predators in the ecosystem. This has implications for setting of Blim levels. - Sensitivity runs on the assumptions of time invariant growth, maturity and natural mortality may need to be considered. For the short term, projections that include different ways to handle mean weight-at-age, including projecting forward with specified uncertainty, should be more fully explored (smoothed historic time series, average over some recent time period, etc.).						
lem.27.3a47d	Cat 3 PA	The current survey indices used for North Sea lemon sole are not able to track cohort strength on a consistent basis, and they exhibit generally poor catchability	A new method of estimating age-based survey catchability coefficients is needed to help to address the problem of negative Z estimates. Age data are lacking from	Reference points are currently based on length-based indicators, and further work could help derive more robust estimates. If a length-based (or	3	4	2	3	3	**3.2**

stock	Type	Benchmark Issues			Scoring Categories					Total
		data and stock ID	assessment	forecast and reference points	1	2	3	4	5	(weighted)
		characteristics which limit the reliability of the advice based thereon. It would be very beneficial to be able to include commercial catch data in the assessment in order to improve reliability and reduce variability. The erroneous length data submitted to InterCatch for 2013 also need to be corrected.	commercial catch data, so a (spatial) length-based assessment using both catch and survey data should be explored (for example, Stock Synthesis 3). It may also be appropriate to reconsider the use of SPiCT as the basis for advice – this was tested and shown not to work at the last benchmark (ICES 2018), but new survey series may improve the applicability of the method.	SPiCT) assessment can be developed using commercial and survey data, a full stochastic forecast method should be explored.						
bll.27.3a47de	Cat 3 PA	- Investigate the availability of more data on this stock (including length and age distributions; discards and BMS landings or historical catches); - Investigate InterCatch raising and length/age allocation procedures also considering area and quarter besides gear; - Explore the availability of more appropriate tuning fleets (both commercial and survey) also in the 3a, 7d and 7e area and revise the current biomass index series (cfr. Tur4 assessment); - investigate biological parameters - Investigate how the biomass index should be corrected for technological creep and changes in the	- Explore whether SPiCT can be further developed as assessment model for Brill. - Further develop the LBI methods once longer time series are submitted.	-calculate reference points based on any new assessment for the stock	3	3	2	3	5	**3.1**

stock	Type	Benchmark Issues			Scoring Categories					Total
		data and stock ID	assessment	forecast and reference points	1	2	3	4	5	(weighted)
		Dutch fleet (Dutch fleet has an increasing amount of pulse trawlers compared to the beginning of the series, who switch back to beam trawl in the most recent year) and investigate the current calculation method of the Dutch lpue series								
ple.27.7d	Cat 1 EU	- evaluate FR GFS index, remove potential vessel affect from the data (possibility of splitting the time series of the index) - investigate if new maturity data are available and useable - data required to update Q1 migration	- test new maturity ogive and Q1 removal	- no issues currently	3	3	5	2	3	**3.1**
gug.27.3a47d	Cat 3 No TAC	- investigate ways to raise discards for métiers with zero landings but no discards reported - investigate potentially better ways to deal with the "generic gurnard grouping" problem for some nations (e.g. Germany and the UK)	- exploratory SPiCT model	- investigate the use of rfb, chr HCR	3	2	1	5	5	**2.9**
nep.fu.34	Cat 4 PA				2	3	3	5	4	**2.9**
nep.27.4outFU	Cat 4 PA	At WGNSSK 2021, the question was raised whether data from the Dutch landings and discards length sampling programme from 2015 onwards might contain errors due to issues with processing codes. This question has been resolved	No changes to the assessment are anticipated	No reference points have been determined	3	1	3	5	5	**2.8**

stock	Type	Benchmark Issues			Scoring Categories					Total
		data and stock ID	assessment	forecast and reference points	1	2	3	4	5	(weighted)
		and there will be no resubmissions to InterCatch.								
nep.fu.5	Cat 4 PA	The only UWTV survey from 2012 is becoming increasingly outdated, which affects the reliability of the estimates of harvest rates. Additionally, recent landings from rectangles outside FU 5 indicate that the eastern part of the functional unit might be connected to a population of *Nephrops* extending towards the northeast outside the functional unit.	No changes to the assessment are anticipated from an outdated UWTV survey, as the abundance is not used in the PA strategy. A redefinition of the boundaries of FU 5, together with the establishment of a new functional unit to the east, would also not affect the PA strategy of a Category 4 stock. However, the new advice value would have to be rescaled according to the relative historical proportion of landings inside and outside the new FU boundaries.	No change to the reference point is anticipated	3	1	3	5	5	**2.8**
tur.27.4	Cat 1 EU	-The available scientific surveys (SNS and BTS-ISIS Q3) have a low internal consistency especially for older ages leading to a low ability to track cohorts over time. - Estimates of discards are available (e.g. Dutch discards are available for 1999-present), however, age-length information is very limited. - More work needed on obtaining LPUE data from other Member States, given the heavy reliance of the assessment on the Dutch LPUE data.	- The over-reliance of the assessment on a single LPUE time series is potentially a problem that may need further investigation, for example by using CVs associated with the estimated index directly in the assessment. - Investigate the use of a more appropriate selectivity in the assessment to construct a model-equivalent index for LPUE	- uncertainty in recruitment and forecast is based on landings instead of catches.	3	3	2	2	2	**2.7**

stock	Type	Benchmark Issues			Scoring Categories					Total
		data and stock ID	assessment	forecast and reference points	1	2	3	4	5	(weighted)
		- A detailed analysis of delta GAM indices with various settings should be carried out once more age information becomes available. -alternatives to smoothing of mean weights-at-age from the fishery to be investigated								
fle.27.3a4	Cat 3 No TAC	- investigate ways to raise discards for métiers with zero landings but no discards reported - investigate ways to raise discards for shrimper fleets operating in coastal waters for which no suitable data are available	- Investigate what could be done/changed to improve the SPiCT model (e.g. include effort data) - Investigate the use of alternative stock indices (DYFS, DFS) which are able to better reflect the stock status -other stock indicators available? e.g. WFD monitoring from coastal areas - evaluate biological data, e.g. growth, maturity - age data are available, SURBAR to be tested	- Investigate available growth data and use of rfb and chr HCR	3	2	1	5	2	**2.6**
wit.27.3a47d	Cat 1 MSY	- no issues currently	-The choice of proportion of fishing mortality and natural mortality before spawning (Fprop and Mprop) to be equal to 0.5 should be evaluated for its biological reasoning.	- The calculation of reference points is based on the whole time series (1940 - 2016), which includes the period before the data start (1940 – 1949) and the period where catch is the only available information (1950 – 1982). The adequacy of the assessment to estimate SSB and recruitment	2	3	3	2	3	**2.5**

stock	Type	Benchmark Issues			Scoring Categories					Total
		data and stock ID	assessment	forecast and reference points	1	2	3	4	5	(weighted)
				during that period should be evaluated, especially concerning their use in estimating reference points.						
dab.27.3a4	Cat 3 No TAC	- investigate ways to raise discards for métiers with zero landings but no discards reported - investigate ways to raise discards for shrimper fleets operating in coastal waters for which no suitable data are available - Investigate extending the delta-GAM index with Belgian and German BTS data (prior to 2002). - Change to a swept area index and compare with old index	- Investigate the use of DYFS, DFS inshore surveys to estimate a recruitment index - Improve the SPiCT model which was recjected in 2022 - evaluate biological data for growth, maturity	- investigate HCR from WKLIFE X	3	2	1	1	2	**2.2**
nep.fu.10	Cat 4 PA				2	1	2	5	4	**2.2**
whg.27.47d	Cat 1 shared	-stock identity (SURBAR runs by component, not an issue yet) -historical stock weights at age re-estimated every year (reconsider if significant changes in historical time series, not issue yet) -include natural mortality estimates (WGSAM) when available (not an issue yet) -DATRAS indices (new French data upload for historical series), exploration of delta GAM method for index calculation	- impact of new 2020 SMS keyrun (WGSAM, 2021) estimates of natural mortality on assessment model: SSB retros just within acceptable limits defined by WKFORBIAS -use of unsmoothed maturity and natural mortality estimates as input (using the new SAM method to estimate missing historical values and forecast) - decreasing abundance of old age classes which required a model	-further investigate alternative SAM forecast (recruitment assumption, split of catches) -Reference points estimated with EqSim with the new survey indices are slightly different from the ones estimated during the 2018 benchmark. - Reference points estimated in 2022 after SAM model update, slightly higher values than those from the 2021 IBP but similar	2	2	4	2	2	**2.2**

stock	Type	Benchmark Issues			Scoring Categories					Total
		data and stock ID	assessment	forecast and reference points	1	2	3	4	5	(weighted)
			update in 2022 (8 plus group to 6 plus group)							
sol.27.7d	Cat 1 shared	- investigate the mechanism of the declining trend in weights-at-age and its impact on the catchability; - investigate natural mortality and maturity - investigate the poorer tracking of cohorts and internal consistency in the UK BTS Q3 tuning fleet	none	none	1	2	5	4	1	**2**
ple.27.420	Cat 1 shared	- WGBEAM indicates an increasing age 0 selectivity in BTS while a decreasing sel in SNS (aim for age0), maybe a combined DYFS-SNS-BTS-IBTSQ3 indices to have the complete spatial and age coverage - Explore stock ID trend and difference between NS and NW-NS: maturity/mortality/sex ratio/growth rate/LF/survey_indices	- "error" in discards due to non-zero survival in assessment (~9%), might lead to overestimate of stock size - explore the impact of age reading error on assessment - there are still some residual age-year patterns for older ages in the BTS+IBTSQ3	- Considering density-dependent growth in reference point calculation?	1	2	5	2	1	**1.8**
nep.fu.7	Cat 1 EU	No known issues	No changes	No changes	1	1	4	2	4	**1.7**
nep.fu.8	Cat 1 EU	No known issues	No changes	No changes	1	1	4	2	4	**1.7**
nep.fu.9	Cat 1 EU	No known issues	No changes	No changes	1	1	4	2	4	**1.7**
had.27.46a20	Cat 1 shared	Investigate indices of reproductive potential and methods to use them in management advice. Explore substock population structure. Address spatial residual patterns in the modelled indices. Consider using survey coefficient of variations	Address residual pattern in the plus group (increase plus group age). Explore model settings to minimise patterns seen in the model residuals.	Review forecast settings for selectivity in line with those recommended by model developer.	2	0	5	2	1	**1.6**

stock	Type	Benchmark Issues			Scoring Categories					Total
		data and stock ID	assessment	forecast and reference points	1	2	3	4	5	(weighted)
		as relative weightings as an assessment model input. Investigate ecosystem drivers for long term forecasts/MSE.								
nep.fu.6	Cat 1 EU	No known issues with data that require a new benchmark	No changes to the assessment are anticipated	No change to the reference point is anticipated	1	1	3	2	4	**1.6**
nep.fu.33	Cat 4 PA	Data from the Dutch landings and discards length sampling programme from 2015 onwards contain errors due to issues with processing codes and need to be resubmitted to InterCatch. On the basis of the revised sampling data, raised discards will then be recalculated. Also, the individual mean weights in landings and discards will be recalculated.	The assessment is based on the harvest rate estimate in relation to the MSY proxy of 7.5%. With the revised discard rates and mean weights, the harvest rates from 2015 will be revised, with potential impacts on the next advice due in 2022.	No change to the reference point is anticipated						**0**
nep.fu.3-4	Cat 1 EU									**0**

Annex 6: Update forecasts and assessments

The Section was added to the report in October 2022

The Working Group on the Assessment of Demersal Stocks in the North Sea and Skagerrak [WGNSSK] (Chairs: Raphaël Girardin, France, and Tanja Miethe, UK) communicated by correspondence at the beginning of October 2022 to evaluate new information from the fisheries-independent surveys carried out during 2022 subsequent to the meeting of the group in April/May. For cod in 4, 20 and 7.d, with most recent SSB estimates being below MSY $B_{trigger}$, the re-opening protocol was run and concluded that re-opening of advice in autumn was required.

A.6.1 Cod in Subarea 4, Division 7.d and Subdivision 20

A.6.1 New fishery information

Absolute landings data for 2022 up to 30 June and up to 30 September were made available for a potential autumn forecast. The data were submitted by nation from official sources and are provided in Table A.6.1. Nations indicated that the quality of data should be good, although some small amounts of data may be missing for Q3 due to the short time elapsed. Using relationships derived by WKNSROP (ICES WKNSROP, 2020), the landings data submitted for quarters 1–2 and quarters 1–3 were used to predict landings and catches (assuming the same discard ratio by age for 2021) for the whole year, and subsequently compared to the intermediate year assumptions of the May forecasts. The outcome of this analysis was as follows:

	Intermediate year assumptions				Submitted landings		Predicted landings		Predicted catches	
Year	F	Assumption	Catch	Landings	Q12	Q123	pred Q12	pred Q123	pred Q12	pred Q123
2022	0.21	27% overshoot	20207	17064	6553	10936	15098	13430	17789	15823

Reported landings for quarters 1–2 and quarters 1–3 in 2022 (Submitted landings) were lower than all landings values used to fit the regressions (based on InterCatch data from 2002–2019). The predicted annual landings are therefore extrapolations from the WKNSROP relationships.

A.6.2 New survey information

New survey information, in the form of the IBTS Q3 2022 data, are available, subjecting this assessment to the AGCREFA protocol for re-opening advice in the autumn. The Delta-GAM model was re-applied to the full IBTS Q3 time series of North Sea cod data from DATRAS to provide a Q3 index for this stock. The new Delta-GAM Q3 index time series and associated standard deviations are given in Table A.6.2.

A.6.3 RCT3 analysis

Following the protocol stipulated by AGCREFA (ICES-AGCREFA, 2008) and revised by WKNSROP (ICES-WKNSROP, 2020) and WKNSEA (ICES-WKNSEA, 2021), RCT3 analyses were run to provide estimates of the abundances of the incoming 2021 and 2022 year-classes at age 1. The RCT3 input and output files are given in Tables A.6.3 and A.6.4–A.6.5, respectively.

A.6.4 Update protocol calculations

The outcome of the application of the protocol was as follows:

Calculations for 2021–2022 year-classes at age 1	2021 YC	2022 YC
Log WAP from RCT3 (R)	12.49	12.72
Log of recruitment assumed in spring (A)	12.04	12.27
Int SE of log WAP (S)	0.214	0.490
Distance D $\left(D = \frac{R-A}{S}\right)$	**2.097**	**0.923**

A.6.5 Conclusions from Protocol

As the distance ǀDǀ > 1 for the 2021 year-class, the protocol concludes that **the advisory process for North Sea cod should be reopened**. The autumn indices suggest that the size of the incoming 2021 year-class is significantly higher than what had been assumed in the forecast produced by WGNSSK in May 2022.

A.6.6 Updated forecast

Given the conclusion of the application of the protocol, the forecast and assessment were revised for North Sea cod. The assessment was re-run with the new time-series of q3 survey data (table A.6.2), including the observation of age 0 from the IBTS Q3 in 2022 forward shifted to age 1 in 2023. The forecasts were then re-run using (1) the SAM estimate of recruitment in the TAC year (2023) rather than a resampled recruitment, as done in May; and (2) an intermediate year annual landings assumption of 15 098 tonnes based on the data submitted for quarters 1–2 ($L_y = 1.9864 L_{Q1-2} + 2080.9$; $R^2 = 0.8574$; ICES WKNSROP, 2020). This results in an intermediate year annual catch assumption of 17 789 tonnes (table A.6.7). Otherwise, the settings and assumptions were unchanged from those used by WGNSSK in May 2022.

Outputs from the assessment re-run with the new Q3 data included are given in Table A.6.6 and Figure A.6.1, and the updated catch options in Table A.6.7. Residual plots, leave-one-out analyses and retrospective plots are presented in Figures A.6.2–A.6.4.

Following the ICES MSY approach, the new short-term forecast led to an **increase in advised catch from 22 946 tonnes to 26 008 tonnes** (an increase of 3062 tonnes).

A.6.7 References

ICES-AGCREFA (2008). Report of the Ad hoc Group on Criteria for Reopening Fisheries Advice (AGCREFA). ICES CM 2008/ACOM:60.

ICES-WKNSEA (2021). Benchmark Workshop on North Sea Stocks (WKNSEA). ICES Scientific Reports. 3:25. 756 pp. https://doi.org/10.17895/ices.pub.7922

ICES-WKNSROP (2020). Workshop on the North Sea reopening protocol (WKNSROP). ICES Scientific Reports. 2:108. 74 pp. https://doi.org/10.17895/ices.pub.7576

Table A.6.1. Cod in Subarea 4, Division 7.d and Subdivision 20. Absolute landings data for 2022 up to 30 June and 30 September respectively, in tonnes.

	Landings up to 30 June	Landings up to 30 September
Belgium	46	105
Denmark	1649	2385
France	110	231
Germany	304	555
Netherlands	283	510
Norway	808	1845
Sweden	347	489
UK England	78	125
UK Scotland	2927	4691
Total	6553	10936

Table A.6.2. Cod in Subarea 4, Division 7.d and Subdivision 20. Survey tuning indices and standard deviations for Q3 (NS-IBTS Delta-GAM indices). Data that are used in the assessment are highlighted in bold font. Note that age 0 is included as a separate index for recruits (see Section 4.2.4 and Table 4.6).

NS cod indices Q3													
1992	2022												
1	1	0.5	0.75					Standard deviations					
0	5							0	1	2	3	4	5
1	**5850.955**	**12086.44**	**1610.327**	**446.6394**	**190.9587**	135.9392	1992	**0.264**	**0.110**	**0.159**	**0.146**	**0.148**	0.215
1	**5384.142**	**2468.494**	**3215.084**	**487.0247**	**144.1957**	150.8796	1993	**0.280**	**0.133**	**0.149**	**0.163**	**0.155**	0.233
1	**11687.31**	**14147.8**	**1899.372**	**788.1731**	**145.8371**	100.2606	1994	**0.263**	**0.122**	**0.127**	**0.137**	**0.178**	0.221
1	**5934.355**	**7053.718**	**4861.465**	**678.3722**	**243.3817**	77.9425	1995	**0.311**	**0.117**	**0.132**	**0.155**	**0.146**	0.236
1	**15558.57**	**3394.716**	**1919.66**	**619.0917**	**168.5058**	127.6012	1996	**0.276**	**0.130**	**0.173**	**0.146**	**0.162**	0.221
1	**145.034**	**23369.18**	**2656.617**	**592.939**	**190.1378**	115.6534	1997	**0.396**	**0.154**	**0.201**	**0.233**	**0.262**	0.297
1	**8124.376**	**713.8338**	**6961.024**	**516.2314**	**131.8136**	127.0067	1998	**0.398**	**0.155**	**0.134**	**0.139**	**0.173**	0.227
1	**1927.153**	**3140.64**	**436.5831**	**1173.977**	**115.8547**	49.5302	1999	**0.351**	**0.169**	**0.153**	**0.123**	**0.144**	0.230
1	**1064.554**	**4788.401**	**924.8771**	**89.3613**	**232.5045**	60.4436	2000	**0.938**	**0.278**	**0.275**	**0.205**	**0.240**	0.279
1	**9639.586**	**1366.74**	**1637.523**	**278.6945**	**56.7521**	96.595	2001	**0.485**	**0.187**	**0.140**	**0.140**	**0.172**	0.244
1	**317.0782**	**3933.611**	**791.1427**	**584.1116**	**186.1179**	64.9654	2002	**0.594**	**0.192**	**0.158**	**0.132**	**0.147**	0.184
1	**3884.168**	**563.0815**	**940.2191**	**186.8247**	**160.0027**	177.4692	2003	**0.442**	**0.167**	**0.152**	**0.155**	**0.180**	0.211
1	**1905.72**	**3096.384**	**597.8353**	**372.107**	**74.0766**	82.1344	2004	**0.575**	**0.198**	**0.150**	**0.157**	**0.182**	0.210
1	**3099.234**	**1022.987**	**711.7638**	**191.3056**	**92.5952**	66.2956	2005	**0.302**	**0.189**	**0.163**	**0.142**	**0.142**	0.202
1	**2240.982**	**3897.123**	**621.1997**	**458.5111**	**85.0611**	38.3108	2006	**0.418**	**0.153**	**0.164**	**0.176**	**0.168**	0.231
1	**4932.822**	**1667.198**	**2169.659**	**365.1156**	**144.4043**	123.9276	2007	**0.462**	**0.181**	**0.156**	**0.163**	**0.162**	0.186
1	**673.3228**	**1875.329**	**844.4261**	**848.3093**	**175.696**	112.3616	2008	**0.491**	**0.178**	**0.152**	**0.150**	**0.149**	0.174
1	**957.7147**	**1677.949**	**680.9589**	**221.2901**	**218.626**	86.4461	2009	**0.465**	**0.208**	**0.163**	**0.192**	**0.196**	0.234
1	**141.7094**	**2005.395**	**1320.245**	**405.923**	**133.2065**	104.3661	2010	**0.559**	**0.132**	**0.135**	**0.136**	**0.137**	0.157
1	**6338.144**	**872.1653**	**2423.046**	**1129.173**	**274.8388**	192.2646	2011	**0.664**	**0.164**	**0.133**	**0.190**	**0.152**	0.180
1	**623.2952**	**1686.731**	**807.9914**	**999.2395**	**309.8033**	114.6374	2012	**0.609**	**0.177**	**0.155**	**0.135**	**0.134**	0.170
1	**295.4318**	**1586.841**	**884.8202**	**382.804**	**429.9912**	199.6639	2013	**0.536**	**0.146**	**0.169**	**0.153**	**0.152**	0.168
1	**419.705**	**1975.015**	**1268.478**	**538.0504**	**219.907**	287.6278	2014	**0.453**	**0.131**	**0.141**	**0.149**	**0.147**	0.154
1	**25.7581**	**997.3161**	**2315.102**	**854.9464**	**351.1451**	251.7184	2015	**0.721**	**0.167**	**0.124**	**0.138**	**0.132**	0.153
1	**3274.091**	**695.659**	**830.2381**	**1082.75**	**597.5551**	264.9433	2016	**0.268**	**0.175**	**0.143**	**0.124**	**0.124**	0.139
1	**230.9571**	**3814.685**	**500.032**	**388.9349**	**371.054**	279.6106	2017	**0.553**	**0.133**	**0.155**	**0.162**	**0.145**	0.155
1	**171.1493**	**525.3387**	**1599.483**	**270.2127**	**180.2506**	215.4817	2018	**0.599**	**0.158**	**0.140**	**0.131**	**0.151**	0.168
1	**2099.269**	**1292.809**	**350.5673**	**442.3391**	**93.3992**	116.1382	2019	**0.464**	**0.134**	**0.145**	**0.155**	**0.162**	0.208
1	**733.2196**	**2212.489**	**919.5586**	**137.1076**	**169.0382**	100.8971	2020	**0.326**	**0.155**	**0.135**	**0.160**	**0.164**	0.202
1	**1014.897**	**1098.758**	**1816.91**	**531.6934**	**140.9834**	129.6952	2021	**0.521**	**0.132**	**0.143**	**0.147**	**0.156**	0.166
1	**2229.546**	**2193.446**	**845.8329**	**761.7718**	**305.3984**	157.9499	2022	**0.662**	**0.156**	**0.140**	**0.143**	**0.152**	0.199

Table A.6.3. Cod in Subarea 4, Division 7.d and Subdivision 20. RCT3 Inputs. Data from the IBTS Q3 2022 survey are highlighted.

yearclass	recruitment	deltaGAMq31	deltaGAMq30
1991	959675	12086.4373	
1992	436956	2468.4939	5850.9545
1993	1068662	14147.8035	5384.1423
1994	687254	7053.7184	11687.3079
1995	477313	3394.716	5934.355
1996	1536169	23369.1842	15558.5734
1997	146708	713.8338	145.034
1998	312329	3140.6395	8124.376
1999	452206	4788.4013	1927.1526
2000	182378	1366.7402	1064.554
2001	260328	3933.6107	9639.5857
2002	120773	563.0815	317.0782
2003	241673	3096.3842	3884.1677
2004	188651	1022.9874	1905.72
2005	419451	3897.1225	3099.2338
2006	187496	1667.1981	2240.9823
2007	212742	1875.3286	4932.8218
2008	237406	1677.9494	673.3228
2009	306690	2005.3947	957.7147
2010	143469	872.1653	141.7094
2011	222444	1686.7308	6338.1439
2012	250277	1586.8409	623.2952
2013	314562	1975.0151	295.4318
2014	147637	997.3161	419.705
2015	104054	695.659	25.7581
2016	318892	3814.6853	3274.091
2017	71266	525.3387	230.9571
2018	136603	1292.8087	171.1493
2019	228698	2212.4891	2099.2685
2020	132685	1098.7581	733.2196
2021		2193.4455	1014.8969
2022			2229.546

Table A.6.4. Cod in Subarea 4, Division 7.d and Subdivision 20. RCT3 Outputs for the 2021 year-class.

```
Analysis by RCT3 ver4.0


Data for 1 surveys over 32 year classes: 1991 - 2022
Regression type = C
Tapered time weighting not applied
Survey weighting not applied
Final estimates not shrunk towards mean
Estimates with S.E.'S greater than that of mean included
Minimum S.E. for any survey taken as    0
Minimum of   3 points used for regression

Forecast/Hindcast variance correction used.

                  WAP logWAP int.se

yearclass:2021 264595  12.49 0.2143
```

Table A.6.5. Cod in Subarea 4, Division 7.d and Subdivision 20. RCT3 Outputs for the 2022 year-class.

```
Analysis by RCT3 ver4.0


Data for 1 surveys over 32 year classes : 1991 - 2022
Regression type = C
Tapered time weighting not applied
Survey weighting not applied
Final estimates not shrunk towards mean
Estimates with S.E.'S greater than that of mean included
Minimum S.E. for any survey taken as    0
Minimum of   3 points used for regression

Forecast/Hindcast variance correction used.

                  WAP logWAP int.se

yearclass:2022 333559  12.72 0.4898
```

Table A.6.6. Cod in Subarea 4, Division 7.d and Subdivision 20. Assessment summary. Weights are in tonnes.

	Recruits age 1 ('000)	Low	High	TSB (tonnes)	Low	High	SSB (tonnes)	Low	High	Catches (tonnes)	Low	High	Fbar 2-4	Low	High
1963	448879	324792	620375	314475	261855	377669	129744	80067	210245	117243	103555	132739	0.467	0.399	0.547
1964	735304	533085	1014232	359739	307714	420559	138581	86052	223177	145212	130759	161261	0.515	0.447	0.595
1965	979441	713413	1344669	457471	396944	527228	162757	101106	262001	199151	176798	224330	0.57	0.495	0.657
1966	1193002	869320	1637204	543105	475556	620249	182574	115129	289529	240868	214326	270698	0.574	0.5	0.658
1967	1015848	739578	1395321	608100	534306	692086	205322	132748	317573	288847	256461	325323	0.618	0.542	0.704
1968	505145	367177	694954	588320	523033	661757	209979	133903	329277	295319	266253	327557	0.656	0.574	0.75
1969	438697	316988	607138	482224	426539	545178	208284	139792	310334	225096	206660	245175	0.61	0.535	0.695
1970	1469677	1067927	2022564	536654	473025	608841	213929	150307	304482	251643	220545	287127	0.645	0.569	0.731
1971	1949023	1410772	2692632	644454	568449	730621	220614	162924	298732	352476	301422	412176	0.745	0.662	0.839
1972	482251	348806	666750	612103	542803	690250	201619	147641	275331	367940	319824	423295	0.817	0.727	0.919
1973	696940	504713	962380	453926	412379	499658	166614	117292	236677	258716	234465	285476	0.788	0.7	0.888
1974	691259	499735	956185	435011	391791	482998	178411	132011	241121	233827	208262	262531	0.745	0.661	0.841
1975	1189072	852892	1657764	418373	376020	465496	169146	133122	214920	245121	213610	281279	0.808	0.72	0.907
1976	806197	574772	1130803	396897	354036	444947	146131	116883	182698	248005	214128	287241	0.868	0.773	0.976
1977	1985757	1423576	2769946	413549	367040	465952	122529	98027	153155	258086	213504	311978	0.818	0.728	0.918
1978	1188124	851102	1658601	514922	452130	586434	118197	97585	143164	358583	295613	434967	0.925	0.826	1.035
1979	1481562	1061449	2067952	519936	467784	577901	118543	97689	143849	331270	283853	386606	0.835	0.745	0.936
1980	2348608	1676185	3290782	563870	501202	634374	118543	98654	142443	386608	321408	465036	0.923	0.827	1.029
1981	940544	672449	1315525	582144	517440	654940	128378	107991	152613	392323	332957	462275	0.931	0.836	1.036
1982	1470717	1066685	2027785	513827	464701	568147	129400	109838	152447	378603	323099	443643	1.055	0.951	1.17
1983	834323	621240	1120493	439649	393705	490956	108670	92726	127355	316124	269937	370215	1.035	0.933	1.147
1984	1497219	1123872	1994591	391259	354194	432203	96563	82121	113545	271145	232184	316644	0.964	0.869	1.07
1985	371613	271730	508210	361717	324608	403068	92500	78705	108713	236427	205043	272614	0.92	0.828	1.021
1986	1811547	1364437	2405169	324675	292181	360782	80540	68518	94673	229958	193325	273532	0.999	0.903	1.106

	Recruits age 1 ('000)	Low	High	TSB (tonnes)	Low	High	SSB (tonnes)	Low	High	Catches (tonnes)	Low	High	Fbar 2-4	Low	High
1987	708292	533461	940420	392985	346402	445833	83513	70871	98409	269388	226859	319888	0.972	0.878	1.076
1988	473589	350826	639310	305140	279038	333684	78012	65129	93443	210180	185699	237890	0.996	0.9	1.103
1989	844008	630369	1130051	258084	233949	284710	74712	64093	87090	181247	156006	210572	1.023	0.925	1.132
1990	339517	253228	455209	215956	195070	239077	66205	56968	76940	140911	122642	161901	0.949	0.854	1.054
1991	398867	300420	529576	187435	171226	205177	66219	57167	76704	121191	107101	137134	0.935	0.843	1.037
1992	964171	741048	1254474	230168	206646	256367	68143	59378	78201	145538	123085	172088	0.907	0.82	1.003
1993	439577	339775	568694	242901	218103	270519	69976	60083	81499	159956	138011	185391	0.977	0.883	1.081
1994	1057585	817990	1367359	230629	209723	253618	72382	62451	83891	148895	128950	171925	0.946	0.855	1.046
1995	692028	537669	890702	283168	254651	314879	77700	67164	89888	168939	145153	196623	0.875	0.788	0.972
1996	477477	368489	618701	261173	238454	286056	92943	80535	107263	159040	140354	180213	0.904	0.815	1.002
1997	1535829	1188143	1985258	305346	272883	341670	94962	83716	107719	182445	154274	215761	0.927	0.839	1.023
1998	142751	107228	190042	276320	245127	311483	98574	83892	115824	186154	160422	216013	1.123	1.025	1.23
1999	312322	237112	411390	153764	142549	165861	79182	69075	90767	110248	100202	121301	1.145	1.047	1.252
2000	451128	346605	587169	133833	120697	148398	56004	49433	63449	91515	79334	105566	1.164	1.06	1.279
2001	183102	139729	239937	107480	97159	118898	43384	37413	50309	59301	52068	67539	0.868	0.782	0.963
2002	261754	198891	344485	93566	86012	101784	46653	40760	53399	62411	56051	69493	1.062	0.958	1.177
2003	121914	92547	160599	73612	66958	80928	34911	30446	40030	38364	34162	43083	0.752	0.668	0.846
2004	241882	184028	317924	63663	57943	69947	33269	29327	37742	35203	31802	38968	0.801	0.716	0.895
2005	189014	143459	249036	71922	64739	79902	32081	27786	37038	41968	36900	47732	0.82	0.734	0.917
2006	420206	324684	543831	88595	79089	99243	34227	29291	39994	32901	29048	37265	0.73	0.648	0.824
2007	187994	144327	244872	105756	94412	118464	45174	38441	53087	53183	46441	60903	0.666	0.587	0.755
2008	211252	162672	274338	123979	111736	137564	64486	55312	75183	51936	46992	57401	0.642	0.562	0.732
2009	236841	180483	310798	120631	107380	135518	64626	55236	75613	54662	49236	60687	0.625	0.541	0.723
2010	305331	236731	393809	132471	116220	150993	67293	56274	80470	49045	44324	54268	0.524	0.447	0.614
2011	145183	110218	191241	135295	116215	157508	75754	61607	93151	43160	39100	47641	0.404	0.346	0.472

	Recruits age 1 ('000)	Low	High	TSB (tonnes)	Low	High	SSB (tonnes)	Low	High	Catches (tonnes)	Low	High	Fbar 2-4	Low	High
2012	223399	169740	294019	141639	121844	164650	80025	64813	98807	39367	36300	42694	0.372	0.317	0.436
2013	250024	191570	326315	142120	121968	165603	80507	65171	99452	41170	37716	44939	0.368	0.315	0.431
2014	317889	246480	409986	155898	135015	180011	78644	63702	97090	44860	40886	49220	0.374	0.322	0.435
2015	148615	114275	193276	171614	149041	197607	83922	67758	103942	50050	45604	54929	0.38	0.33	0.438
2016	104716	80111	136879	154354	134359	177324	84688	68950	104019	49929	46221	53934	0.376	0.326	0.434
2017	318508	243223	417095	142455	123731	164013	84181	69030	102658	46515	43158	50133	0.421	0.367	0.484
2018	71823	54985	93817	124017	106947	143812	73762	60068	90579	48676	44501	53242	0.535	0.464	0.617
2019	140015	107549	182281	91860	77291	109175	58998	46524	74816	36208	33467	39173	0.49	0.418	0.574
2020	228230	171016	304585	83482	69799	99848	44289	34029	57644	21901	19938	24057	0.361	0.302	0.43
2021	132322	96208	181993	95986	79807	115444	44335	33667	58383	21238	18802	23990	0.247	0.2	0.305
2022	204530	118927	351748	120590	97978	148419	54148	41137	71276						
2023	222820	50960	974261												

Table A.6.7. Cod in Subarea 4, Division 7.d and Subdivision 20. Catch options. Units are tonnes (SSB, landings, discards and catch) or thousands (recruitment).

Forecast assumptions

variable	value
Fbar(2022)	0.179
SSB(2023)	73038
R(2022)	201238
R(2023)	233050
Catch(2022)	17789
Landings(2022)	15098
Discards(2022)	2691

Catch scenarios

Basis	Catch (2023)	Landings (2023)	Discards (2023)	F_{total} (2023)	$F_{landings}$ (2023)	$F_{discards}$ (2023)	SSB (2024)	% SSB change	% TAC change	% advice change	Risk
MSY approach	26008	21785	4223	0.21	0.166	0.043	91130	25	63	82	0.075
$F_{MSY\ lower}$ x SSB(2023) / $B_{trigger}$	17863	14989	2874	0.139	0.11	0.029	97892	34	12.3	25	0.034
F = 0	0	0	0	0	0	0	112672	54	-100	-100	0.003
F_{pa}	53641	44359	9282	0.49	0.39	0.1	69181	-5.3	240	280	0.52
F_{lim}	61064	50279	10785	0.58	0.46	0.119	63339	-13.3	280	330	0.67
SSB(2024) = B_{lim}	52784	43673	9111	0.48	0.38	0.098	69841	-4.4	230	270	0.5
SSB(2024) = $B_{trigge\ r}$= B_{pa}	17997	15099	2898	0.14	0.111	0.029	97777	34	13.1	26	0.036
TAC(2022) -20%	12729	10699	2030	0.097	0.077	0.02	102182	40	-20	-10.8	0.022
TAC(2022) -15%	13524	11368	2156	0.104	0.082	0.022	101533	39	-15	-5.3	0.025
TAC(2022) -10%	14320	12032	2288	0.11	0.087	0.023	100877	38	-10	0.31	0.027
TAC(2022) -5%	15116	12698	2418	0.116	0.093	0.023	100207	37	-5	5.9	0.028
Constant TAC	15911	13370	2541	0.123	0.098	0.025	99554	36	0	11.5	0.028
TAC(2022) +5%	16707	14041	2666	0.129	0.103	0.026	98892	35	5	17	0.033
TAC(2022) +10%	17502	14696	2806	0.136	0.108	0.028	98200	34	10	23	0.034
TAC(2022) +15%	18297	15346	2951	0.143	0.113	0.03	97502	33	15	28	0.037
TAC(2022) +20%	19093	16011	3082	0.149	0.119	0.03	96820	33	20	34	0.041
F = F_{2022}	22523	18897	3626	0.179	0.142	0.037	93985	29	42	58	0.056
$F_{MSY\ lower}$	23374	19604	3770	0.186	0.148	0.038	93301	28	47	64	0.059

Basis	Catch (2023)	Landings (2023)	Discards (2023)	F_{total} (2023)	$F_{landings}$ (2023)	$F_{discards}$ (2023)	SSB (2024)	% SSB change	% TAC change	% advice change	Risk
F_{MSY}	33693	28121	5572	0.28	0.22	0.057	84708	16	112	136	0.149
$F_{MSY\ upper}$	50111	41577	8534	0.45	0.36	0.092	71853	-1.62	210	250	0.44

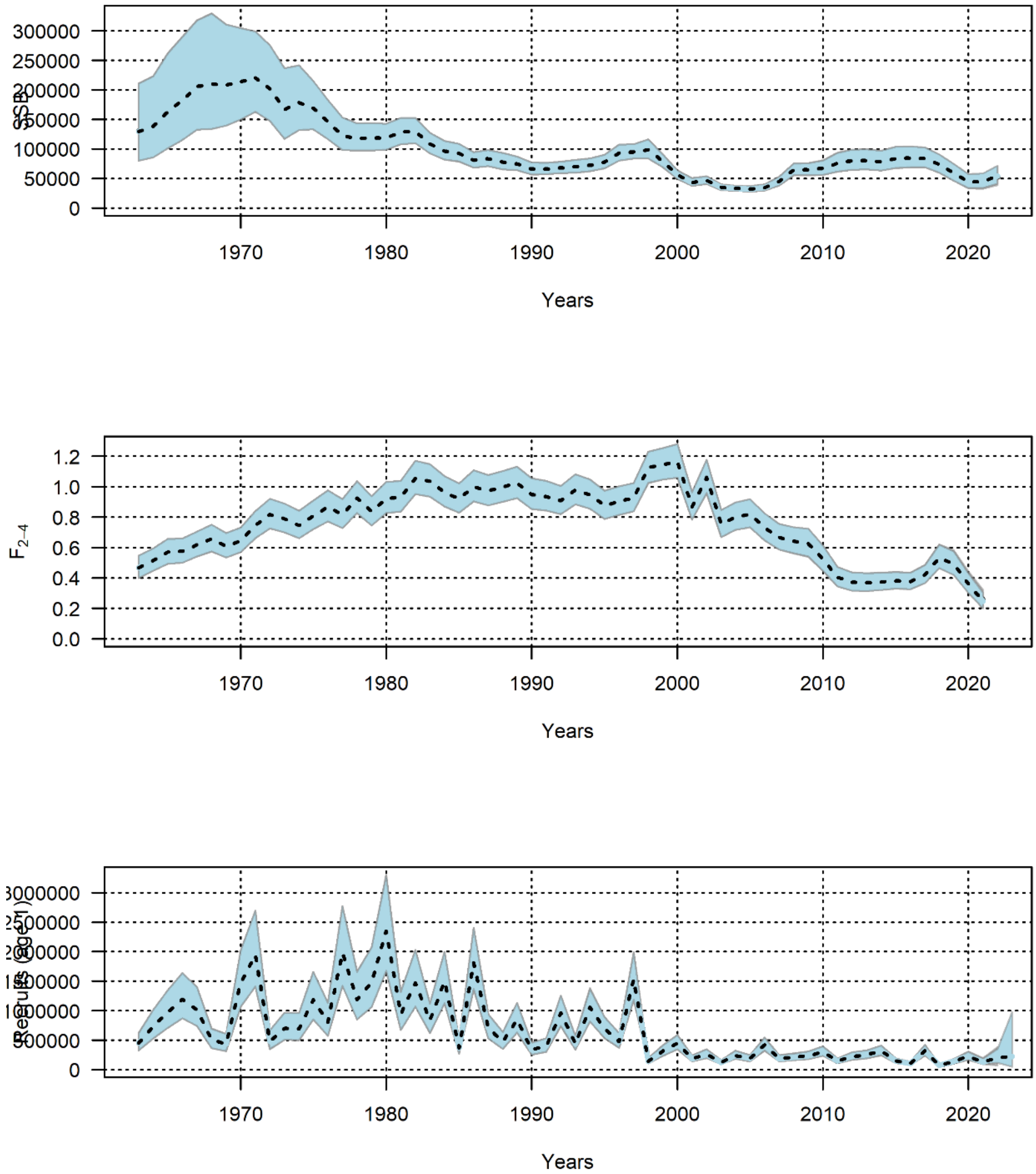

Figure A.6.1. Cod in Subarea 4, Division 7.d and Subdivision 20. Summary of stock assessment with pointwise 95% confidence intervals. The SAM assessment produced by WGNSSK in May 2022 is plotted in black for comparison.

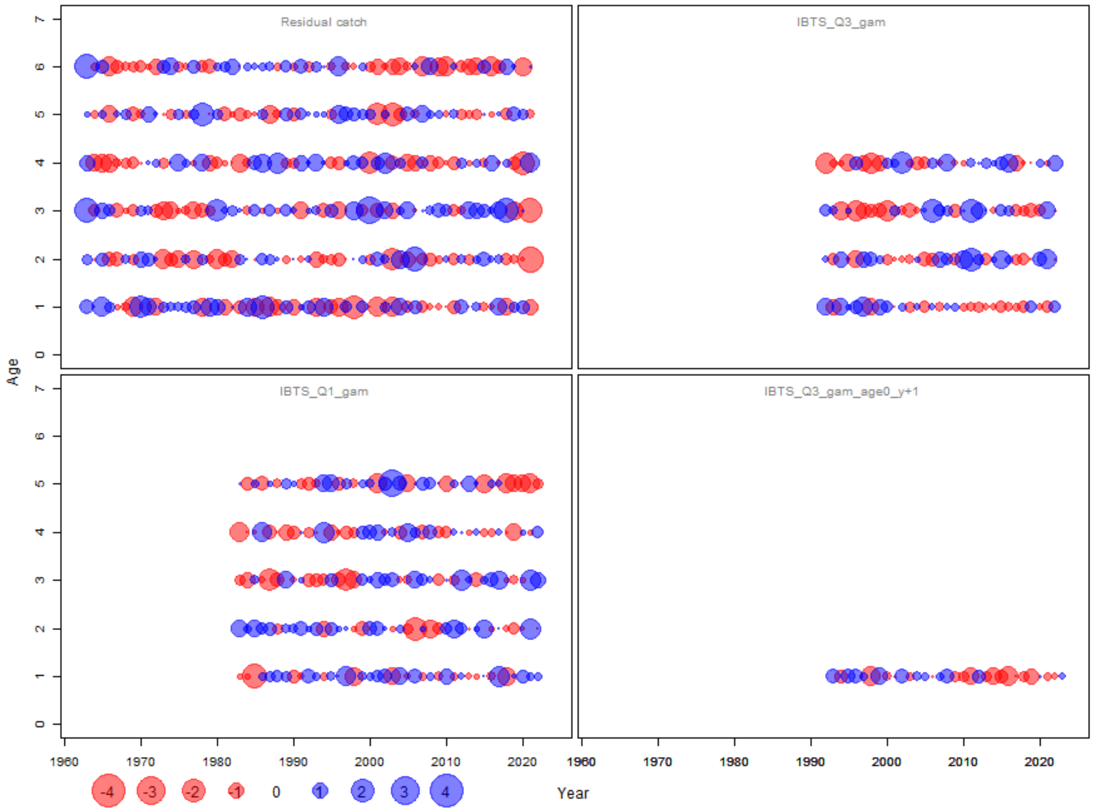

Figure A.6.2a. Cod in Subarea 4, Division 7.d and Subdivision 20: One step ahead (OSA) residuals for the SAM assessment for (top left) total catch, (bottom left) IBTS–Q1, (top right) IBTS–Q3 and (bottom right) the IBTS–Q3 recruitment index. Blue circles indicate a positive residual and red circles a negative residual.

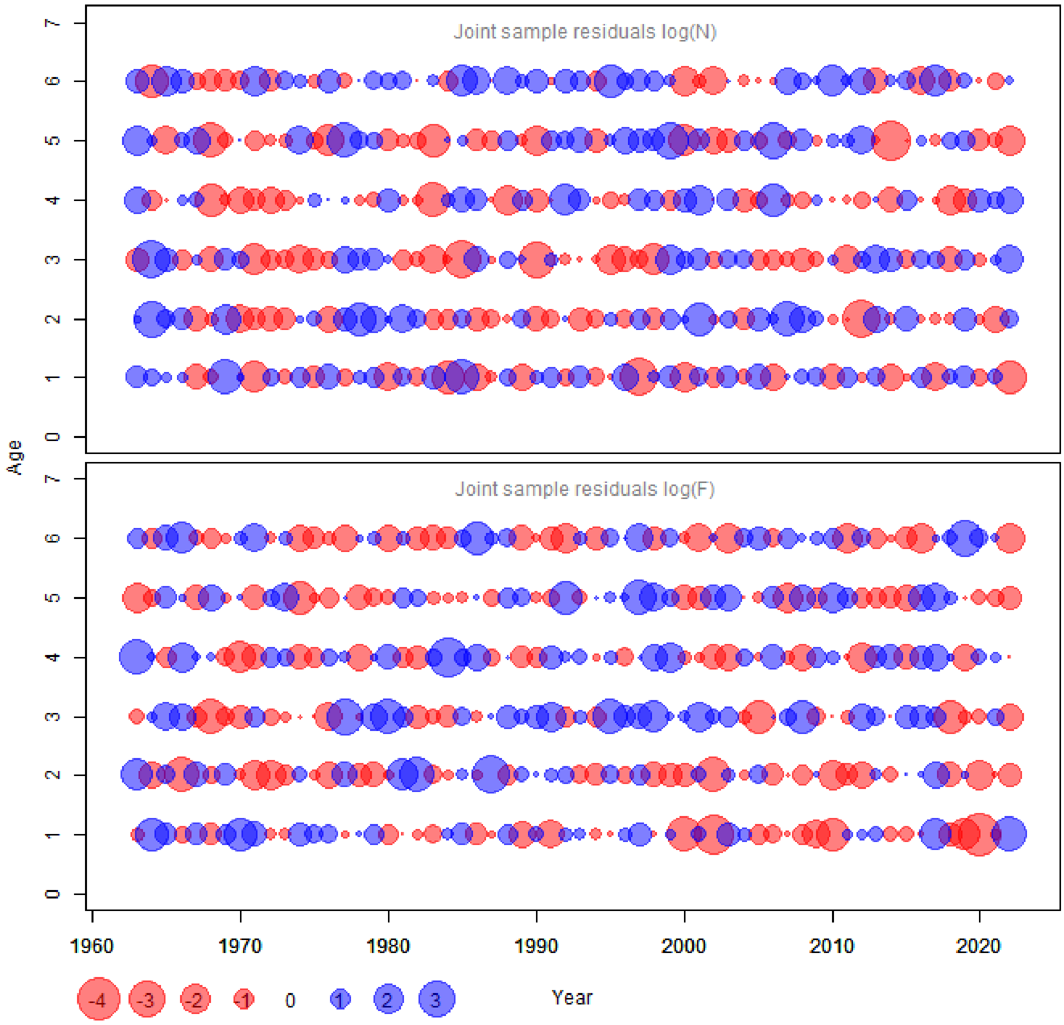

Figure A.6.2b. Cod in Subarea 4, Division 7.d and Subdivision 20: SAM standardised joint-sample residuals of process increments for (top) stock numbers and (bottom) fishing mortality. Blue circles indicate a positive residual and red circles a negative residual.

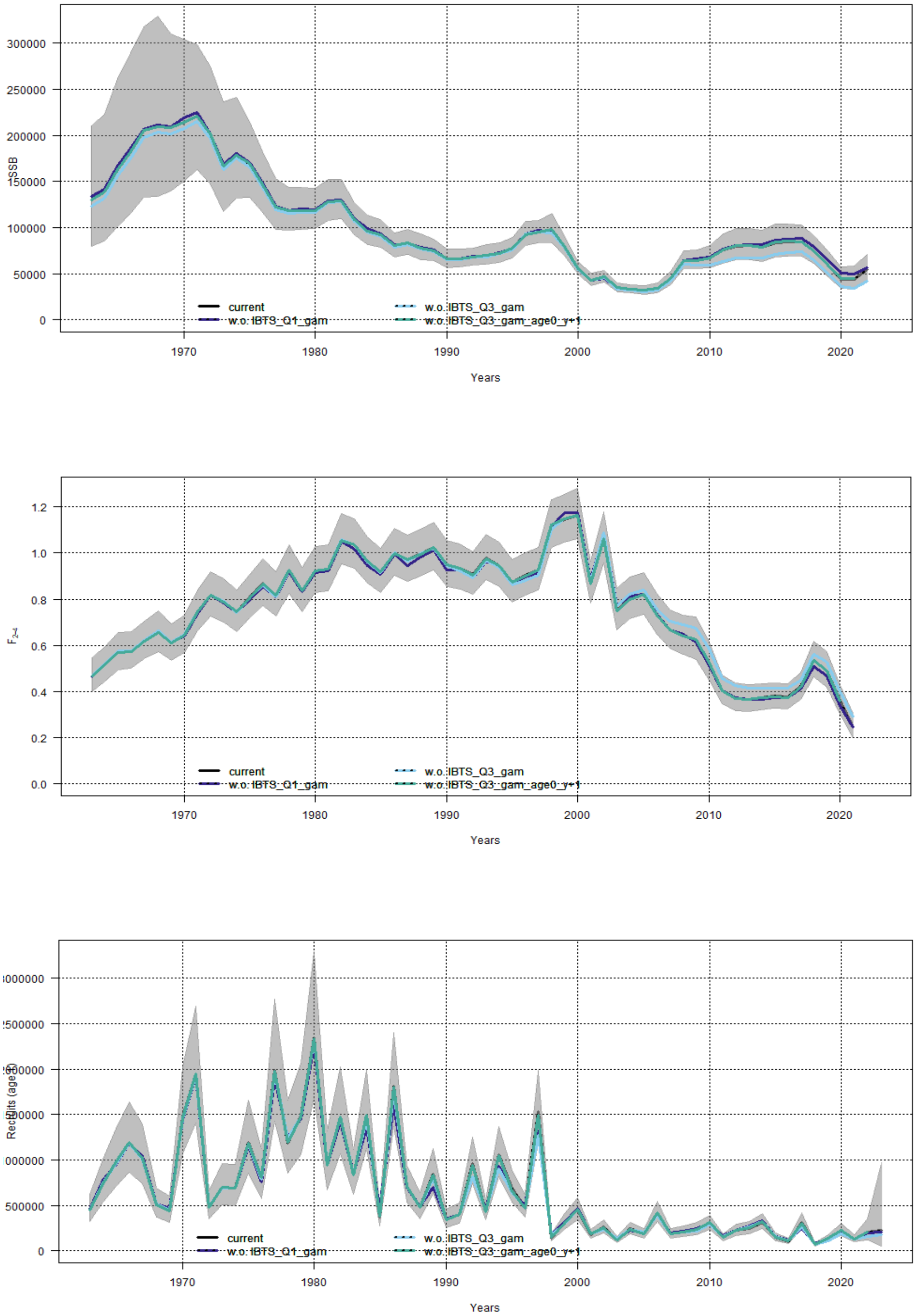

Figure A.6.3. Cod in Subarea 4, Division 7.d and Subdivision 20: Leave-one-out analysis for the SAM assessment. Estimated yearly SSB (top), average fishing mortality (middle) and recruitment age 1 (bottom), together with corresponding pointwise 95% confidence intervals.

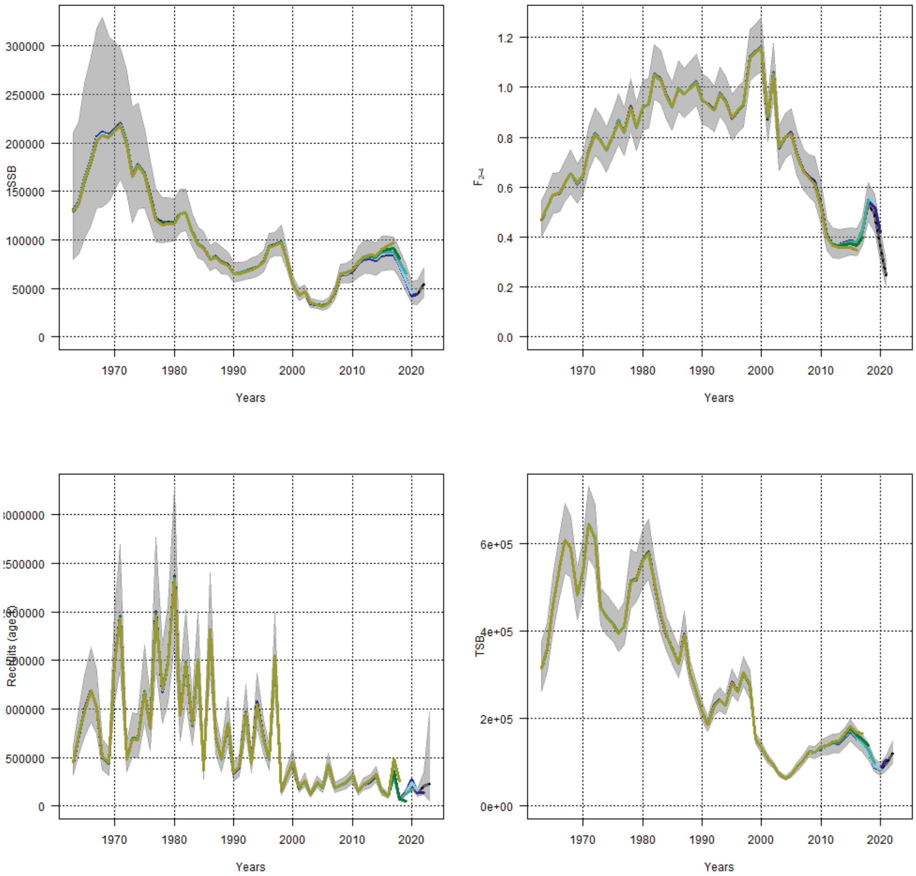

Figure A.6.4. Cod in Subarea 4, Division 7.d and Subdivision 20: Retrospective estimates (5 years) from the SAM assessment. Estimated yearly SSB (top left), average fishing mortality (top right), recruitment age 1 (bottom left) and TSB (bottom right), together with corresponding pointwise 95% confidence intervals.

Annex 7: Data call: Data submission for ICES fisheries advisory work

Joint ICES Fisheries Data call for landings, discards, biological and effort data and other supporting information in support of the ICES fisheries advice in 2022.

ICES. 2022. ICES Fisheries Data call 2022 for landings, discards, biological sample, catch and effort data. https://doi.org/10.17895/ices.pub.10038.

Annex 8: Working Documents

Working document 1: Changes made to the assessment of Northern Shelf haddock (had.27.46a20) at WGNSSK 2022

Harriet Cole

Marine Scotland Science

Introduction

At WGNSSK 2022, two survey data issues were encountered that may have had implications for the conclusions of the recent benchmark of Northern Shelf haddock in early 2022 (WKNSCS; ICES 2022). The first of these issues was the addition of a new maturity scale in 2021 which was not included in the maturity analysis at the benchmark. This only affects the benchmark analysis, because previously a time-invariant knife-edged maturity ogive was used. The second was a reduction in sampling coverage for the Q1 surveys in 2022 that resulted from a combination of several major winter storms and mechanical issues with some vessels. This Working Document provides details on the effect these issues had on the haddock stock assessment and recent benchmark work and the steps taken to evaluate and minimise the impact of these issues. The updates to the assessment model described here have been used to produce the 2022 advice.

New maturity scale codes

A new maturity scale devised by WKASMSF (ICES 2018) was used by some countries submitting data to DATRAS since 2021. We were not aware of this new maturity scale during the benchmark meeting (WKNSCS 2022). Therefore, maturity samples recorded using the new scale would not have been included when deriving the maturity ogives used in the benchmark assessment. This has implications not only for the final spawning stock biomass (SSB) estimate but also for the estimation of the reference points. Since the stock-recruit model used in the haddock assessment is a random walk the maturity ogives are only used to calculate SSB and not used in the fitting of the assessment model. Therefore, only the biomass reference points B_{lim}, B_{pa} and MSY $B_{trigger}$ could be affected by this issue.

The new maturity scale is compared to the ICES M6 scale in Table A8.1.1. Two surveys are used to derive maturity ogives for this stock: NS-IBTS Q1 and SCOWCGFS Q1. The maturity samples recorded using the new maturity scale represent 31% of the total number of haddock maturity samples recorded in 2021 during these surveys. The effect that omitting these samples had on the benchmark assessment was investigated by recalculating the maturity ogives with these missing data included. Then, the benchmark assessment was updated with this new input dataset. The full methodological details on the calculation of the maturity ogives are available in the WKNSCS benchmark report (ICES 2022) and a detailed summary is given in the stock annex.

ICES M6 scale	WKASMSF revised maturity scale
61 Immature	A Immature
62 Maturing	B Maturing
63 Spawning	C Spawning
64 Spent	D Spent (Resting/Regenerating)
65 Resting	E Omitted spawning
66 Abnormal	F Abnormal

Table A8.1.1: Comparison of the ICES M6 scale to the new maturity scale revised by WKASMSF 2018

A comparison of the updated maturity ogives to those used in the benchmark assessment is shown in Figure A8.1.1. Differences in the proportion mature are seen to be minimal for most ages and are only noticeable in the last few years of the time series (Figure A8.1.1). The largest differences are seen in age 1 and age 2 where the updated maturity ogives estimate a slightly larger proportion of mature fish for both age classes. However, these differences translate into a minor change in the estimated SSB (Figure A8.1.2) with the updated maturity ogives increasing SSB by approximately 4% in both 2020 and 2021 compared to the benchmark assessment. The maturity ogives estimated from DATRAS data are smoothed, thereby the change in maturity scales since 2021 can affect the estimates for years 2021 as well as 2020.

Since haddock is a sporadic spawner the value of B_{lim} is set to the lowest SSB that results in a large recruitment event. During the benchmark, this criterion meant that the value of B_{lim} was set to the SSB estimate for 1999. The 1999 SSB estimate from the updated benchmark assessment was seen to be virtually identical to that estimated at the benchmark (a difference of 1/200th of a percent). The values of B_{pa} and MSY $B_{trigger}$ are dependent on the value of B_{lim} (see WKNSCS report for details; ICES 2022) and so it follows that the impact of the updated maturity ogives on the value of these reference points would also be negligible.

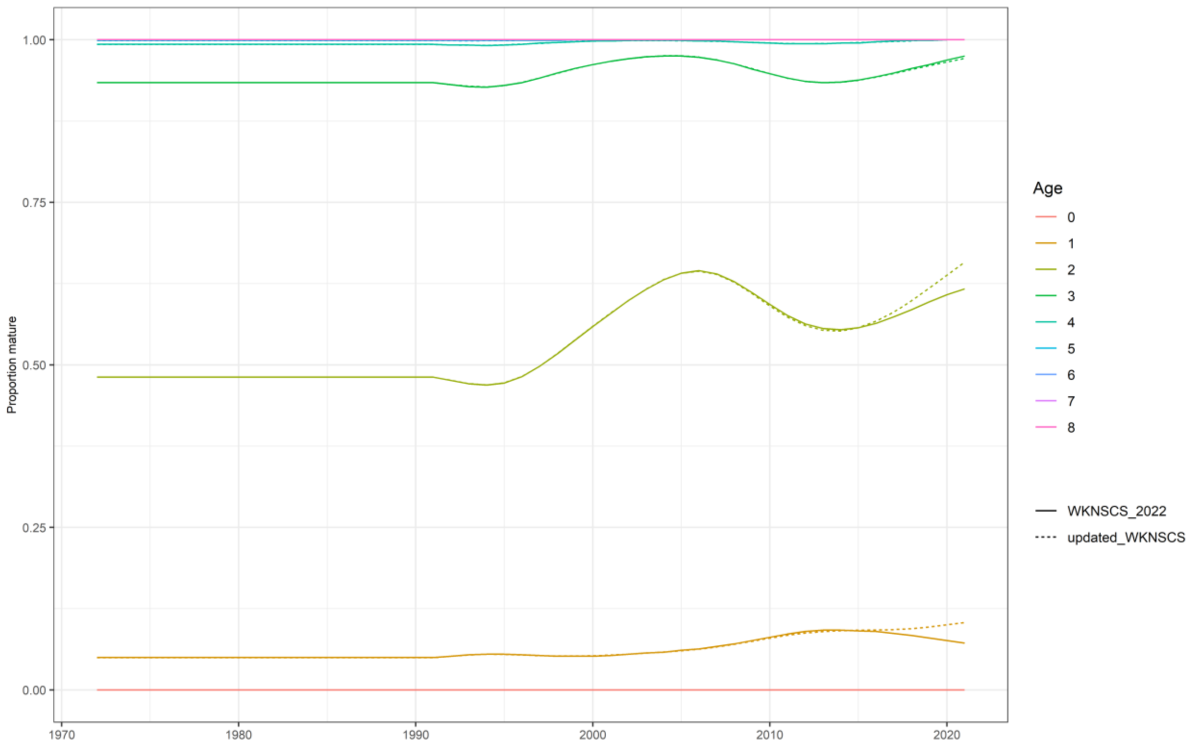

Figure A8.1.1: Comparison of maturity-at-age used in the benchmark assessment ("WKNSCS_2022"; solid line) and with the update to include the maturity data recorded using the new maturity scale ("updated_WKNSCS"; dashed line).

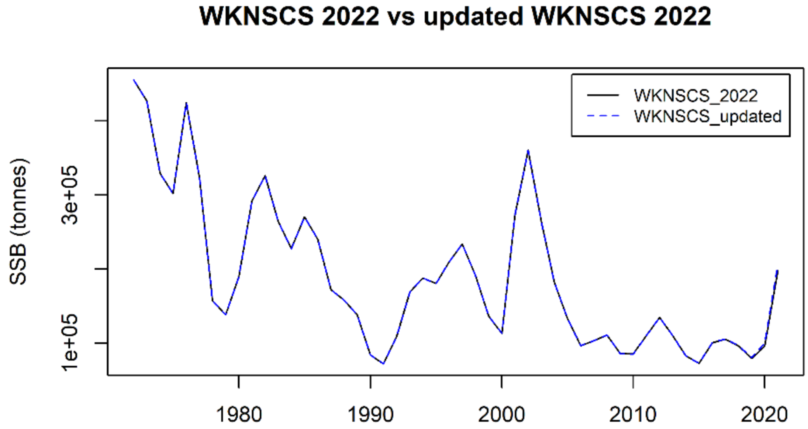

Figure A8.1.2: Comparison of SSB estimates from the benchmark assessment ("WKNSCS_2022"; black solid line) and from an assessment using the updated maturity ogives ("WKNSCS_updated"; blue dashed line).

Q1 survey sampling issues

A combination of several storms and mechanical issues with some vessels during Q1 of 2022 resulted in a reduction in the sampling coverage of the NS-IBTS Q1 survey and the cancellation of the SCOWCGFS Q1 survey. Both these surveys are used to produce a combined North Sea-West Coast of Scotland (NS-WC) abundance index for the Northern Shelf haddock stock assessment using a delta-GAM modelling approach (ICES 2022, Berg et al., 2014). The ICES rectangles which were not sampled are shown in Figure A8.1.3, though it should be noted that some sampled rectangles were only sampled once. Usually, each rectangle is sampled twice during these surveys.

This reduction in sampling coverage was expected to have an impact on the accuracy of the Q1 survey indices derived from the data which, in turn, has implications for the quality of this year's assessment and the production of advice. To investigate the impact that this reduced sampling coverage could have on the haddock stock assessment results a sensitivity analysis was conducted. The reduced sampling seen in Q1 2022 was replicated in the Q1 survey data in previous years (2021 and 2020) by removing data collected at stations closest to those missed in 2022. The NS-WC Q1 survey indices were then recalculated using the reduced datasets for use in a stock assessment. This produced two sets of "reduced sampling coverage" indices; the first spanning 1983-2020 and the second spanning 1983-2021 where the reduced sampling coverage was replicated only in the final year of the series. These new indices were then used as input to the stock assessment model (SAM; Nielsen and Berg, 2014) and the resulting estimates were then compared to the stock assessment estimates produced using modelled survey indices with full sampling coverage in the final year of the series.

Usually, the NS-WC Q1 survey indices include data collected in the same year as the year in which the annual stock assessment is taking place at WGNSSK (referred to as the "assessment year"). This means that the stock assessment results include an estimate of SSB in the assessment year since indices are provided for that year. A further comparison was made between the "full data coverage" stock assessment and a "no Q1" stock assessment where the NS-WC Q1 survey data collected in the assessment year were wholly excluded. In the event that the reduced sampling coverage in Q1 of 2022 meant that the resulting indices were too unreliable for use, this comparison would help to evaluate the impact of this exclusion on the quality of the assessment.

A summary of the assessment runs used in this analysis are given in Table A8.1.2.

Name	Assessment year	Q1 sampling coverage	Q1 survey years
Full coverage	2021	Full sampling coverage	1983-2021
Reduced coverage	2021	Reduced sampling coverage in the assessment year where the reduction replicates that seen in 2022	1983-2021
No Q1	2021	All Q1 data for the assessment year is excluded	1983-2020
Full coverage	2020	Full sampling coverage	1983-2020
Reduced coverage	2020	Reduced sampling coverage in the assessment year where the reduction replicates that seen in 2022	1983-2020
No Q1	2020	All Q1 data for the assessment year is excluded	1983-2019

Table A8.1.2: Summary of the stock assessment runs and the details of the data used to produce the NS-WC Q1 survey indices. All other input datasets remain the same as described in the stock annex.

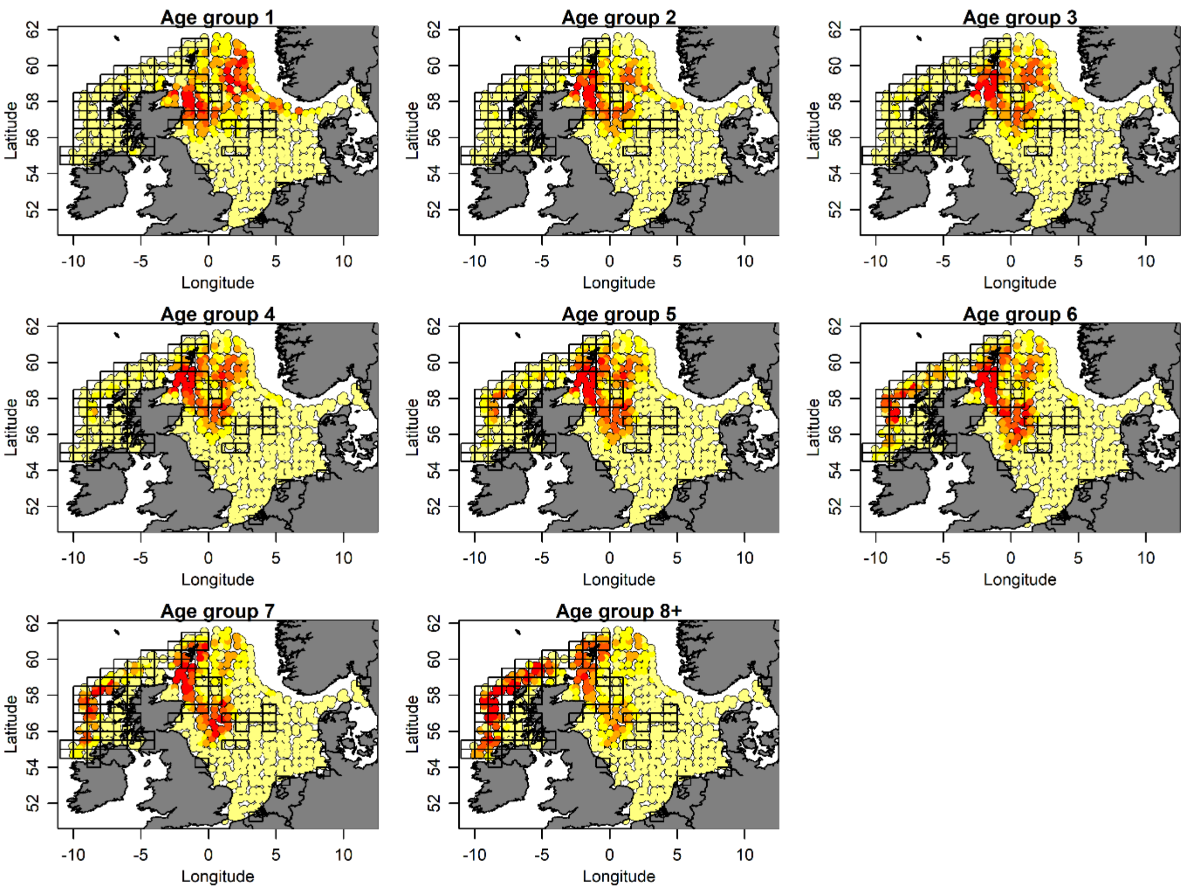

Figure A8.1.3: Northern Shelf haddock. Relative abundance by age class across all years (1983:2022). Rectangles shown are those not sampled during Q1 of 2022.

Comparison of assessment results

A comparison of the "full coverage" NS-WC Q1 indices to the "reduced coverage" NS-WC Q1 indices is shown in Figures A8.1.4 and 5 for assessment year 2020 and 2021 respectively. Little difference is seen between the two indices for the majority of the time series across all the ages. However, larger differences are seen in the last year of the time series and some age classes (ages 1, 2, 6 and 7) show persistent differences across several years towards the end of the time series.

A comparison of the assessment results using the "full coverage" NS-WC Q1 indices to the assessment results using the "reduced coverage" and "no Q1" indices for assessment years 2020 and 2021 are shown in Figures A8.1.6 and 7 respectively. Overall, little difference is seen between the assessment estimates of SSB, recruitment, fishing mortality and catch across most years. However, large differences are seen towards the end of the time series as the influence of the data points in the last year of the NS-WC Q1 indices becomes greater. Most of these differences are within 20% of the "full coverage" assessment estimates but the largest seen is a 43% reduction in the estimated recruitment (see Table A8.1.3). Furthermore, larger differences are seen with the "no Q1" than with the "reduced coverage" assessment results.

A wave pattern can be seen in the comparison of the recruitment estimate of the "no Q1" and the "full coverage" 2021 assessments (Figure A8.1.7). This wave pattern is linked to smoothing within the assessment model. A different coefficient of variation (CV) was estimated for recruitment in these two assessments which relates to smoothing within the model. The model smoothing acts to dampen the recruitment estimate in some years more than others which then becomes apparent when compared to other assessment results. Despite this, and excepting the final year estimates, the recruitment estimates over the rest of the time series from the "no Q1" assessment still gives similar trends over time to the "full coverage" assessment.

The large final year differences seen between the assessment results would likely have significant effects on the results of the short term forecast and that the reduced sampling coverage seen in Q1 of 2022 will likely affect the quality of the 2022 assessment. However, it is difficult to definitively predict the final outcome on the 2022 assessment given the interannually variable nature of biological datasets. These results also show that using a reduced survey dataset is preferable to omitting it completely as the final year differences are largest when the Q1 survey data are wholly excluded. However, the sensitivity of the assessment results to the reduced survey coverage indicates that there is a need for an approach that will mitigate the impact on the final year estimates.

Assessment year	Compared runs	SSB	F	Recruitment	Catch
2020	Full vs reduced	-6.3%	+5.0%	+13.2%	+1.61%
2020	Full vs no Q1	+13.4%	-7.1%	-19.5%	-3.2%
2021	Full vs reduced	+6.5%	-3.5%	+17.7%	-1.12%
2021	Full vs no Q1	-22%	+3.8%	-43%	-1.44%

Table A8.1.3: Northern Shelf haddock. Summary of the final year differences (% difference), for assessment years 2020 and 2021, between the "reduced coverage" and "no Q1" assessments compared to the "full coverage" assessment results.

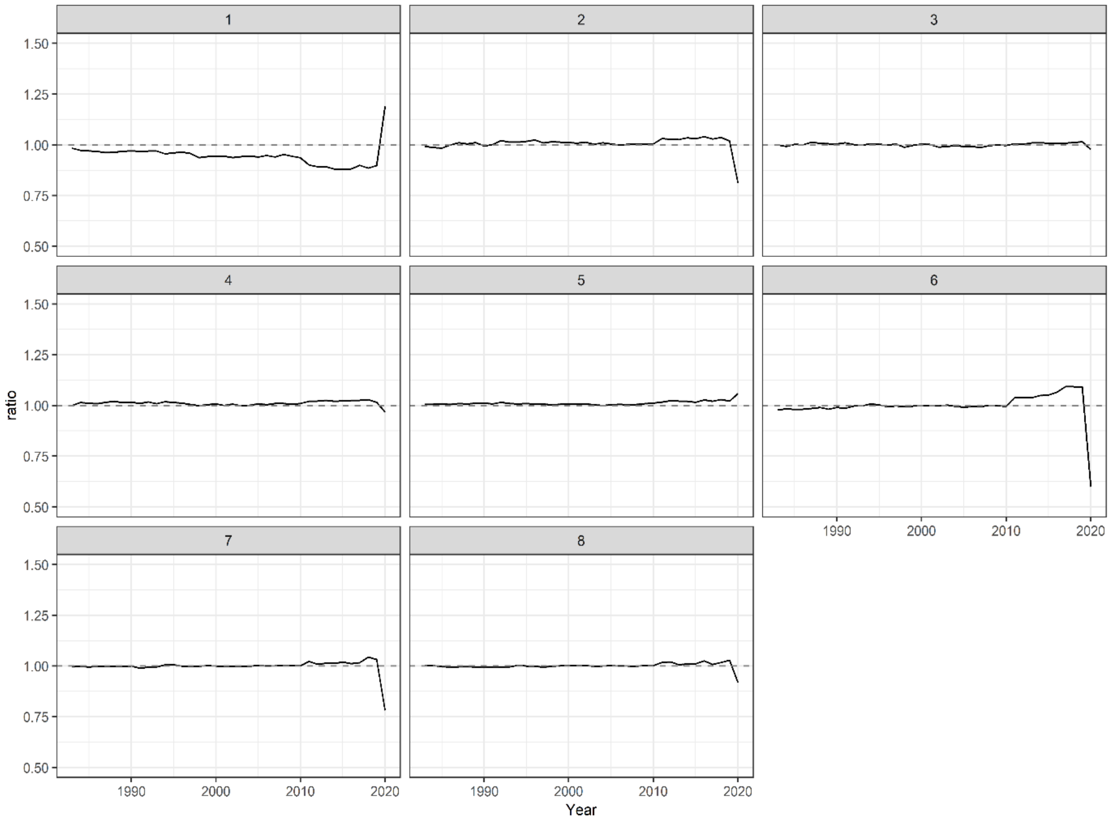

Figure A8.1.4: Northern Shelf haddock. Ratio for each age (1 – 8+) of the "reduced coverage" Q1 indices to the "full coverage" Q1 indices (1983:2020) where the reduced data coverage seen in 2022 is replicated in 2020. The horizontal, grey, dashed line indicates a ratio of 1:1.

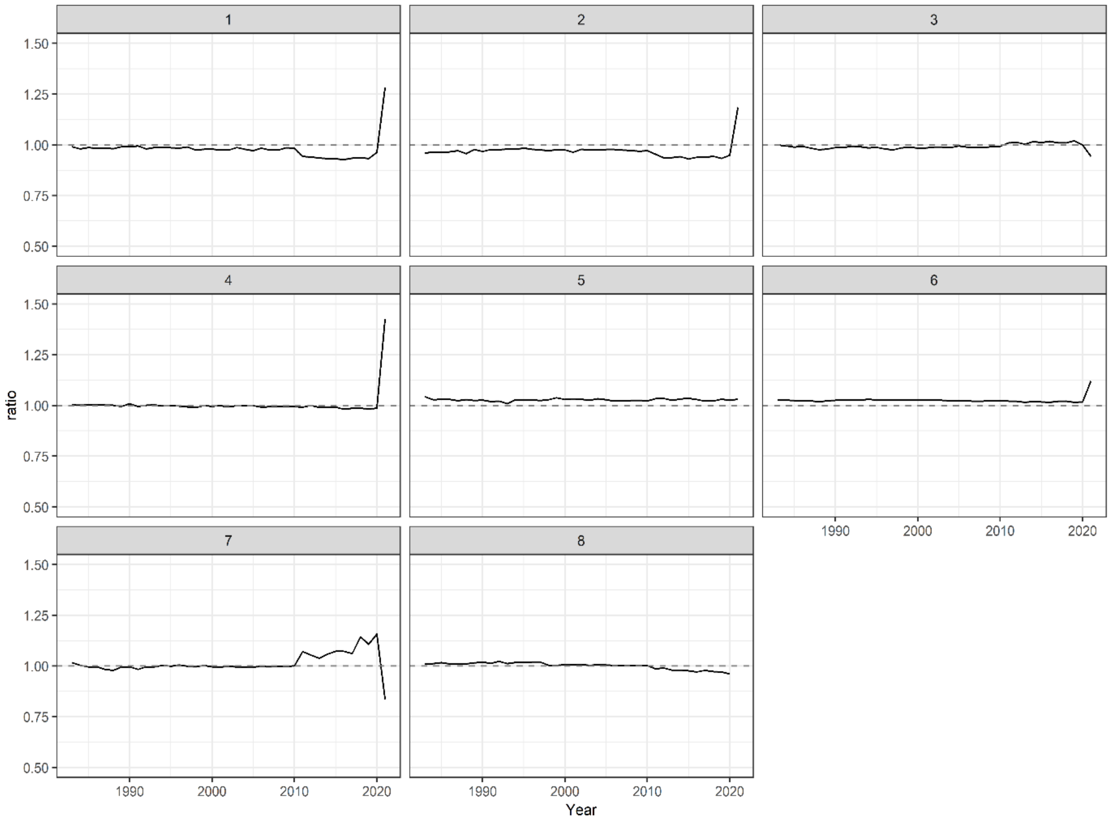

Figure A8.1.5: Northern Shelf haddock. Ratio for each age (1 – 8+) of the "reduced coverage" NS-WC Q1 indices to the "full coverage" NS-WC Q1 indices (1983:2021) where the reduced data coverage seen in 2022 is replicated in 2021. The horizontal, grey, dashed line indicates a ratio of 1:1.

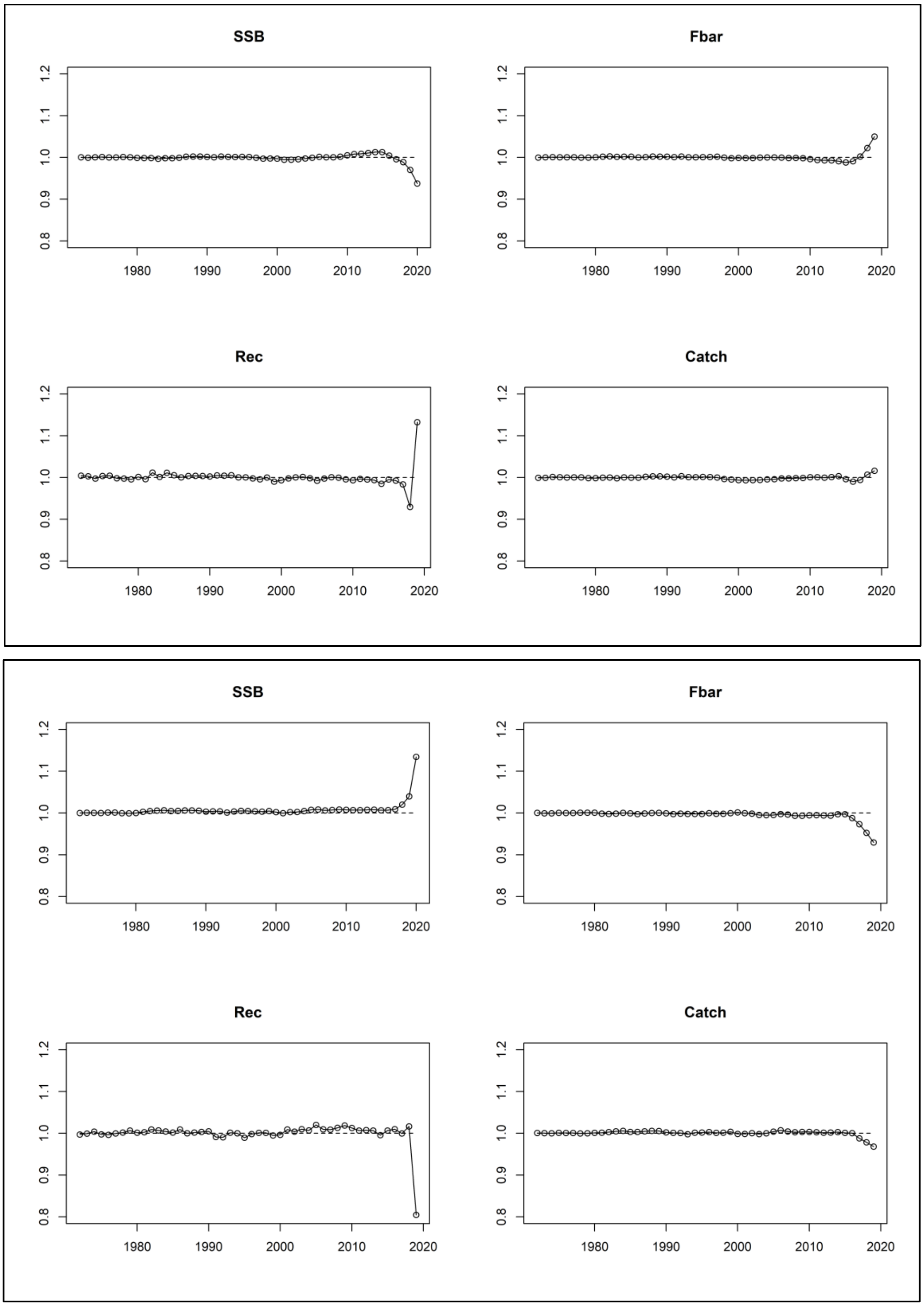

Figure A8.1.6: Northern Shelf haddock. Ratio of the assessment estimates. For assessment year 2020, resulting from using the "reduced coverage" NS-WC Q1 indices (top panel) and the "no Q1" NS-WC Q1 indices (bottom panel) to the "full coverage" NS-WC Q1 indices (1983:2020). The horizontal, grey, dashed line indicates a ratio of 1:1.

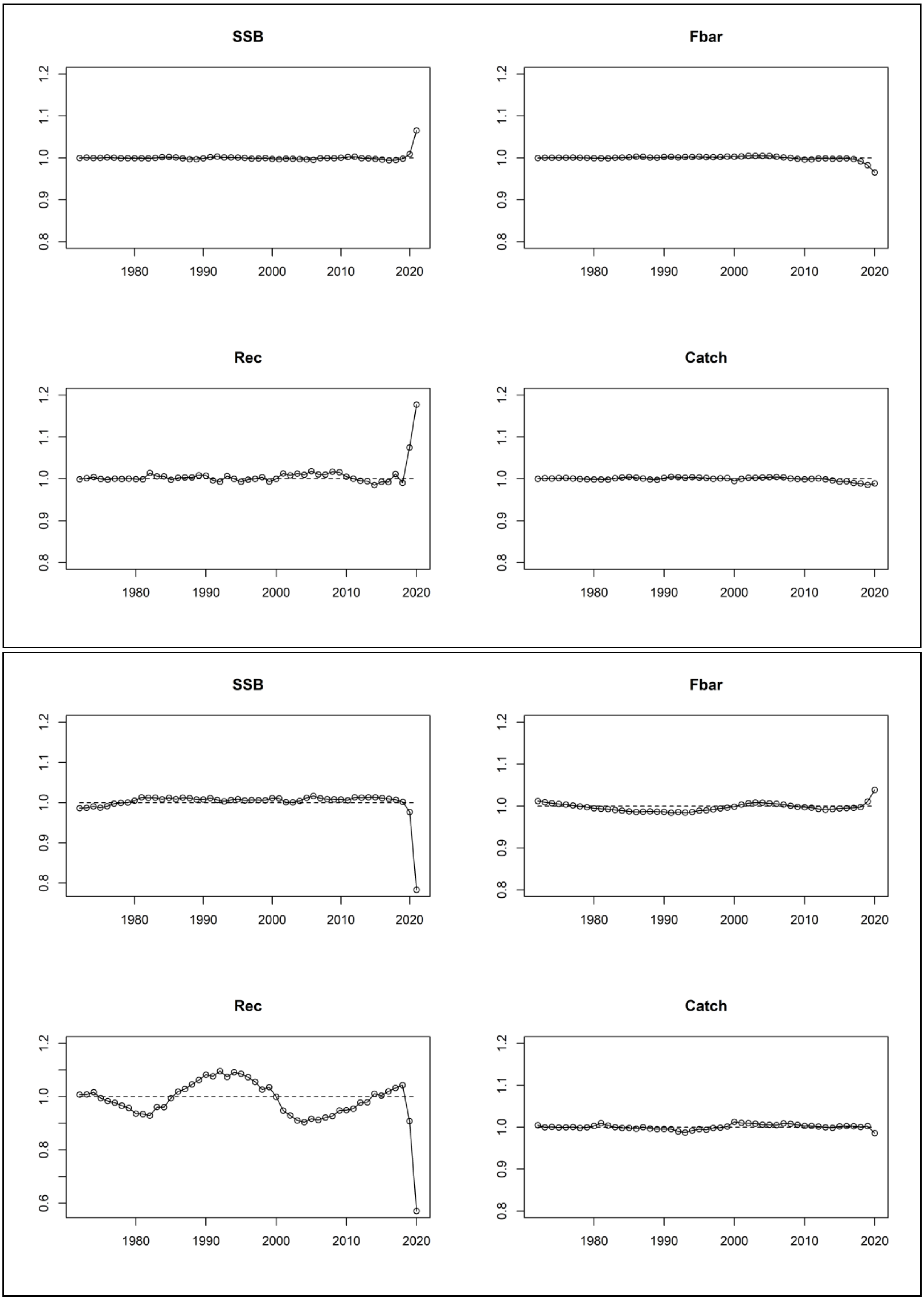

Figure A8.1.7: Northern Shelf haddock. Ratio of the assessment estimates, for assessment year 2021, resulting from using the "reduced coverage" NS-WC Q1 indices (top panel) and the "no Q1" NS-WC Q1 indices (bottom panel) to the "full coverage" NS-WC Q1 indices (1983:2021). The horizontal, grey, dashed line indicates a ratio of 1:1.

Use of relative weightings

The NS-WC Q1 indices used in the haddock stock assessment are modelled which means that coefficients of variation (CV) for each point in the indices time series can also be generated. These can then be used as relative weightings within the assessment model to indicate the relative amount of confidence the model should give to each data point.

The logarithms of the Q1 survey observations are assumed to follow a normal distribution with means as predicted by the survey equation and variance proportional to the externally estimated survey variances

$$\log(I_{ay}) \sim N\left(\log(Q_a) + \log(N_{ay}), \frac{\sigma_a^2}{W_{ay}}\right)$$

It is assumed that $Q_7 = Q_{8+}$ and that $\sigma_2^2 = \cdots = \sigma_{8+}^2$.

The Q1 survey provides externally calculated estimates of the CV_{ay} of each individual observation I_{ay}. The CV of the natural scale observation corresponds to a variance of the log-observation of $\log(CV^2 + 1)$, so, to account for the differences in the precision of the estimated log-survey indices $\log(I_{ay})$ the observation variances are scaled by $W_{ay} = \frac{1}{\log(CV_{ay}^2+1)}$.

Figure A8.1.8 shows the ratio between the CVs for the "reduced coverage" to "full coverage" NS-WC Q1 indices. The CVs are seen to be similar across all years except for the last year of the time series where the CVs are larger for the "reduced coverage" indices. The difference in CVs in the last year is also seen to increase with age.

To investigate how much the use of CVs in the assessment model might address the increase in uncertainty in the NS-WC Q1 indices additional "reduced coverage" assessments were conducted with the inclusion of the CVs for the NS-WC Q1 indices (named "reduced coverage with CVs"). These new assessments were then compared to the "full coverage" assessment results (Figure A8.1.9).

The comparisons show that the differences in SSB, fishing mortality and catch in the last few years of the times series caused by the reduction in sampling coverage are much smaller when the NS-WC Q1 CVs are used in the assessment. For recruitment, the differences are also reduced in all expect the last two years in the time series. The larger CVs on the final year data points in the indices mean that the influence of these data on the modelling of cohorts is relatively lower compared to other data input to the assessment model. Thus, the abundance estimates in the last few years are affected less by these less accurate data points. This results in estimates of SSB, fishing mortality and catch which are closer to those given by the "full coverage" assessment. However, the recruitment estimates in the final two years are still affected by the reduced sampling as there are no other data on these cohorts available to the model. It should also be noted that the ratios shown in Figure A8.1.9 show lots of small fluctuations compared to those in Figures A8.1.6 and 7. These small fluctuations come from small changes in the assessment results from adding the CVs as an input.

As explained in the New Maturity Scale Codes section, B_{lim} is set equal to the SSB in 1999. The effect of the reduced sampling coverage, both with and without the inclusion of CVs, on the estimate of B_{lim} is summarised in Table A8.1.4 and Figure A8.1.10. Overall, the changes in SSB in 1999 are small (<1%) though are seen to be larger when the CVs are included. As seen in the previous section, the influence of reduced sampling in the final year on the historic time series is small (Figures A8.1.6 and 7) whereas the inclusion of the CVs has a relatively greater influence on the historic time series as new information is provide at each time point (Figure A8.1.9). However, it should be noted that the differences in the historic time series are still small.

Assessment year	Compared runs	% change in B_{lim} (SSB in 1999)
2020	Full vs reduced	-0.04%
2020	Full vs reduced with CVs	-0.89%
2021	Full vs reduced	-0.26%
2021	Full vs reduced with CVs	-0.78%

Table A8.1.4: Northern Shelf haddock. Comparison of B_{lim} (SSB in 1999) in the "reduced coverage" and "reduced coverage with CVs" assessment runs with the "full coverage" assessment runs for assessment years 2020 and 2021.

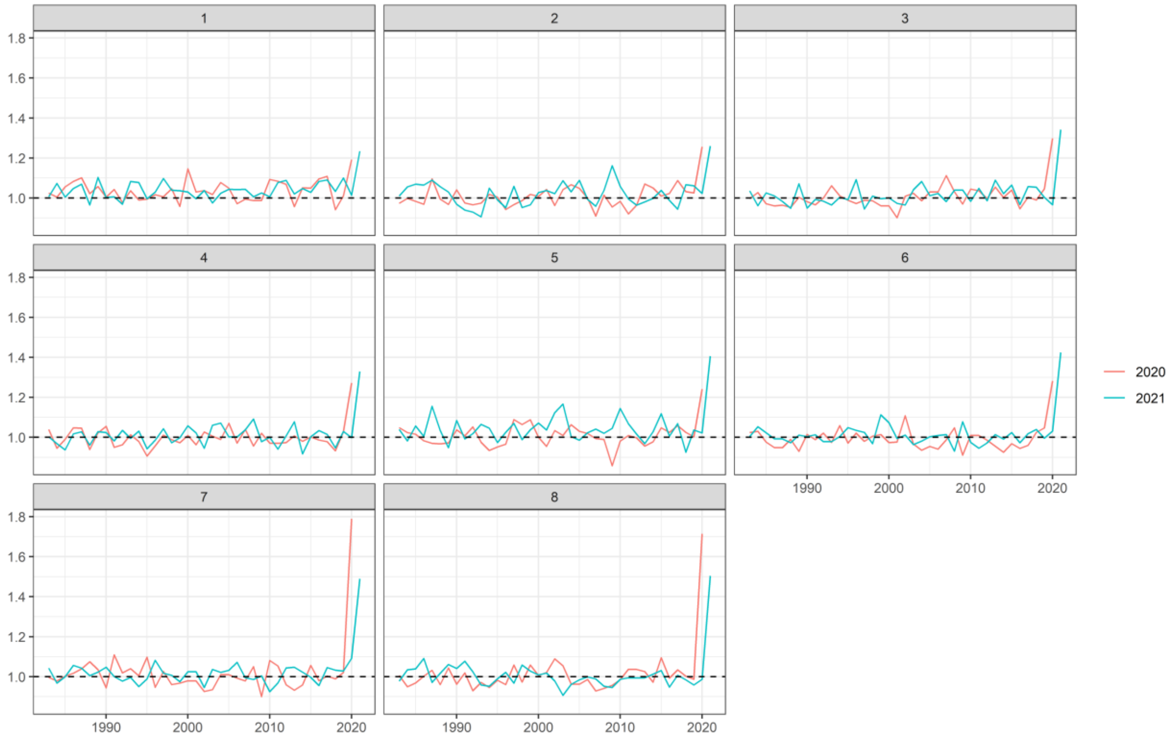

Figure A8.1.8: Northern Shelf haddock. Ratio of the coefficients of variation by age class associated with the "reduced coverage" NS-WC Q1 indices to the "full coverage" NS-WC Q1 indices for assessment year 2020 (red; 1983:2020) and assessment year 2021 (blue; 1983:2021).

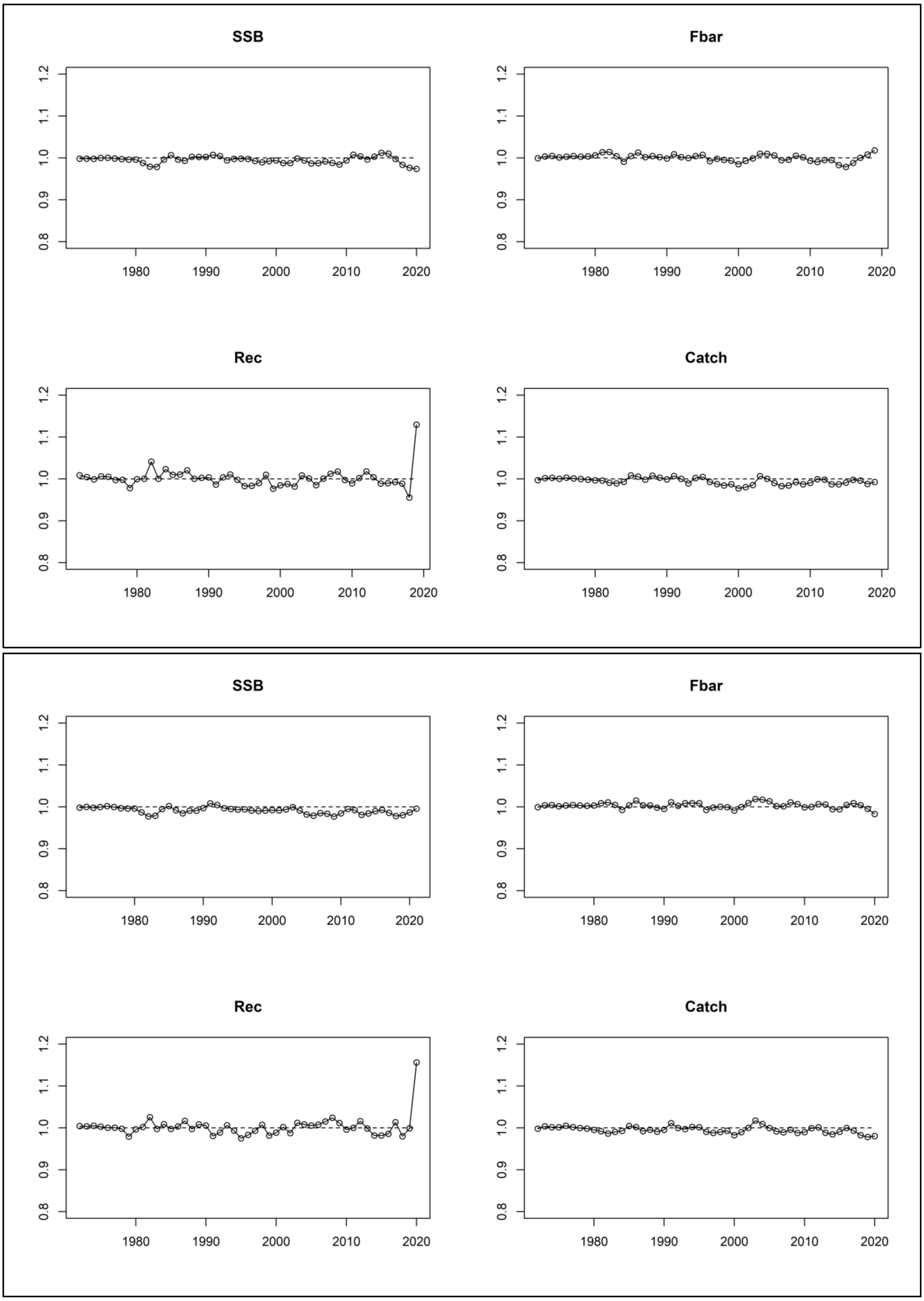

Figure A8.1.9: Northern Shelf haddock. Ratio of the assessment estimates resulting from using the "reduced coverage with CVs" NS-WC Q1 indices to the "full coverage" Q1 indices for assessment years 2020 (top panel) and 2021 (bottom panel). The horizontal, grey, dashed line indicates a ratio of 1:1.

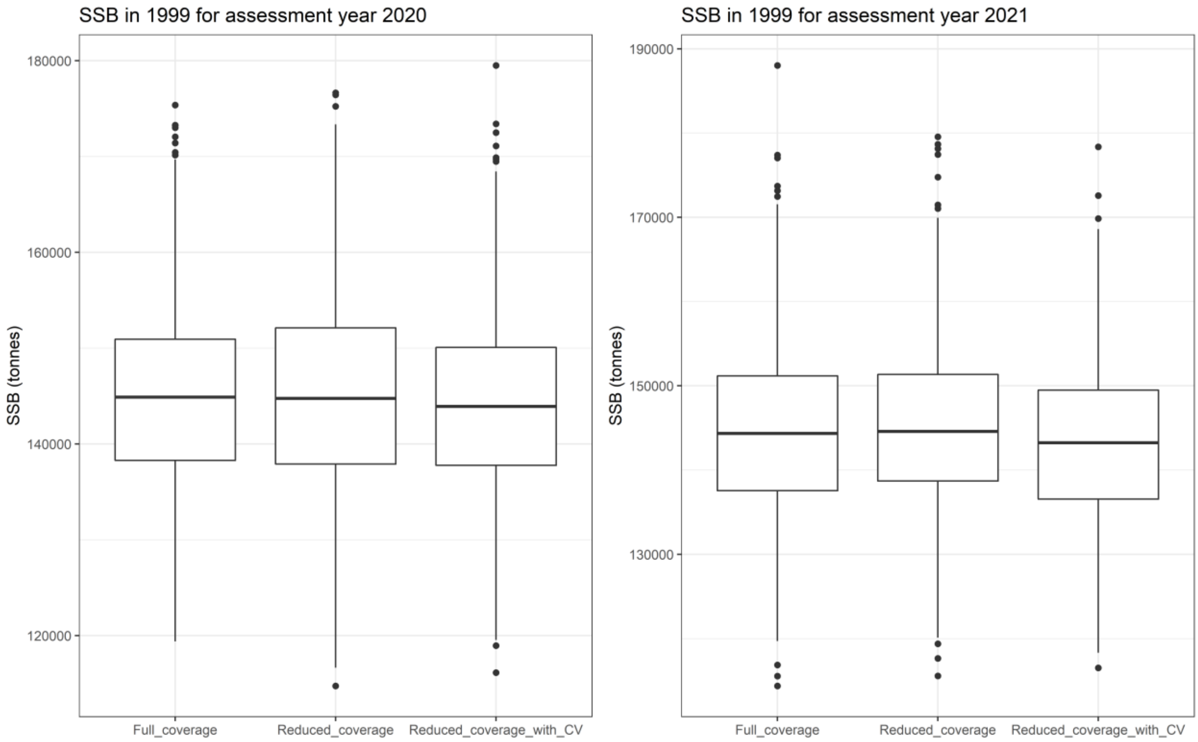

Figure A8.1.10: Northern Shelf haddock. Comparison of B_{lim} estimate (SSB in 1999) for the "full coverage", "reduced coverage" and "reduced coverage with CVs" assessment runs for assessment year 2020 and 2021.

Updating the benchmark assessment to include CVs for the Q1 survey indices

The results from the investigation into the effect the reduced sampling in Q1 of 2022 indicate that the 2022 data can be used to generate the modelled NS-WC Q1 indices but that the associated CVs should be added as an input to the assessment model. This recommendation was followed at WGNSSK 2022 to conduct the stock assessment used to produce the 2022 advice. However, this represents a change from the assessment model settings and inputs as detailed in the stock annex and may have implications for the reference points set at the WKNSCS benchmark meeting (see Table A8.1.5 for a summary of the differences). Although, based on the results shown in the previous section, any differences are expected to be small.

Name	Assessment year	Catch data	Biological data	Survey indices	Comments
WKNSCS 2022	2021	Number and mean weight-at-age 1972:2020	Mean stock weights 1972:2020 Maturity 1991:2021 Natural mortality 1974:2020	NS-WC Q1 1983:2021 NS-WC Q3+Q4 1991:2020	Benchmark assessment. Maturity inputs do not include the new maturity scale (described above).
WKNSCS 2022 with the NS-WC Q1 CVs	2021	Number and mean weight-at-age 1972:2020	Mean stock weights 1972:2020 Maturity 1991:2021 Natural mortality 1974:2020	NS-WC Q1 including CVs 1983:2021 NS-WC Q3+Q4 1991:2020	Benchmark assessment plus just the Q1 survey CVs. Maturity inputs do not include the new maturity scale (described above).
WGNSSK 2022	2022	Number and mean weight-at-age 1972:2021	Mean stock weights 1972:2021 Maturity 1991:2022 Natural mortality 1974:2020	NS-WC Q1 including CVs 1983:2022 NS-WC Q3+Q4 1991:2021	Assessment used for 2022 advice. Maturity inputs include the new maturity scale (described above).

Table A8.1.5: Northern Shelf haddock. Summary of assessment model inputs for the benchmark assessment (WKNSCS 2022), a benchmark assessment updated with the NS-WC Q1 CVs (WKNSCS 2022 with the NS-WC Q1 CVs) and the latest assessment (WGNSSK 2022) used to produce the 2022 advice. For years where biological data are not provided, values are set equal to those for the nearest year.

The CVs for the 2022 Q1 indices are shown in Figure A8.1.11 along with the CVs for the reduced coverage indices for 2020 and 2021 for comparison. The increase in the CVs in the final year for the 2022 indices compared to the CVs for 2020 and 2021 indices are of similar magnitude for ages 3-6, slightly larger for age 2 and difficult to separate from the interannual variability in ages 1, 7 and 8.

An updated benchmark assessment was run to assess the effect the inclusion of CVs for the NS-WC Q1 survey indices would have had on the benchmark assessment. A comparison of these results is shown in Figure A8.1.12. As expected, the differences between the two assessments are small. A summary of the differences in SSB and fishing mortality can be seen in Table A8.1.6 where the differences are compared to those seen between the benchmark assessment and the WGNSSK 2022 assessment use to produce the 2022 advice. The changes in the benchmark 2020 and 2021 values compared with the WGNSSK 2022 values are seen to be larger than the changes seen when including the CVs in the benchmark assessment. This is due to the influence of the extra year of data in the WGNSSK 2022 assessment that directly affects the latest cohorts. However, as the focus here is on reference points the comparison of the historic time series is of most interest. Following the same comparison of SSB in 1999 as done in the "New maturity scale codes" section, the addition of the NS-WC Q1 CVs reduces the 1999 SSB (value of B_{lim}) by a small amount (1.37%). It follows that the values of B_{pa} and MSY $B_{trigger}$ would also be reduced by a similar percentage. We also see that the mean and maximum differences in SSB and fishing mortality from adding the NS-WC Q1 CVs are small compared to the differences seen from adding a year of data to the input datasets for the WGNSSK 2022 assessment (Table A8.1.6). Therefore, the experts attending WGNSSK 2022 agreed that the addition of the Q1 CVs to the assessment did not require an update to the reference points.

	Benchmark assessment vs benchmark assessment with NS-WC Q1 CVs	**Benchmark assessment vs WGNSSK 2022**
SSB in 1999	-1.37%	0.87%
SSB in 2020	-1.66%	11.6%
SSB in 2021	-1.04%	4.7%
Mean absolute difference in SSB*	1.23%	2.1%
Max absolute difference in SSB*	3.4%	6.5%
Mean absolute difference in Fbar*	0.75%	1.40%
Max absolute difference in Fbar*	2.2%	10.0%

Table A8.1.6: Northern Shelf haddock. Summary of the differences seen in SSB and fishing mortality (Fbar) when comparing the benchmark assessment with the NS-WC Q1 CVs added as an input and the WGNSSK 2022 assessment with the benchmark assessment (WKNSCS; ICES 2022).

* Comparison was done for the years 1972:2019 to focus on the effects on the historic time series.

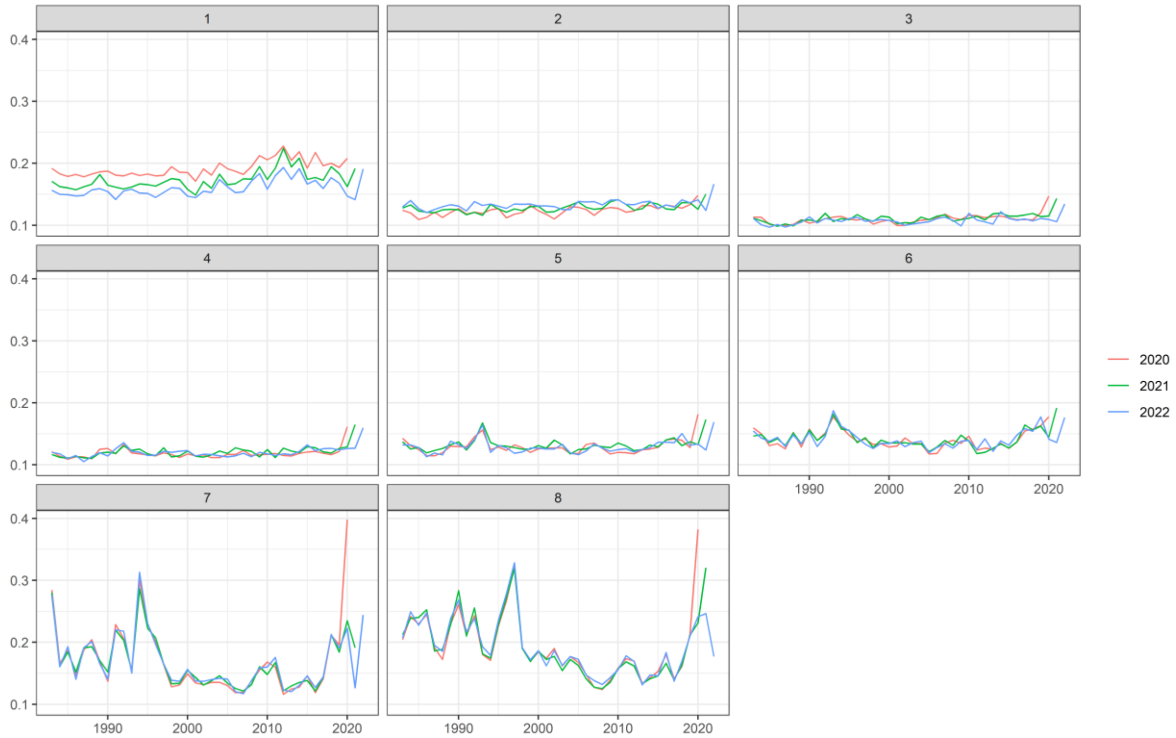

Figure A8.1.11: Northern Shelf haddock. CVs for the 2022 Q1 survey indices as used in the WGNSSK 2022 assessment (blue) compared to the CVs for the reduced coverage Q1 indices for assessment year 2020 (red) and 2021 (green).

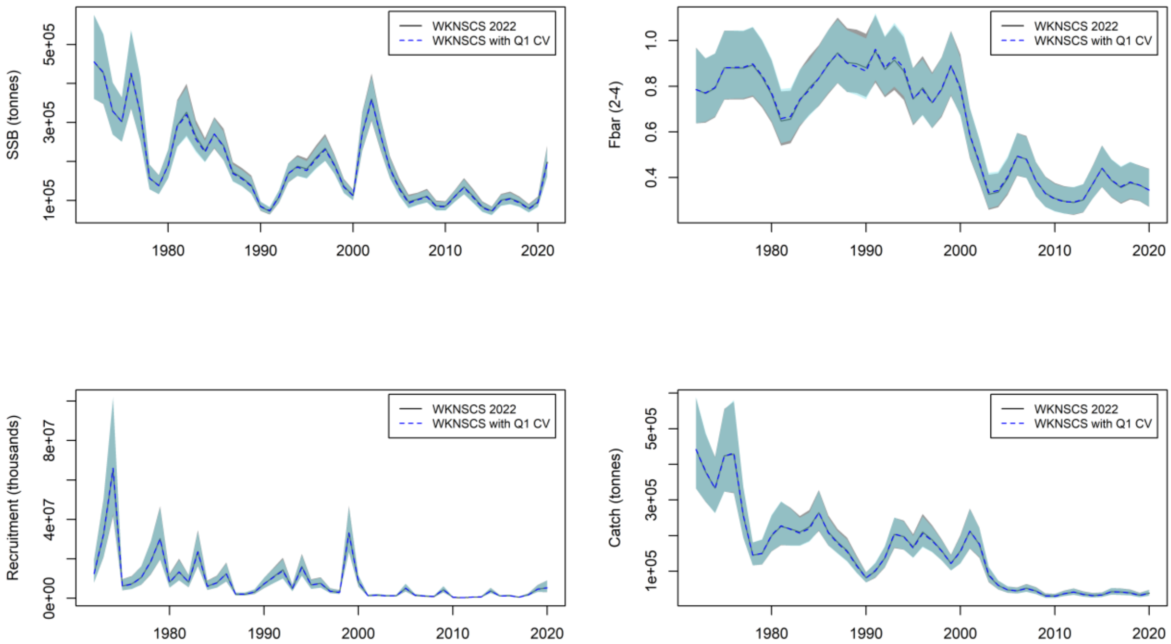

Figure A8.1.12: Northern Shelf haddock. Comparison of SSB (top left), fishing mortality (top right), recruitment (bottom left) and total catch (bottom right) estimates from the benchmark assessment ("WKNSCS 2022"; black solid line) and the WKNSCS 2022 assessment with CVs for the NS-WC Q1 survey indices ("WKNSCS with Q1 CV"; blue dashed line). Shaded regions indicate the pointwise 95% confidence intervals.

Conclusions

Two issues came to light during WGNSSK 2022 that had implications for the conclusions of the recent benchmark for Northern shelf haddock.

The first was the omission of maturity samples that used a new maturity scale. The results here show that the inclusion of these missing data had a minimal impact on the benchmark assessment results and virtually no impact on the calculation of the biomass reference points (B_{lim}, B_{pa} and MSY $B_{trigger}$).

The second was a reduction in the sampling coverage of the Q1 surveys used to calculate indices for use in the assessment. A sensitivity analysis found that the reduced sampling coverage in 2022 would have likely affected the quality of the WGNSSK 2022 assessment results though it is difficult to be definitive about the effects due to interannual variability in the population. However, this analysis found that the impact of the reduced sampling coverage could be mitigated by using the CVs associated with the NS-WC Q1 indices as an additional input to the assessment model. Since this represented a change to the model setup accepted at the benchmark a further comparison was done to check the effect that adding the CVs would likely have on the reference points. This comparison suggests that the changes would be small. ICES procedures for updating reference points between benchmarks are contingent on the magnitude of the effects on the historic time series and the consensus of the WG experts. The consensus reached at WGNSSK 2022 was that the reference points do not need to be recalculated and can remain as set at the benchmark meeting. However, all changes to the assessment described in this document will be included the next time reference points need to be re-calculated for this stock.

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Working document 2: FR-CGFS Survey index for ple.27.7d stock assessment: WGNSSK 2022.

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Date: 16-05-2022

Introduction

Eastern English Channel (7d) Plaice (*Pleuronectes platessa*) stock is currently assessed using two survey indices: UK-BTS in Q3, and FR-CGFS in Q4. During 2021 WGNSSK working group (ICES, 2021a), several issues were uncovered regarding FR-CGFS survey index. The current index is based on a stratified mean approach to derive index at age, ages 1- 6 are then used in the assessment. Firstly in 2020, due to the COVID-19 pandemic and the lockdown in place in France at that time, there was a delay in submitting the cruise application form for the FR-CGFS2020 to the French Foreign Ministry. The net result was that no authorisation was provided to allow the survey to trawl within UK EEZ, and only 70% of the core survey stations were completed by the French RV Thalassa in 2020. In addition, while investigating the issue, mistakes were found in the calculation of the index. While sorting samples by age using an age length key (ALK) filled in based on expert knowledge, some hauls with no catch were dropped from the calculation. To address both issues, new methods were investigated to try to extrapolate missing information in 2020 using the spatial distribution observed in the time series and to include all surveys hauls. Delta-GAMM and Delta-GLMM were investigated and at the same time new ALK were estimated.

Data available and pre-processing: The French Channel Ground Fishing Survey (FR-CGFS)

FR-CGFS data used for the analyses were extracted from ICES trawl surveys database DATRAS from 1988-2021 (https://datras.ices.dk/Data_products/Download/Download_Data_public.aspx, 11-04-2022). Biological samples are only available in for FR-CGFS from 2008 onwards, prior to 2008 biological samples were extracted from Ifremer biological samples database Bargeo.

The Channel Ground Fishing Survey occurred every year in October since 1988, covering the Eastern English Channel (7.d) and part of the Southern North Sea (4.c). The survey used a systematic sampling design based on a grid of 15′ of latitude and 15′ of longitude. Each cell is sampled at least once, corresponding to a maximum of 82 stations. From 1988-2014 sampling was realised on board the RV Gwen Drez′, a 25 m vessel using a GOV gear. The vessel was reformed in 2015 and had to be replaced by the RV Thalassa, a 75 m vessel using similar gear. To accommodate for the change of vessels, the survey sampling design was redefined to avoid shallow water stations and an inter-calibration between the two vessels was realised to assess any change in catchabilities (Figure A8.2.1a). In 2018, the survey was extended to cover the Western English Channel (7.e), the area 7.e is sampled during the end of September and the 7.d remains sampled in the beginning of October. During the entire period, haul duration was kept at 30 minutes with a tow speed between 2.5 and 4 knots.

In 2020, delay in transmission of trawling application form by the French Foreign Affair Administration to the UK Administration due to Covid-19 pandemic lead to a non-authorisation of trawling in UK EEZ. Only stations in French EEZ were covered by CGFS survey reducing the sampling coverage by around 30% (Figure A8.2.1b; ICES, 2021b).

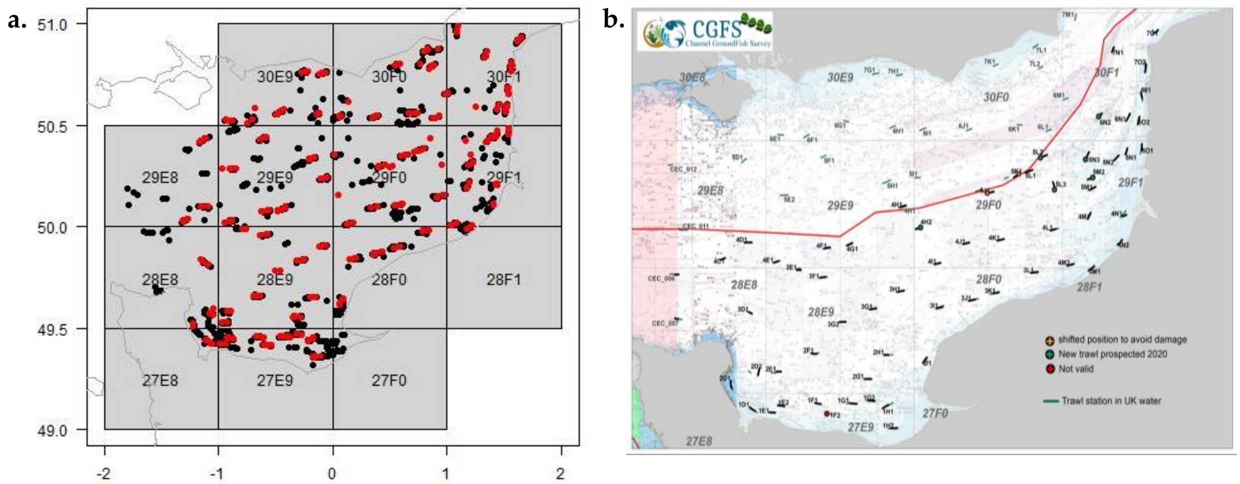

Figure A8.2.1. Plaice in 7d: (a) FR-CGFS survey station in the Eastern English Channel (ICES sub area 7.d) from 1988 to 2021. In black, stations covered by the RV Gwen Drez' from 1988 to 2014 and in red, survey stations covered by the RV Thalassa from 2015 to 2021. (b) 2020 hauls planned in UK EEZ (in green) and realised (in black) by the RV Thalassa.

To produce age-based survey indices for Plaice 7.d stocks, the analysis only focused on CGFS survey hauls in 7.d and hauls located in Bay of Seine estuary (27F0 ICES statistical rectangle; Figure A8.2.1a) were removed as since 2015 the RV Thalassa cannot sample in shallow waters.

CGFS index calculation

Age Length Key estimates

Since 1990, plaice biological samples are collected during CGFS survey. However, from 1990-2005, otolith were binned by length class of 1cm and ICES subareas with no information on other individual parameters or sampling stations. From 1990-2007 empirical age length keys (ALK) were recorded in Ifremer Database and were used in the current analysis.

Since 2008, biological samples are available in DATRAS database and they were used to derive the ALK. The model of Berg & Kristensen (2012) is fitted to age and length data for each year to obtain the ALK which is then applied to the length frequency for each haul to calculate numbers at age per haul. The approach consist of fitting a continuation ratio logits model to estimate probability of age given fish length. A spatial effect was tested to account for haul location (lat, lon) using a two-dimensional thin plate spline, however model wasn't able to converge for each year so the variable was dropped from the analysis. The model is implemented within the R DATRAS package using the function *fitALK*. Model parameters are estimated for each year with:

$$\mathrm{logit}(\mathrm{p}_{ay}[\mathbf{x}_i]) = \alpha_{ay}+\beta_{ay}\mathrm{L}_i$$

where p is the conditional probability of a fish being of age a; i is the i^{th} fish; L corresponds to the length of the fish.

Plaice 7.d assessment model used CGFS survey index ages 1-6, so the ALK model was fitted using ages 0-7+ (Figure A8.2.2).

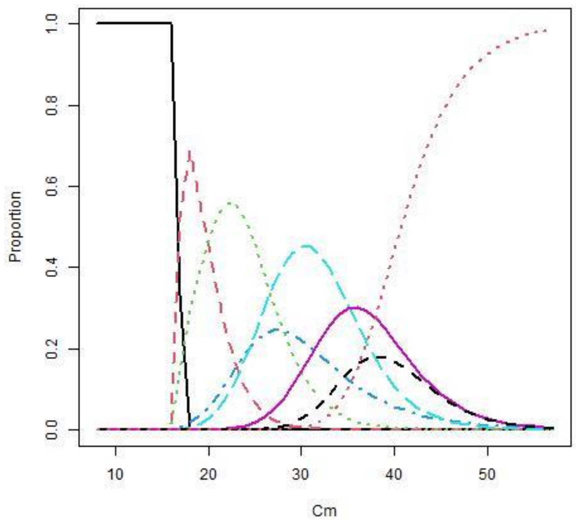

Figure A8.2.2 Plaice in 7d age-length keys derived from a continuation logit ratio model fitted on 2018 CGFS survey biological samples. Each curve represents the distribution of probability of plaice being of a certain age given its size in cm. Each curve corresponds respectively, from left to right, to age 0 to 7+.

Survey age based CPUE standardization

To address the lack of sample in UK EEZ in 2020 and included all CGFS hauls in our index calculation, two spatial modelling approach were investigated, a delta-GAMM model based on Berg *et al* (2014) methods and a delta-GLMM using an INLA approach (Rue et al., 2017; Zuur and Ieno, 2018).

Delta-GAMM

The analysis is performed using the surveyIndex R package that applied the methodology described in Berg et al (2014). Delta-lognormal GAMM's are fitted to each haul estimates for each age class separately. (Alternatives distributions tweedy and delta-gamma were tested but provides a worse fit). The model is composed of two parts also fitted independently:

- The probability of occurrence (binomial)
- The amount catch abundance when non-zero catch (log-normal, positive continuous)

In the full model, both parts took the form of:

$$g(\mu_i) = Year(_i) + f_1(lon_i,lat_i) + f_2(depth_i) + U(Ship) + log(Swept\_area_i)$$

where for each haul *i*,

μ_i is the expected response (number at age for the positive model or 1/0 for the binomial)

Year(*i*) a categorical year effect

f_1 is a 2-D thin plate regression spline ("ts") on the latitude/longitude coordinates

f_2 is a 1-D thin plate spline ("ts") for the bottom depth effect

U is a random Ship effect

g is the link function (logit or log transformed response)

$log(Swept\_area_i)$ is an offset to standardize the response by the swept area.

Conversion from length frequencies to age using ALK can lead to small abundance, so a cutoff value of 0.1 was applied in this analysis. Abundance at age by haul below 0.1 are assumed to be zero. Sensitivity runs to the cutoff value of 0.05 and 0.01 were investigated and had no impact on model fit or outcome.

Several models formulation were explored to assess the impact of Ship effect and the spatial regression spline smooth on the fit. To increase the number of knots used in the 2D spline the model was only fitted to ages 0-6. The best model is selected based on AIC and BIC.

A summary of the model is given below:

Model	variable	ages	Number of knots 2D spline (Bin, LN)
1	Year, Swept area, lat/lon, depth	0-7+	(8^2, 12^2)
2	Year, Swept area, lat/lon, depth, Ship	0-7+	(8^2, 12^2)
3	Year, Swept area, lat/lon, depth	0-6	(8^2, 12^2)
4	Year, Swept area, lat/lon, depth	0-6	(10^2, 14^2)

Delta-GLMM with INLA

The same way as before a delta-lognormal model is fitted to each series of abundance at age separately. However, rather than using a 2D regression spline to capture the spatial effect, a Gaussian Markov random fields (GMRF) is fitted using an INLA approach. The analysis is performed using R-INLA package. A mesh and a system of partial differential equation is defined to estimates spatial effect/auto-correlation (Figure A8.2.3).

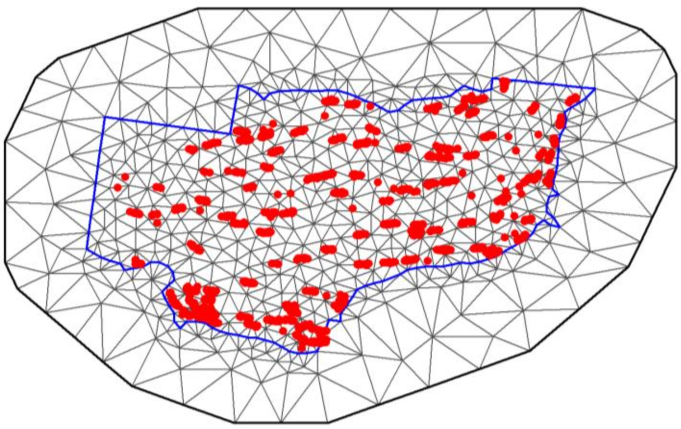

Figure A8.2.3 Plaice in 7d: Mesh (grey lines), model boundaries (blue line) and CGFS hauls location (red dots) used to define the Gaussian Markov random fields (GMRF). The mesh is extended outside the model boundaries to account for boundary effect.

Several model formulations were explored, including spatio-temporal correlation that could not be investigated in the delta-GAMM due to model convergence issues.

The full model is defined by two component as:

$$logit(\mu_i 0|1) = depth_i + Swept\_area_i + U_1(Year_i) + U_2(Ship) + GMRF(lon_i,lat_i, Year_i)$$

$log(\mu_i>0.1) = depth_i + U_1(Year_i) + U_2(Ship) + GMRF(lon_i,lat_i, Year_i) + log(Swept\_area_i)$

where for each haul *i*,

μ_i is the expected response (number at age for the positive model or 1/0 for the binomial)

U_1 is a random IID year effect

U_2 is a random IID ship effect

$Swept\_area_i$ is a continuous explanatory variable in the binomial model

$log(Swept\_area_i)$ is an offset to standardize the response by the swept area in the positive model

$depth_i$ is a continuous explanatory variable

$GMRF(lon_i,lat_i, Year_i)$ is a time-varying Gaussian Markov random fields (GMRF)

A summary of the model investigated is given below:

Model	variable	Time-varying spatial random effect
1	Year, Swept area, depth	-
2	Year, Swept area, depth, Ship	-
3	Year, Swept area, depth, lat/lon	GMRF
4	Year, Swept area, depth, lat/lon/Year	GMRF:IID
5	Year, Swept area, depth, lat/lon/Year	GMRF:AR1

The best model is selected based on the DIC and the WAIC. Uncertainty around index at age are derived from 10 000 resampling of parameter posteriors of the binomial and lognormal model.

Model comparisons

Delta-GAMM and Delta-GLMM approach were compared based on their abilities to track cohorts and retrospective analysis, their sensitivity to missing hauls in UK EEZ was investigated. To assess their sensitivity to missing hauls in UK EEZ, one scenario per year in CGFS survey time series was run with each model. For each scenario a different year was selected for which haul in UK EEZ were dropped from data. The indices from each scenarios are then compared to the indices estimated with the full dataset (baseline). For each age class, the standardized sum of squared error (SSE) between each scenario and the baseline is calculated for both modeling approaches to compare them, as:

$$\frac{1}{sd(\boldsymbol{Ibaseline})}\sum_{y=1990}^{2021}\sum_{s=1990}^{2021}\left(\boldsymbol{IwoUK}_{s,y} - \boldsymbol{Ibaseline}_y\right)^2$$

where $\boldsymbol{IwoUK}_{s,y}$ is the index value for year y from the scenario without UK data during year s and $\boldsymbol{Ibaseline}_y$ is the index value for year y from the baseline run. The SSE is standardized by the standard deviation of the baseline index to compare both modeling approaches.

Results

Delta-GAMM

Based on AIC and BIC (Table A8.2.1), adding a random ship effect to capture the change in fishing vessel does not improve the fit of the model. To be sure, an extra analysis was run including inter-calibration data to have one year of overlap between the two vessels but the same result was observed. The rest of the analysis was then performed without the ship random effect. Model 4 with an increased number of knots was selected based on AIC and BIC, and index estimates were produced for age 0-6.

Table A8.2.1 Plaice in 7d: Delta-GAMM Selection criteria: AIC and BIC, as well as the expected degree of freedom from each model

Model	AIC	BIC	edfs
1	29479.370	37041.017	958.409
2	29479.368	37041.005	958.407
3	27856.079	34565.522	865.036
4	27774.364	34889.767	917.375

Some model diagnostics can be found in Figure A8.2.A1 and A2 for the lognormal component of the delta-GAMM.

Delta-GLMM

As in the delta-GAMM, model 1 and 2 present minor difference in their WAIC and DIC across all ages, so the random ship effect was also dropped from the analysis (Table A8.2.2 Plaice in 7d: Delta-GLMM Selection criteria: WAIC and DIC, as well as the effective number of parameters from each model). Adding a GMRF to estimates spatial auto-correlation in the model (model 3, 4 and 5) improved the model. With the best fit using a time-varying GMRF with a first order autoregressive correlation across yearly spatial effect. However by using a time-varying spatial effect most of the data variability was captured by the time-varying GMRF, so the model with time invariant GMRF (model 3) was selected to estimate the yearly index of abundance at age (model 3).

Table A8.2.2 Plaice in 7d: Delta-GLMM Selection criteria: WAIC and DIC, as well as the effective number of parameters from each model

Model		WAIC	DIC	neffp
Binomial	1	15871.819	15882.186	192.328
	2	15841.356	15848.862	157.440
	3	10534.041	10656.216	659.752
	4	14008.139	14233.070	1692.674
	5	10320.084	10520.404	974.547
Lognormal	1	20444.417	20446.775	119.943
	2	20440.663	20443.110	116.380
	3	18840.011	18842.472	371.008
	4	19537.776	19489.229	947.621
	5	17932.515	17915.587	1004.534

Some model diagnostics are presented in Figure A.8.2.A3 and A4 for the lognormal component of the delta-GLMM.

Model comparison

Retrospective analysis

Removing years from the survey index calculation have little effect on both modelling approaches (Figure A8.2.4 and 5). Mohn's Rho value associated with the 5-peels retrospectives analysis are low across ages. They are better in the Delta-GAMM for ages 0-2 and worse from age 3-6.

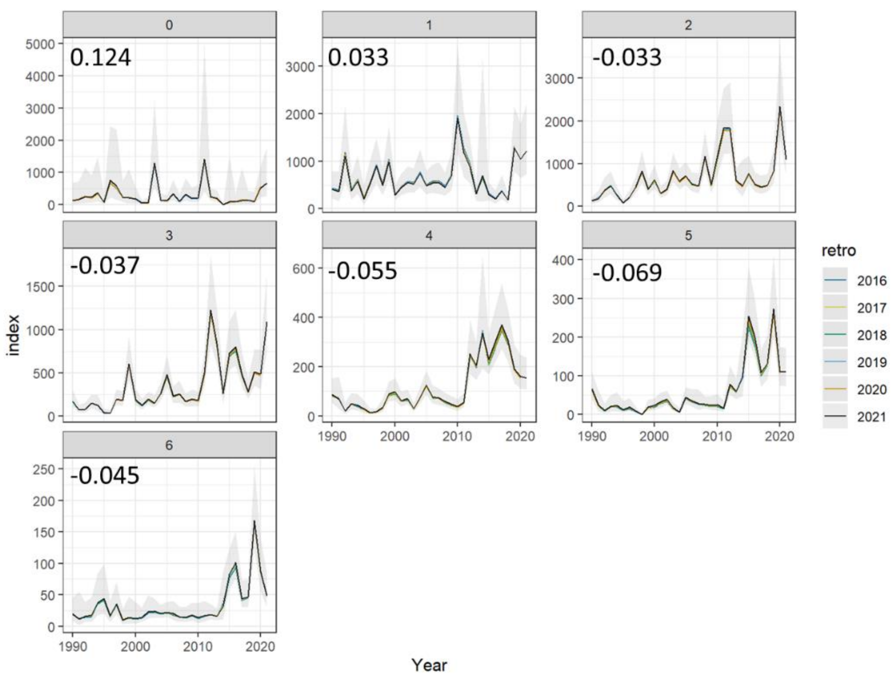

Figure A8.2.4 Plaice in 7d: Delta-GAMM retrospective analysis for ages 0-6 index over the last 5 years with their associated Mohn's Rho.

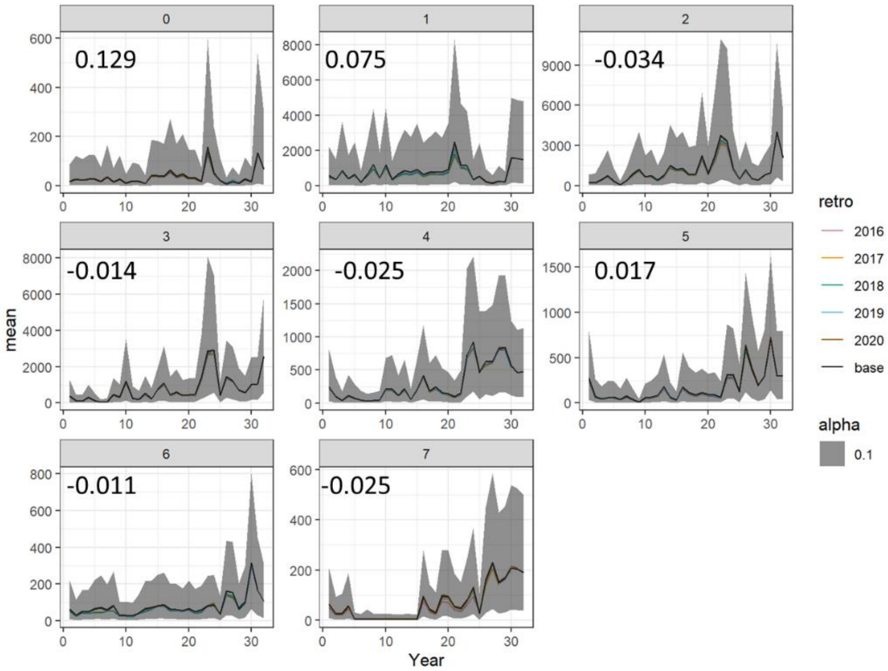

Figure A8.2.5 Plaice in 7d: Delta-GLMM retrospective analysis for ages 0-7+ index over the last 5 years with their associated Mohn's Rho.

Internal consistency

The index at age produced from the Delta-GAMM show better internal consistency between consecutive cohorts than the GLMM approach for ages 2-6 (Figure A8.2.6). Both modelling approaches improved the internal consistency of the index compared to the one in used in the current plaice 7.d stock assessment (stratified mean index).

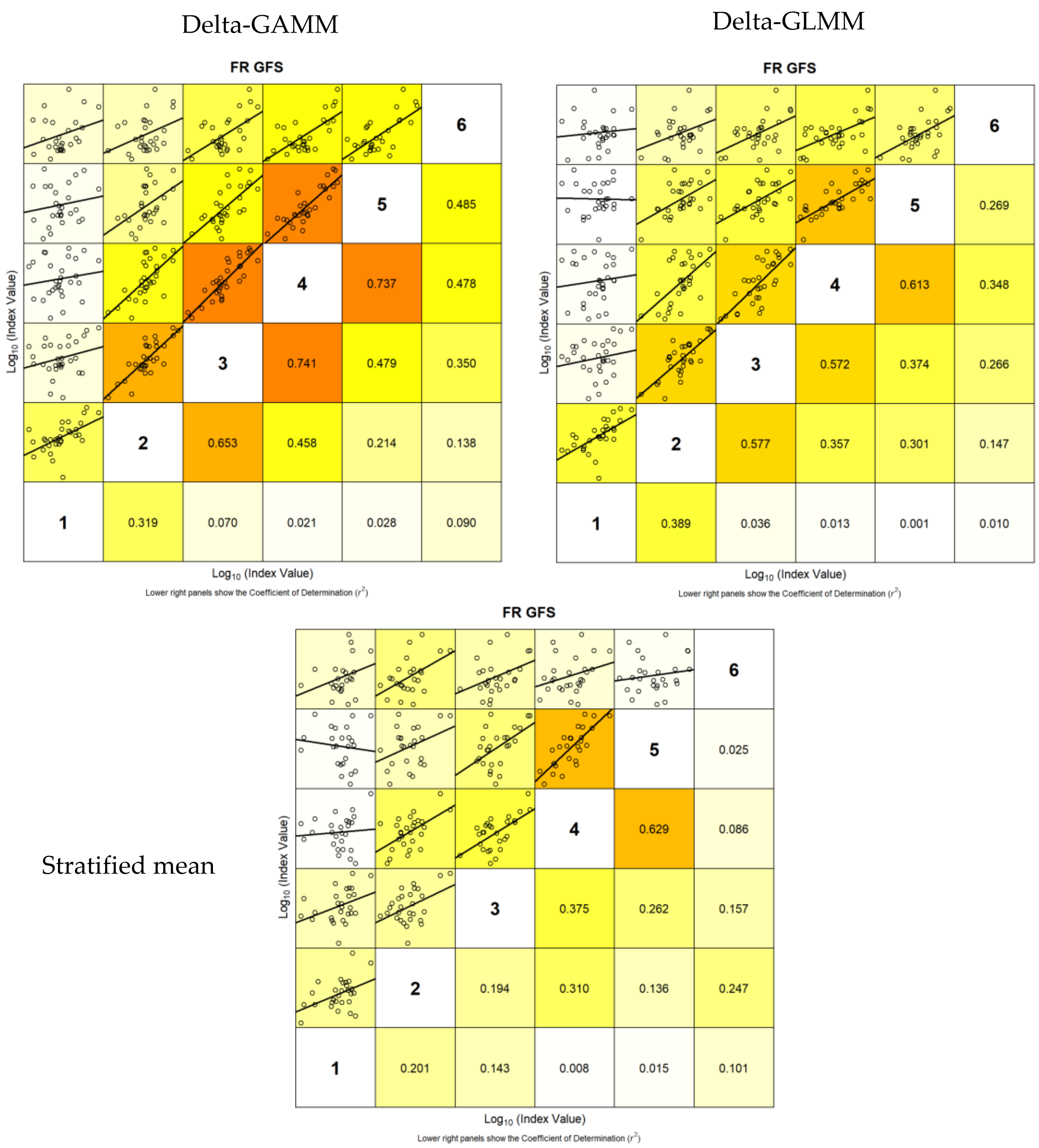

Figure A8.2.6 Plaice in 7d: Delta-GAMM, Delta-GLMM, and stratified mean (currently used in plaice 7.d stock assessment) internal consistency plot showing pairwise regressions and associated R^2 values

Model approach sensitivity to missing haul in UK EEZ

Even with missing haul in UK EEZ in a particular year, each scenario estimates remain within the uncertainty bound of its corresponding baseline model that used the full dataset. In both model approaches older ages (4-6) seem more impacted by missing haul in recent years (Figure A8.2.7 and A8.2.8), this could be related. When comparing the standardized sum of squared error between each scenarios and the baseline for each modelling approaches, the delta-GAMM performed better except for age 1. Scenarios for age 0 were not able to converge with the delta-GAMM (Figure A8.2.7 and Table A8.2.3).

Table A8.2.3 Standardized sum of squared error between index estimates from sensitivity scenarios of missing UK EEZ haul and from the full dataset for each age and model approaches.

Age	0	1	2	3	4	5	6	7+
ΔGAMM		2255	2407	1566	563	247	117	
ΔGLMM	315	2084	3070	3028	1522	621	378	138

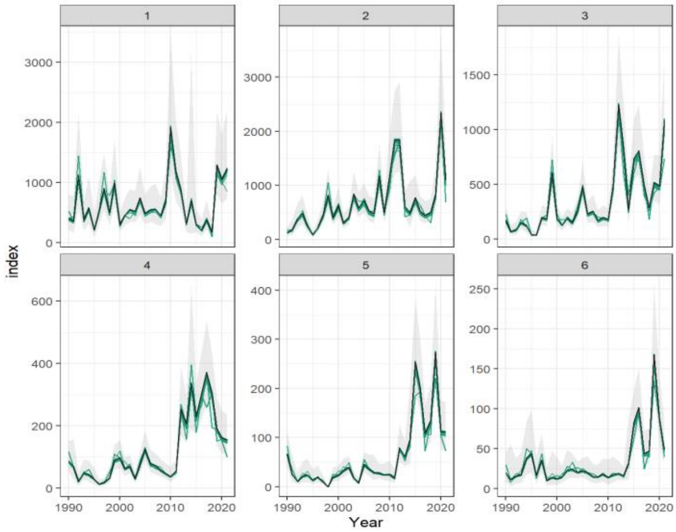

Figure A8.2.7 Plaice in 7d: Delta-GAMM index at age based on all the CGFS survey data (in black) and its uncertainty bound (in grey). Each green line represented a scenario for which during one year hauls in UK EEZ where removed. As many scenarios as years in CGFS time series are presented each with a different year with missing data.

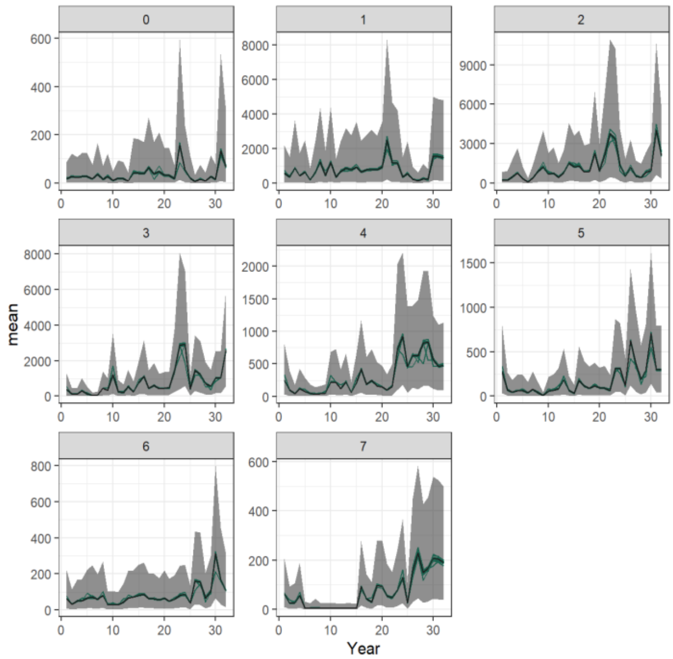

Figure A8.2.8 Plaice in 7d: Delta-GLMM index at age based on all the CGFS survey data (in black) and its uncertainty bound (in grey). Each green line represented a scenario for which during one year hauls in UK EEZ where removed. As many scenarios as years in CGFS time series are presented each with a different year with missing data.

Conclusion

By applying, delta-lognormal models to derive CGFS survey index at age, we improved the internal consistency of our survey index compare to the stratified mean approach used in the current plaice 7.d stock assessment model. Even when including inter-calibration survey between RV Gwen Drez' and RV Thalassa, ship effect did not improved models fit, and the ship effect was excluded from the analysis. Both model approach robust to the lack of data in UK EEZ with each scenarios remaining within the uncertainty bounds of the baseline index. However, the scenarios showed that index for older ages (3-6) are more sensitive to lack of data in UK EEZ in recent years. The retrospective bias of the delta-GAMM and the delta-GLMM were closed to each other with variation depending on the age considered. However, the delta-GAMM was less sensitive to the lack of hauls in UK EEZ and its internal consistency for age 2-6 is better than the delta-GLMM. The used of the index calculated from the delta-GAMM selected in this analysis is recommended to replace the current CGFS index covering ages 0-6 in plaice 7.d stock assessment. A comparison of raw survey index estimated from each methodology is presented in Figure A8.2.A5.

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Appendix

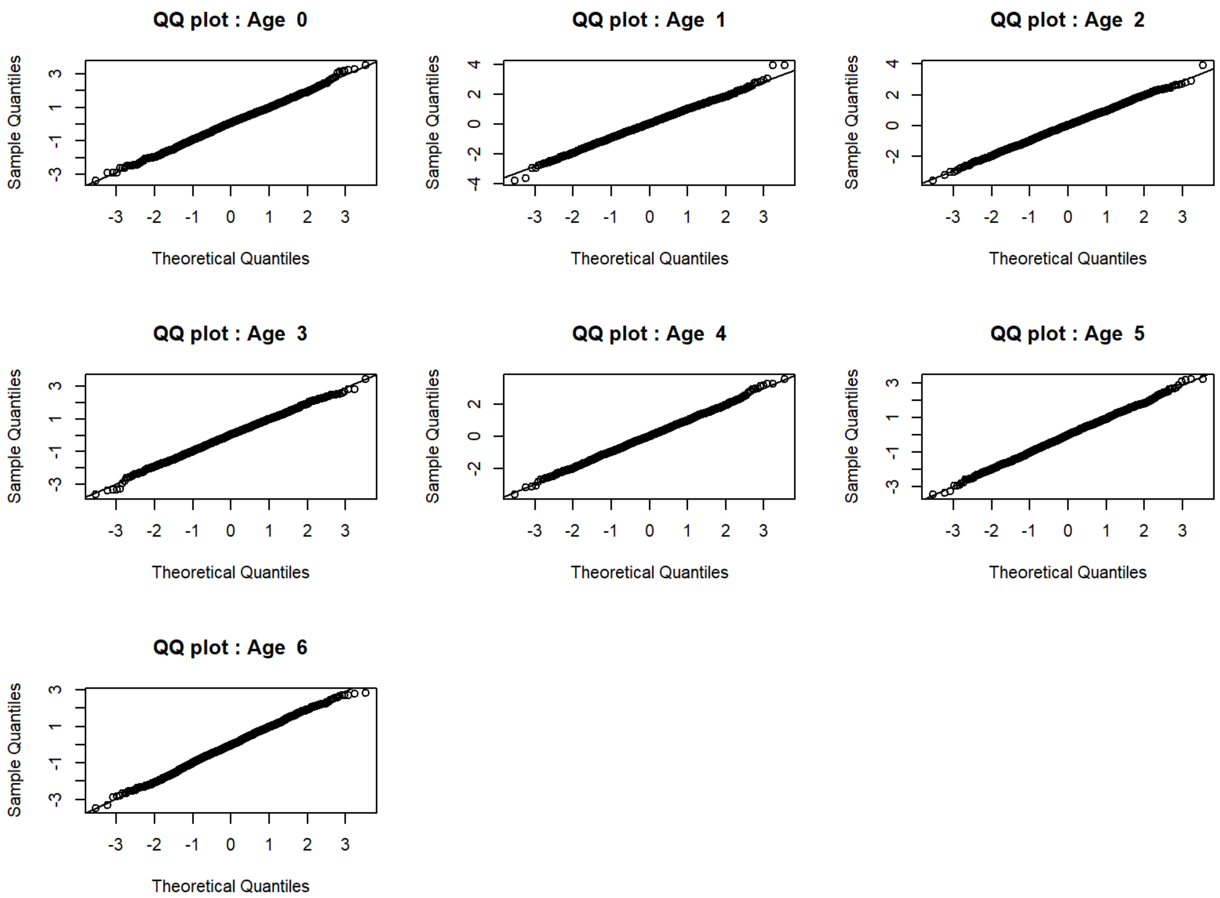

Figure A8.2.A1 Plaice in 7d: Q-Q plot of the lognormal component of the delta-GAMM fitted on CGFS survey abundance at age from 1990-2021, from ages 0 to 6.

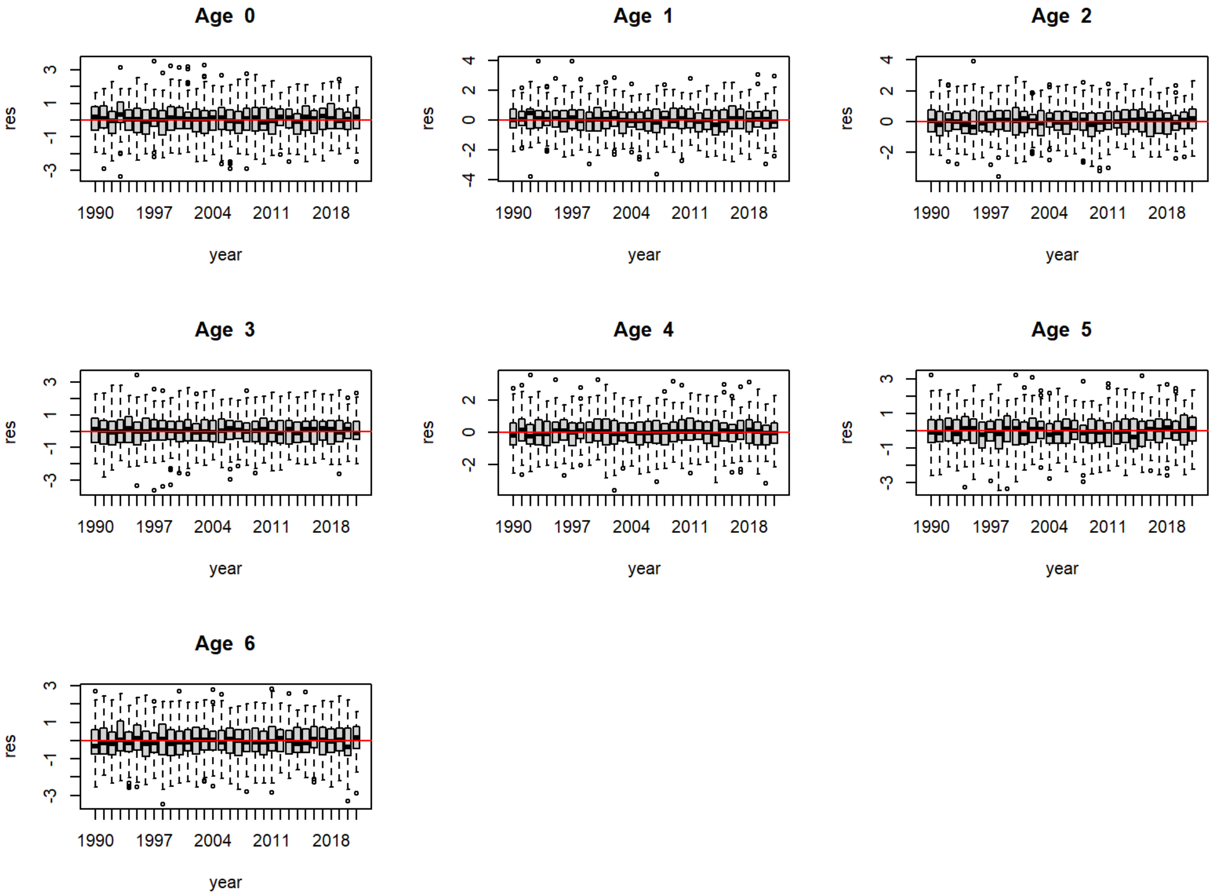

Figure A8.2.A2 Plaice in 7d: Residuals per year from the lognormal component of the delta-GAMM, from ages 0 to 6.

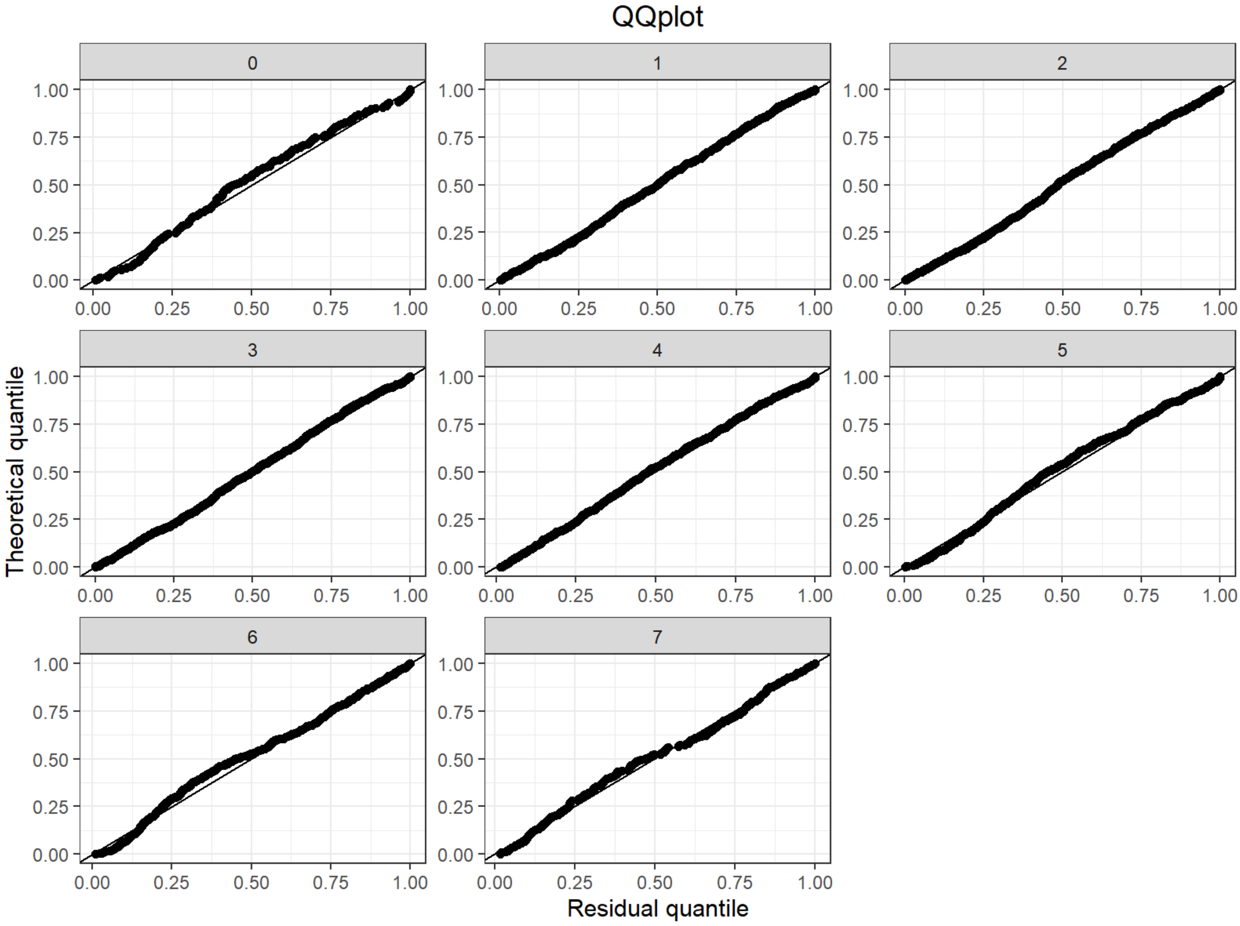

Figure A8.2.A3 Plaice in 7d: Q-Q plot of the lognormal component of the delta-GLMM fitted on CGFS survey abundance at age from 1990-2021, from ages 0 to 7+.

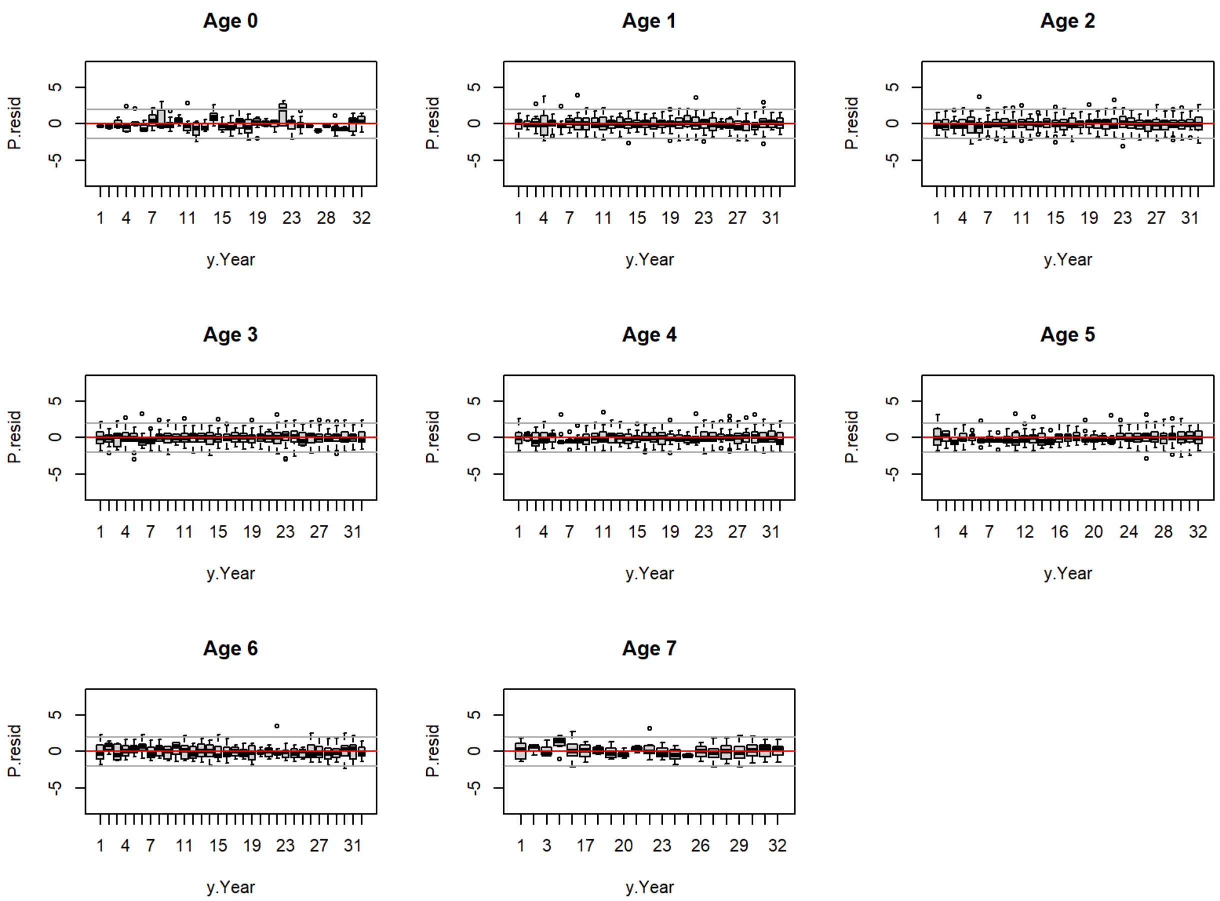

Figure A8.2.A4 Plaice in 7d: Pearson residuals per year from the lognormal component of the delta-GLMM, from ages 0 to 7+.

Figure A8.2.A5 Plaice in 7d: Comparison of CGFS index at age estimated from the stratified mean methods (red) currently used in plaice 7.d stock assessment, the delta-GAMM (green) and the delta-GLMM (red).

Working document 3: Calculation of reference points for Plaice 7.d (Eastern English Channel) based on the updated AAP stock assessment

Ghassen Halouani (IFREMER)[1]

13-05-2022

The estimation of reference points for Plaice (*Pleuronectes platessa*) in Division VIId (Eastern English Channel), was carried out in April 2022 during WGNSSK meeting after the update of the FR CGFS Index, is documented here.

Introduction

A new FR CGFS index is used in 2022 assessment to fix the reported issues in 2021 assessment (ICES 2021); because of the COVID-19 pandemic, only the French waters of the English Channel were sampled during the 2020 CGFS survey, which has an impact on the FR GFS index used in the assessment; in addition, issues in the calculation of the survey index were reported due to some survey hauls dropped during the calculation of the index. The new index (a delta GAM index) was presented during 2022 WGNSSK meeting. The model applied to this stock, the *AAP* statistical catch-at-age with estimates of discards (Aarts and Poos 2009).

Following the benchmark guidelines, a new set of reference points needs to be calculated for this stock. This calculation, carried out following the procedures set in ICES (2021), is documented here.

The code developed for the reference points calculation is available in the Annex A.

Inputs

This analysis is based on the results of the last stock assessment model run conducted during WGNSSK meeting that took place in ICES, Copenhagen (20-29 April 2022). The following inputs and settings were used to run the model:

- Landings-at-age data, years 1980-2021, ages 1-7+
- Discards-at-age data, years 1980-2021, ages 1-7+
- Indices of abundance:
  - UK BTS, years 1989:2021, ages 1-6
  - FR CGFS, years 1993:2021, ages 1-6
- Fbar: ages 3-6.
- Age from which F is constant: qplat.Fmatrix:6
- Dimensions of the F matrix tensor spline: Fage.knots:4; Ftime.knots:14; Wtime.knots:5
- Age from which survey q is constant: qplat.surveys:5

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The assessment model estimates recruitment as independent yearly parameter, so no stock-recruitment relationship is assumed or estimated (Figure A8.3.1).

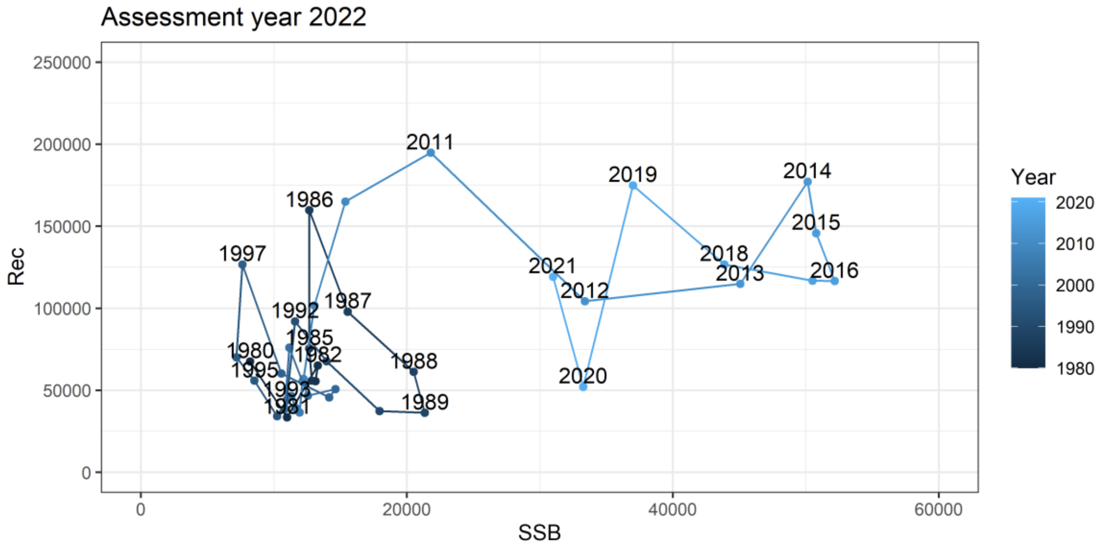

Figure A8.3.1 Plaice in 7d: Estimates of number of age 1 recruits (in thousands) against the SSB (in tonnes) in the previous year obtained from the ple.7.d stock assessment model run used for the reference points analysis. Labels refer to the recruitment year.

Methods

The analysis was conducted applying the methodology presented in ICES (2021) for a category 1 stock, and using version 0.1.19 of the msy package. Simulation runs have been conducted for 10000 iterations (nsmap = 10000). Selectivity patterns, maturity, weights-at-age and natural mortality were sampled from the last five years (2017-2021). The full time-series of the stock and recruitment was used without the last year recruitment (2022) because of a high uncertainty around this value.

Results

An initial stock-recruitment model fit conducted the FLStock object of the last assessment of plaice 7d to explore the support for two alternative stock-recruitment relationships (SRR); Beverton and Holt and segmented regression. The model fit suggests that the observed relationships support the Beverton and Holt model (95%) (Figure A8.3.2)

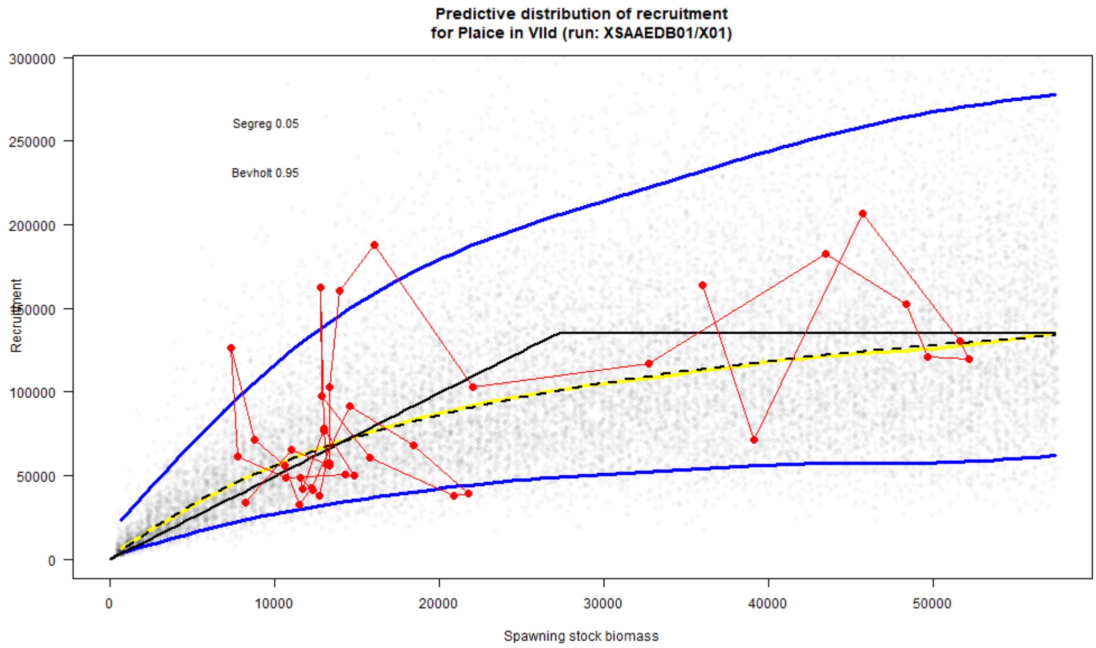

Figure A8.3.2 Plaice in 7d: Fit of the two initial stock-recruitment relationships to the ple.7.d SSB and recruits time series.

The decision was taken to conduct all analyses using Beverton and Holt and the segmented regression SRR, except for the estimation of (B_{lim}) for which only the segmented regression SRR was used. The stock was classified by the group as following under *Type 2* [2] according to the relevant ICES guidelines (ICES 2021), so the biomass limit reference point (B_{lim}) will be set to the inflection point of the segmented regression curve, in this case 27174 t.

Following this, the Precautionary Approach (PA) level of biomass, considered to ensure that the probability of the spawning stock biomass falls below B_{lim} is less than 5%, is set as a product of this reference point times the PA factor, ϕ, defined in this case as the default value of $exp(1.645 \times 0.20)$. This calculation produces a B_{pa} value of 37761 t.

The first forward simulation was conducted assuming no error in the assessment estimates for the advice year 2022, or autocorrelation in those errors (`Fcv = 0, Fphi = 0`). This allowed the calculation of the fishing mortality that would lead the SSB to the level set by B_{lim}, F_{lim} = 0.379.

A new model fit was carried out in which the last year of data was removed. From a forward simulation based on those results, this time conducted with standard values for assessment error and autocorrelation (`Fcv = 0.212, Fphi = 0.423` default suggested values from (ICES 2015b)), an initial estimate of F_{MSY} and $F_{P.05}$ were obtained. A subsequent simulation run provided an initial value for MSY$B_{trigger}$. This value was then applied in a new simulation run to calculate a new candidate value for $F_{P.05}$ (Figure A8.3.3). The F_{pa} was set to equal $F_{P.05}$ when applying ICES MSY advice rule (AR). A comparison of this value with the candidate F_{MSY} led to keep it as value for F_{MSY}, F_{MSY} = 0.156. The $F_{MSYupper}$ was limited to the value of F_{pa} since the first estimate of $F_{MSYupper}$ was higher than F_{pa}. The value of the MSY$B_{trigger}$ reference point was set to equal B_{pa}, at a level of 37761 t since the first estimate of MSY$B_{trigger}$ was lower than B_{pa}.

[2] Stocks with a wide dynamic range of SSB, and evidence that recruitment is or has been impaired (B_{lim} = segmented regression change point).

This rule was applied as the plaice stock hasn't been fished at or below F_{MSY} for 5 years or more according to 2022 assessment.

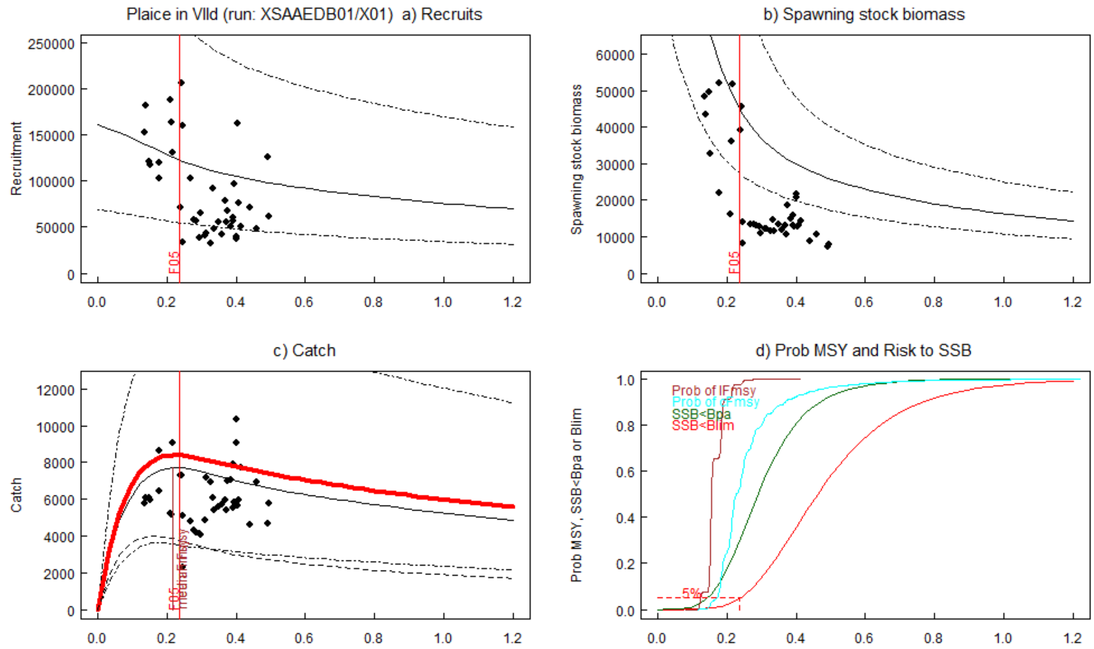

Figure A8.3.3 Plaice in 7d: Summary plot of the final eqsim simulation.

Proposed reference points

The complete table of proposed reference points, obtained from the analysis presented above, can be found in the following table :

Reference point	Value	Technical basis
$MSY\,B_{trigger}$	37761 t	B_{pa}
F_{MSY}	0.156	EQsim analysis based on the recruitment period 1980-2021
B_{lim}	27174 t	Break-point of hockey stick stock-recruit relationship, based on the recruitment period 1980-2021
B_{pa}	37761 t	$B_{lim} \cdot \exp(1.645 \cdot 0.2)$
F_{lim}	0.379	EQsim analysis, based on the recruitment period 1980-2021
F_{pa}	0.236	$F_{P.05}$ with advice rule (AR). The F that provides a 95% probability for SSB to be above Blim
MAP MSY $B_{trigger}$	37761 t	MSY
MAP range $F_{MSYlower}$	0.113-0.156	Consistent with ranges provided by ICES, resulting in no more than 5% reduction in long-term yield compared with MSY
MAP range $F_{MSYupper}$	0.156-0.236	Consistent with ranges provided by ICES, resulting in no more than 5% reduction in long-term yield compared with MSY. Limited to the value of $F_{p.05}$

Discussion

Reference points are different from those estimated in the previous benchmark in 2015. The new $MSYB_{trigger}$ is 42.2% higher than the previous $MSYB_{trigger}$ and the new F_{MSY} decreased by 37.6%. These changes could be explained by :

- The corrections applied to the FR CGFS index.
- The updating of data. During the last benchmark in 2015 (ICES 2015a); the biological data and selectivity pattern were calculated respectively over the periods 2006-2013 and 2004-2013.
- The effect of adding new recruitment data. In the last 10 years, recruitment appears to be significantly higher than during the period before 2011 (Figure A8.3.1). The increase of the number of recruits of age 1 could impact the estimation of B_{lim}.
- Important changes in the stock structure due to a significant decrease in weight at age in the recent year. (Figure A8.3.4).
- Changes in the selectivity pattern for older ages (3-6) in comparison to the previous period (Figure A8.3.4).

The status of the stock changed after the estimation of the new reference points. According to the 2022 assessment $F > F_{MSY}$ and $SSB < MSYB_{trigger}$.

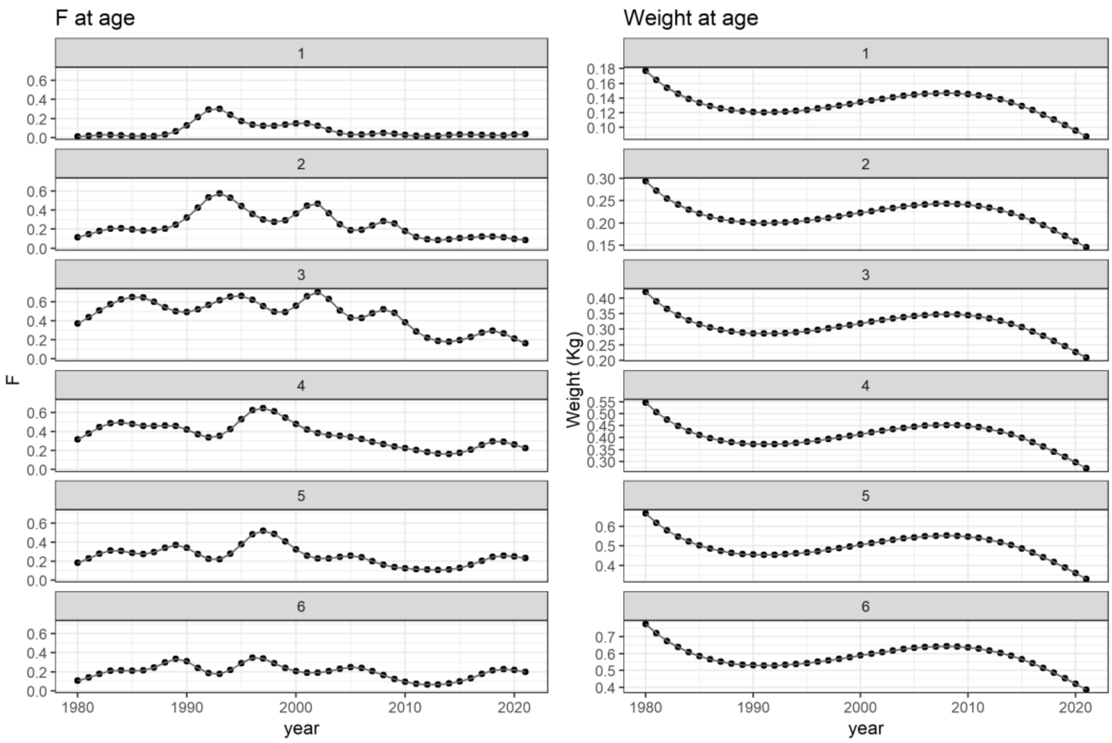

Figure A8.3.4 Plaice in 7d: F and weight at age from the assessment model.

References

Aarts, G., and J. J. Poos. 2009. “Comprehensive Discard Reconstruction and Abundance Estimation Using Flexible Selectivity Functions.” *ICES Journal of Marine Science* 66 (4): 763–71. https://doi.org/10.1093/icesjms/fsp033.

ICES. 2015a. “Report of the Benchmark Workshop on Plaice (WKPLE),” 203.

ICES. 2015b. “Report of the Workshop to Consider FMSY Ranges for Stocks in ICES Categories 1 and 2 in Western Waters (Wkmsyref4),” 187.

ICES. 2021. “Technical Guidelines - ICES Fisheries Management Reference Points for Category 1 and 2 Stocks (2021).” https://doi.org/10.17895/ICES.ADVICE.7891.

Appendix A: Reference points calculation in R

```
# model_refpts.R - Estimate reference points for Plaice 7d
# Iago MOSQUEIRA (WMR) <iago.mosqueira@wur.nl>
# Distributed under the terms of the EUPL-1.2
# Modified April 2022 by Ghassen Halouani, WGNSSK (2022)

## Packages installation
# install.packages("devtools")
# install.packages("FLCore", repo = "http://flr-project.org/R")
# library(devtools)
# install_github("ices-tools-prod/msy")

library(msy)
library(FLCore)

load("output_plaice7d_2022.RData")

# SETTINGS
Fs <- seq(0, 1.5, length=51)
nsamp <- 10000
set.seed(745)

# LOAD assessment stock object
ass.stock@discards.wt
units(ass.stock@harvest) <- "f"

# USE 5 y for selectivity and biology
bio.years <- c(2017, 2021)
sel.years <- c(2017, 2021)

# REMOVE n years (we are not confident about the rec of the last year
s)
remove.years <- 1

# FIT all models
srfit0 <- eqsr_fit(ass.stock, nsamp = nsamp, models = c( "Segreg", "B
evholt"))

png("outputs/SRR_segreg_bevholt.png", width = 1000, height = 600)
eqsr_plot(srfit0)
dev.off()

## Blim estimation ====
# NOTE Segreg CHOSEN for Blim
# FIT segreg to obtain BLIM & BPA (Type 2)
srfit1 <- eqsr_fit(ass.stock, nsamp = nsamp, models = "Segreg")

png("outputs/SRR_segreg.png", width = 1000, height = 600)
eqsr_plot(srfit1)
dev.off()

Blim <- srfit1[["sr.det"]][,"b"]
```

```
## Bpa estimation ====
pa <- exp(1.645 * 0.2)
Bpa <- Blim * pa

## Flim and Fpa estimation ====
# SIMULATE all models w/10 y, Fcv=Fphi=0, Btrigger=0
srsim1 <- eqsim_run(srfit1,
                    bio.years = bio.years, sel.years = sel.years,
                    Fcv = 0, Fphi = 0,
                    Btrigger=0, Blim = Blim, Bpa = Bpa,
                    Fscan = Fs,
                    verbose = FALSE)

# EXTRACT Flim
Flim <- srsim1$Refs2["catF", "F50"]

## cFmsy (=Fmsy candidate) and F05 estimation ====
# Segreg and Bevhold models are choosed to estimate the remaing refpt
s,
srfit2 <- eqsr_fit(ass.stock, nsamp = nsamp,
                   models = c( "Segreg", "Bevholt"),
                   remove.years=remove.years)

# SIMULATE, Fcv=0.212, Fphi=0.423 (WKMSYREF4)
srsim2 <- eqsim_run(srfit2,
                    bio.years = bio.years, sel.years = sel.years,
                    bio.const = FALSE, sel.const = FALSE,
                    Fcv=0.212, Fphi=0.423,
                    Btrigger=0, Blim = Blim, Bpa = Bpa,
                    Fscan = Fs,
                    verbose = FALSE)

cFmsy <- srsim2$Refs2["lanF", "medianMSY"]
F05 <- srsim2$Refs2["catF", "F05"]

eqsim_plot(srsim2)

## Btrigger estimation ====
# SIMULATE for Btrigger
srsim3 <- eqsim_run(srfit2,
                    bio.years = bio.years, sel.years = sel.years,
                    bio.const = FALSE, sel.const = FALSE,
                    Fcv = 0, Fphi = 0,
                    Btrigger=0, Blim = Blim, Bpa = Bpa,
                    Fscan = Fs,
                    verbose = FALSE)

# Btrigger < Bpa -> Bpa
x <- srsim3$rbp[srsim3$rbp$variable=="Spawning stock biomass", ]
cBtrigger <- x[which(abs(x$Ftarget - cFmsy) == min(abs(x$Ftarget - cF
msy))), "p05"]

# SIMULATE
```

```
srsim4 <- eqsim_run(srfit2,
                    bio.years = bio.years, sel.years = sel.years,
                    bio.const = FALSE, sel.const = FALSE,
                    Fcv=0.212, Fphi=0.423,
                    Btrigger=cBtrigger, Blim = Blim, Bpa = Bpa,
                    Fscan = seq(0, 1.2, len = 40),
                    verbose = FALSE)

F05 <- srsim4$Refs2["catF", "F05"]

# If F05 < Fmsy, then Fmsy = F05
if(cFmsy > F05) {
  Fmsy <- F05
} else {
  Fmsy <- cFmsy
}

# IF Btrigger < Bpa, then Btrigger = Bpa, then redo srsim4
# OR IF Fbar 5yr != Fmsy
if(cBtrigger < Bpa | all(tail(fbar(ass.stock), 5) > Fmsy)) {

  Btrigger <- Bpa

  srsim4 <- eqsim_run(srfit2,
                      bio.years = bio.years, sel.years = sel.years,
                      bio.const = FALSE, sel.const = FALSE,
                      Fcv=0.212, Fphi=0.423,
                      Btrigger=Btrigger, Blim = Blim, Bpa = Bpa,
                      Fscan = seq(0, 1.2, len = 40),
                      verbose = FALSE)

  cFmsy <- srsim4$Refs2["lanF", "medianMSY"]
  F05 <- srsim4$Refs2["catF", "F05"]

  # If F05 < Fmsy, then Fmsy = F05
  if(cFmsy > F05) {
    Fmsy <- F05
  }
} else {Btrigger <- cBtrigger}

png("outputs/eqsim_diagnostic.png", width = 1000, height = 600, point
size=20)
eqsim_plot(srsim4)
dev.off()

# The new definition of Fpa (2021)
Fpa <- F05

# FMSY (low - up) w/o Btrigger
lFmsy <- srsim3$Refs2["lanF", "Medlower"]
uFmsy <- srsim3$Refs2["lanF", "Medupper"]

if(uFmsy > Fpa) {
  uFmsy <- Fpa
```

```
}

# REFPTS
refpts <- FLPar(Btrigger=Btrigger, Fmsy=Fmsy, Blim=Blim, Bpa=Bpa,
                Flim=Flim, Fpa=Fpa, lFmsy=lFmsy, uFmsy=uFmsy,
                units=c("t", "f", rep("t", 2), rep("f", 4), rep("t",
2)))

refpts_df <- as.data.frame(refpts)
names(refpts_df) <- c("Reference point", "", "Value")
refpts_df <- refpts_df[,-2]
write.csv(refpts_df, "refpts_plaice7d_2022.csv", row.names = FALSE)
save.image(file = "my_work_space_refpts_estim.RData")
```

Working document 4: New stock assessment model configuration for North Sea Whiting in area 27.4 and 7d

Alan Baudron, Tanja Miethe

Marine Scotland Science, 375 Victoria Road, AB119DB, Aberdeen, Scotland, UK

Since the benchmark in 2018, the SAM model used to assess the North Sea whiting stock has had a plus group at age 8, with a fishing mortality (F) averaged across age 2 to 6. However, during 2022 WGNSSK it became apparent that this model failed to produce satisfactory retrospective patterns in SSB and F which meet the standards set by WKFORBIAS. This was caused by the dwindling abundance of the age classes 7 and 8+ observed across the past few years, resulting in uncertainty in catch numbers at older ages. In addition, Q1 survey data from the 2022 NS-IBTS were compromised by poor sampling due to technical difficulties, and maturity scales were updated resulting in a new time-varying maturity ogive. Both these data are used in the North Sea whiting model and could cause issues for the assessment. The SAM model was updated with a plus group at age 6 and F averaged across age 2 to 5. The model settings were also updated to allow the catch variance parameter to be estimated separately for age 6+. These changes resulted in satisfactory retrospective pattern in both SSB and F which met the acceptable threshold set by WKFORBIAS. Following approval by WGNSSK participants, this updated model was used for the 2022 assessment of North Sea whiting. Neither the poor sampling in Q1 survey data nor the changes in maturity scales were found to impact the model results.

Data issues

The North Sea whiting stock (whg.27.47d) is assessed with a SAM model with a plus group at age 8 and a fishing mortality (F) averaged across age 2 to 6 (ICES, 2018a). Data used to calibrate the model include catch data, and both Q1 and Q3 DATRAS indices from the NS-IBTS. IBTS Q1 survey data also contain maturity information which are used to estimate maturity ogives used in the model (ICES, 2021c). During WGNSSK 2022, two data issues became apparent. The first relates to the reduced 2022 Q1 NS-IBTS sampling: due to a combination of mechanical problems, COVID restrictions, and severe storms, 26 rectangles were not sampled and many were sampled with only one tow. This resulted in incomplete survey coverage, especially in the central and northern North Sea (Fig. A8.4.1)

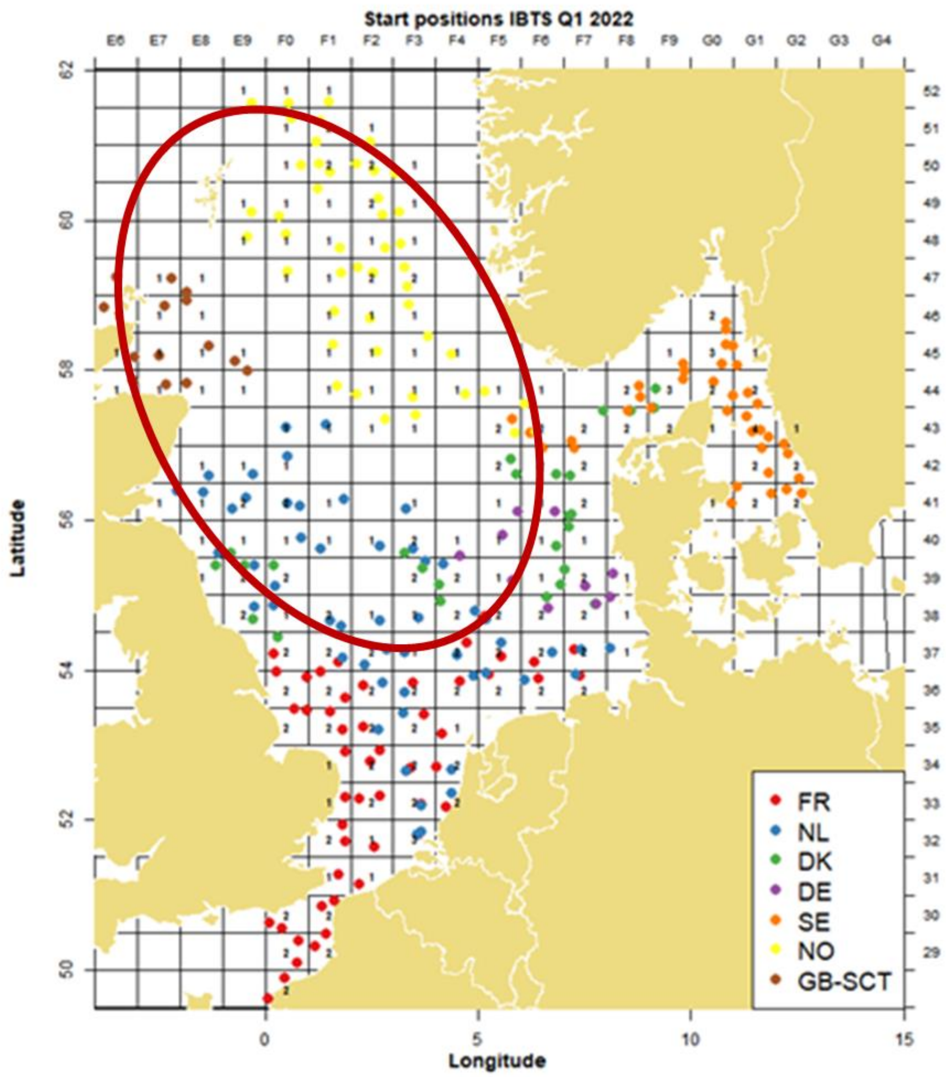

Figure A8.4.1. Whiting in 4 and 7d: Start position of the hauls for the 2022 Q1 NS-IBTS survey shown by country. The red line shows the area where sampling was reduced compared to previous years.

The second relates to a change in the way the maturity data are recorded in surveys since 2021: maturity data is now uploaded in the A-E scale instead of the 61-66 scale by Denmark, France and the Netherlands, where previously all countries used the 61-66 scale (ICES, 2018b). This resulted in a change of the perceived maturity for North Sea whiting (Fig. A8.4.2), which could potentially affect the assessment.

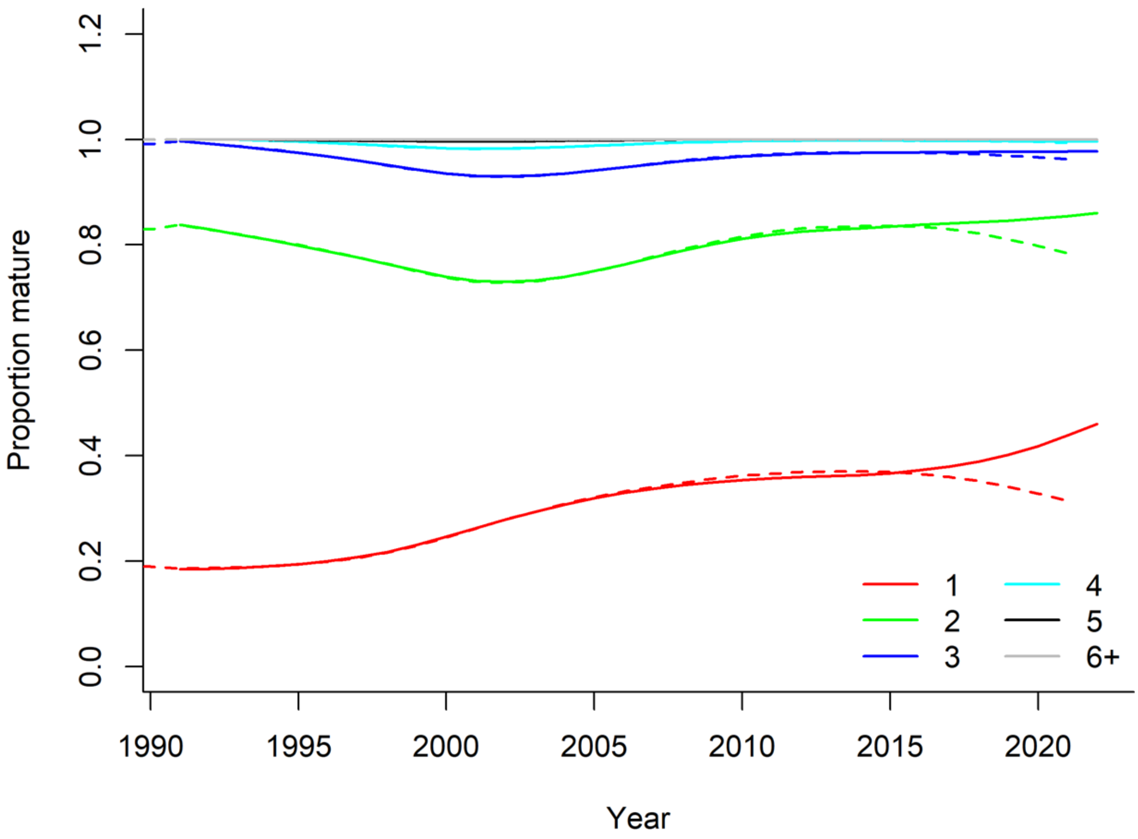

Figure A8.4.2. Whiting in 4 and 7d: Proportion of mature individuals at age estimated with the new maturity ogive for North Sea whiting during the 2022 WGNSSK (solid lines) compared to the ones estimated in the previous year (ICES, 2021c) without data using the updated maturity scale (dashed lines).

Impact of data issues

In order to assess the impact of the 2022 Q1 NS-IBTS sampling issues, the SAM model for the 2022 North Sea whiting assessment was fitted both with and without 2022 Q1 NS-IBTS indices. Both these models were run with the old maturity ogive.

In addition, in order to assess the impact of changes in maturity scale, the model with 2022 Q1 NS-IBTS indices was re-run with the new maturity ogive in order to compare it the model run with the old ogive.

Both the inclusion of 2022 Q1 NS-IBTS indices and the use of new maturity ogive were found to have negligible impacts on the model. Model summary plots were almost identical between the three models, bar a very slight difference in SSB estimates in the last couple of years between the models with the old and new maturity estimates (Fig. A8.4.3). Likewise, abundances at age estimated by the three models were almost identical, bar a slight difference in age zero abundances in the last year between the models with and without 2022 Q1 NS-IBTS indices (Fig. A8.4.4).

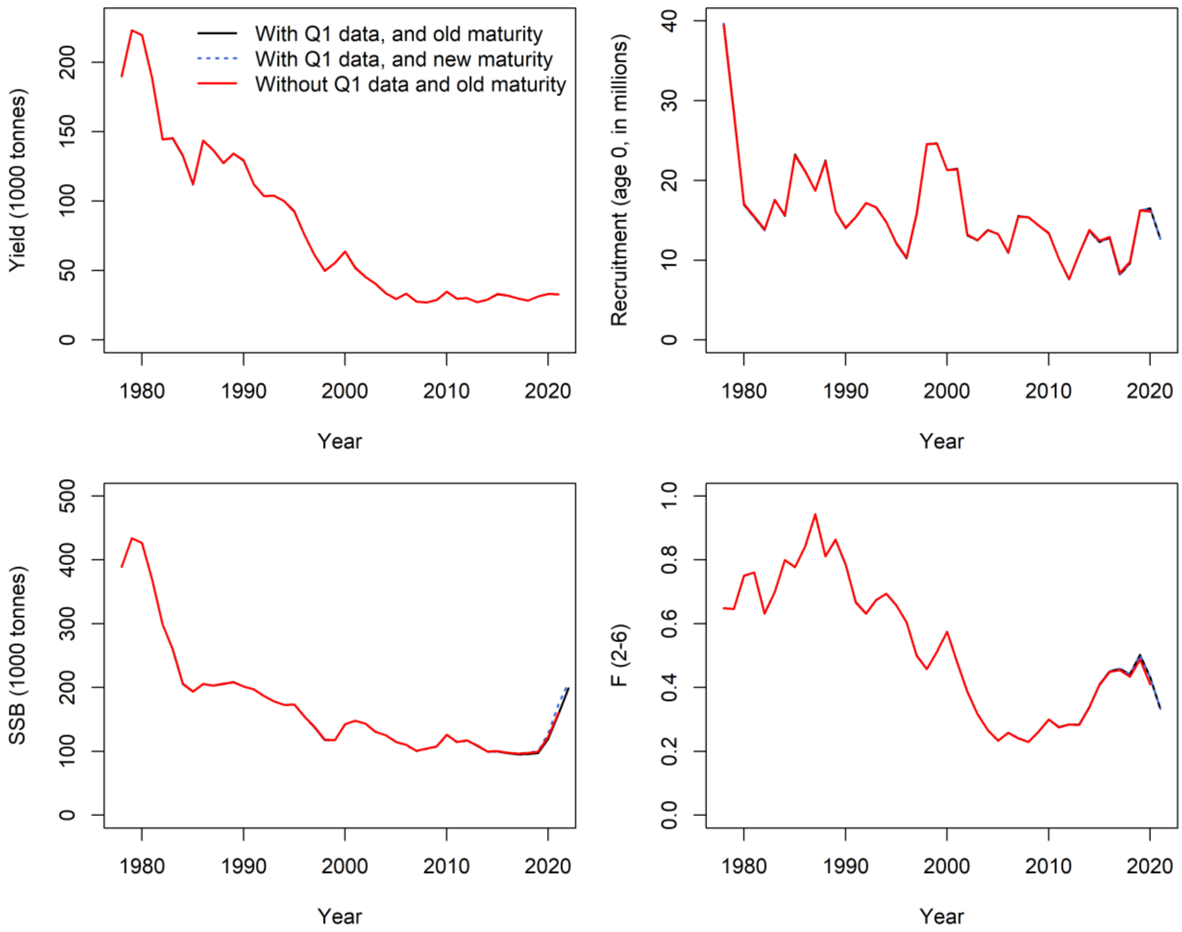

Figure A8.4.3. Whiting in 4 and 7d: Comparison of summary plots between models with and without 2022 Q1 NS-IBTS indices, and with old and new maturity ogives.

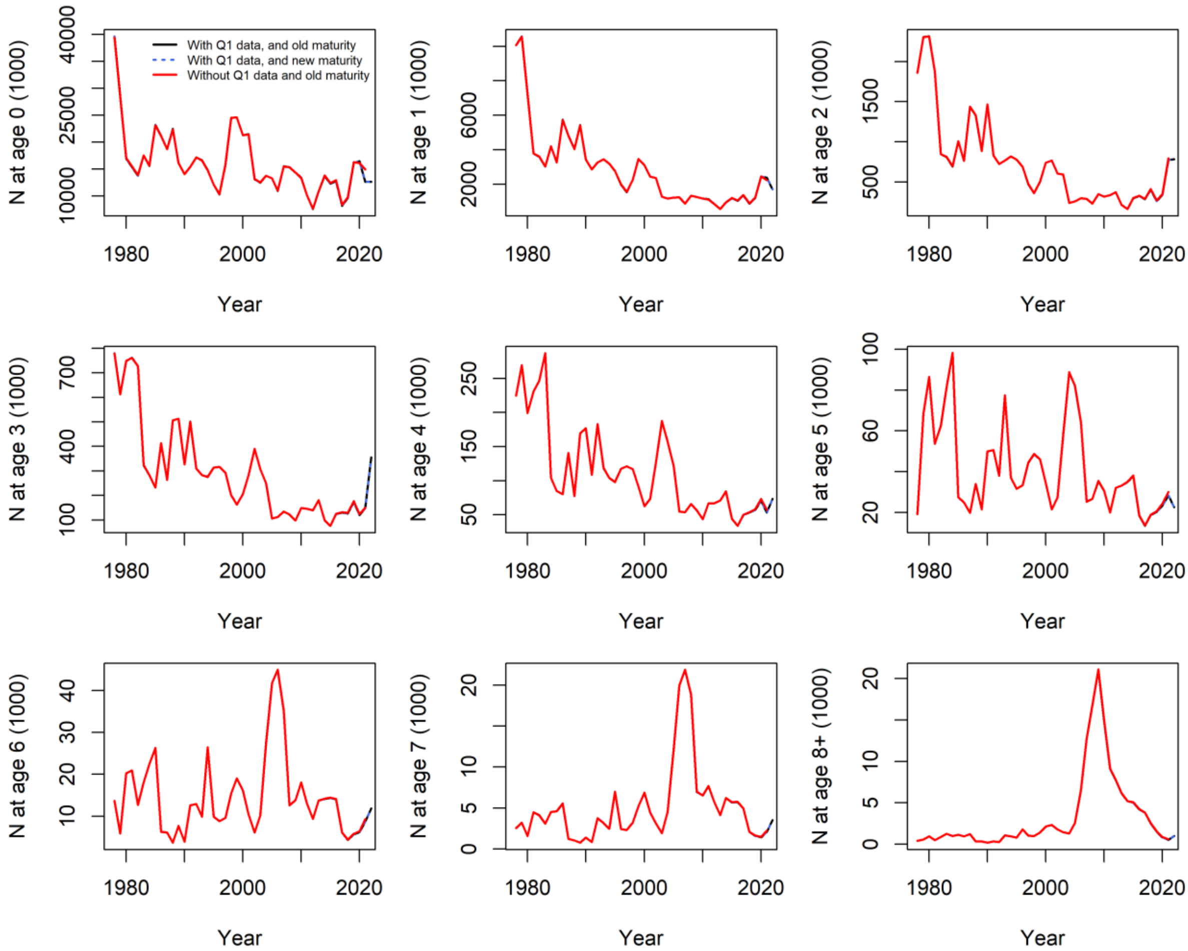

Figure A8.4.4. Whiting in 4 and 7d: Comparison of abundance at age estimated with models with and without 2022 Q1 NS-IBTS data, and with old and new maturity ogives.

The lack of any significant impact of the inclusion of 2022 Q1 NS-IBTS indices despite the subpar sampling in 2022 may be due to the fact that the sampling issues occurred in the central and northern North Sea, whereas the largest densities of whiting in Q1 are observed in the southern and western North Sea along the UK's east coast (Fig. A8.4.5).

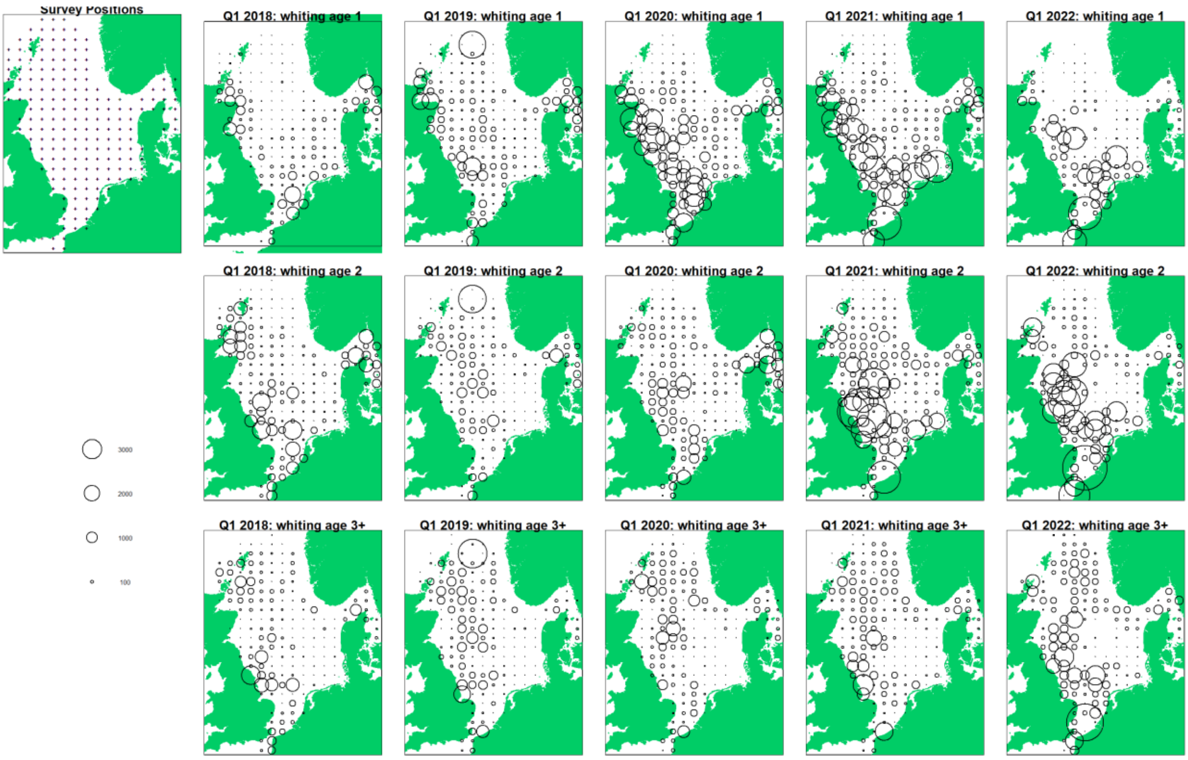

Figure A8.4.5. Whiting in 4 and 7d: Whiting densities observed in the Q1 NS-IBTS survey from 2018 to 2022.

Since the inclusion of 2022 Q1 NS-IBTS indices has negligible impact on the model despite the subpar sampling in 2022, it was decided to include this information in the model. It was also concluded that switching to the new maturity ogive didn't affect the assessment.

Model issues

The SAM model with a plus group at age 8 and F averaged across age 2 to 6 (ICES, 2018a) was successfully fitted to the data (including 2022 Q1 NS-IBTS survey indices and new maturity ogive) for the 2022 assessment of the North Sea whiting stock. However, the model estimated a much higher F and a much lower SSB across the last eight years compared to the 2021 assessment (Fig. A8.4.6). Most importantly, the model estimates showed strong retrospective patterns in both F and SSB (Fig. A8.4.7) which did not meet the acceptable standards set by

WKFORBIAS: the SSB Mohn's rho value was 0.613 which is above the acceptable 0.2 threshold, and all five peels were outside the 95% confidence interval when only two peels outside are considered acceptable (ICES, 2019).

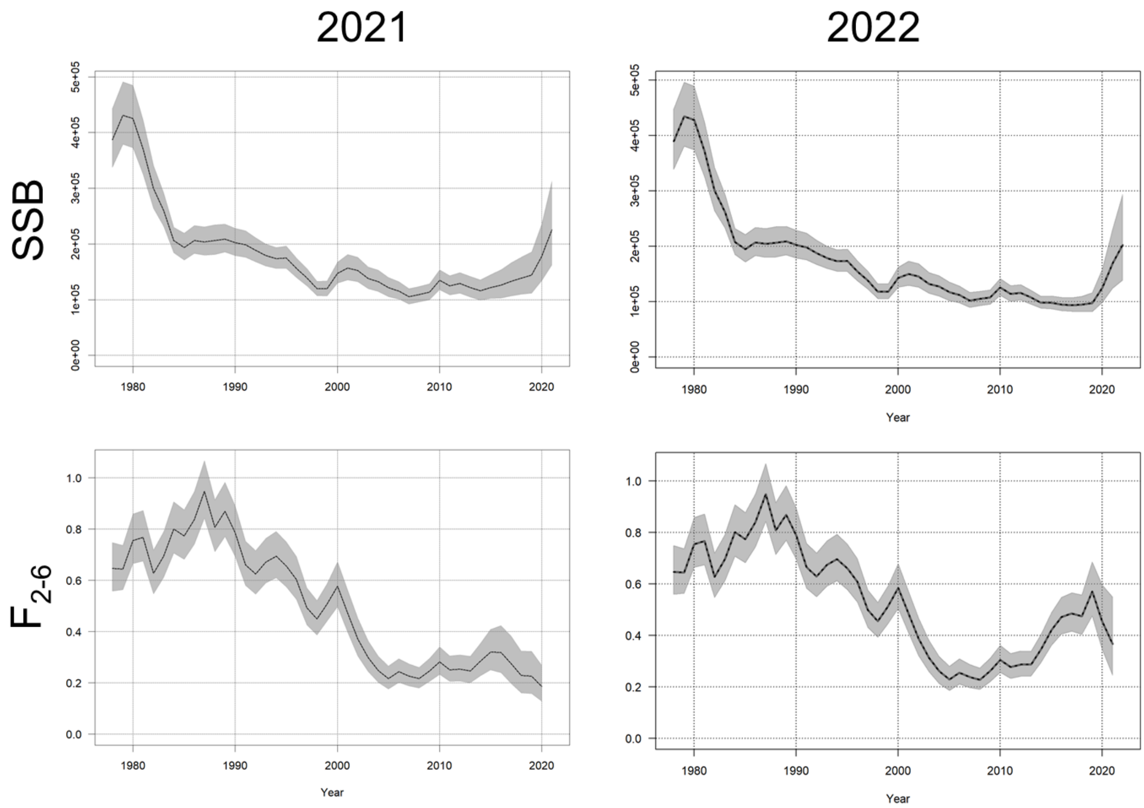

Figure A8.4.6. Whiting in 4 and 7d: Comparison of the SSB (top) and F (bottom) estimates from the 2021 (left) and 2022 (right) SAM model assessments.

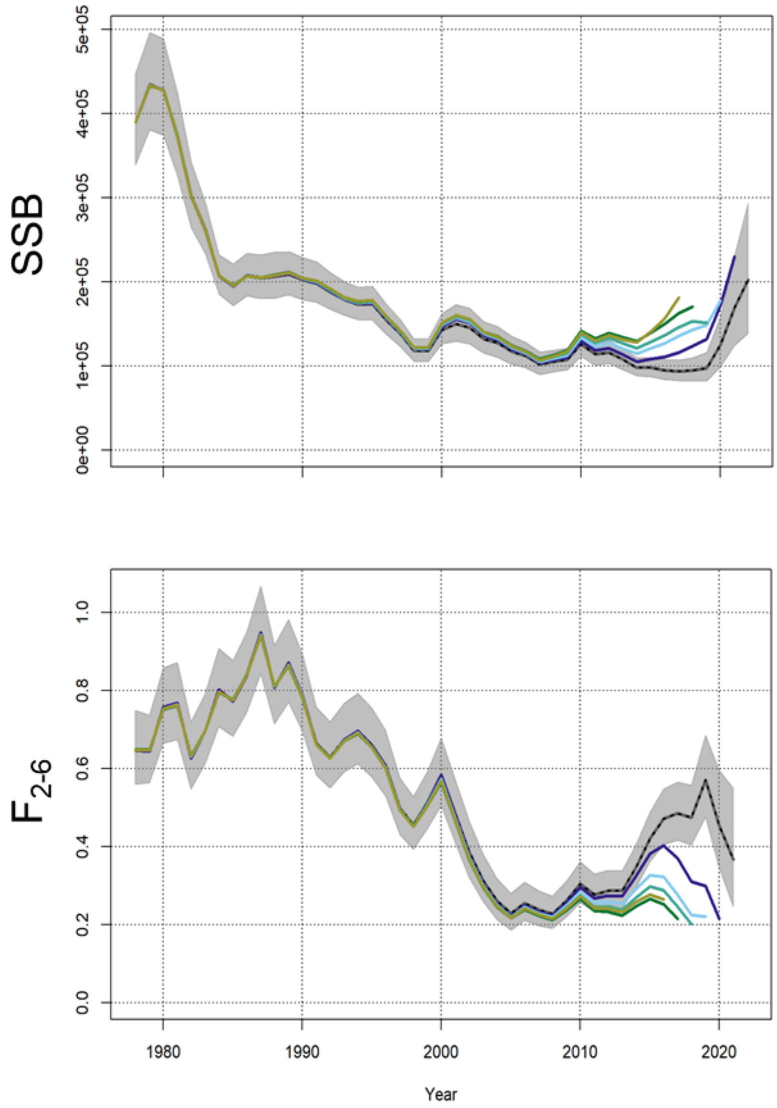

Figure A8.4.7. Whiting in 4 and 7d: SSB and F retrospective peels obtained with the SAM model with a plus group at age 8 for the 2022 assessment of North Sea whiting.

The higher F and lower SSB compared to previous assessments, and consequently the poor retrospective patterns, are due to a sharp reduction in the abundance at age 8+ (and age 7 to some extent) over the past few years, as shown by the estimated catch numbers used to fit the model (Table A8.4.1). In order to fit the lower abundance at age 8+, the model adjusted to a higher F, and by association a lower SSB, a few years prior when the cohorts relating to the recent low number of individuals at age 8+ was exploited. This is also apparent in the model residuals which show a strong negative pattern at age 8+ over the past few years (Fig. A8.4.8).

Table A8.4.1. Whiting in 4 and 7d: Estimated catch at age numbers for North Sea whiting used to fit the SAM assessment model (only last 10 years shown). Age 8 is a plus group: numbers at age 8 are the sum of ages 8 and above.

Year/Age	0	1	2	3	4	5	6	7	8+
2012	3548	53445	32509	18882	14862	6952	2773	1558	2371
2013	4341	20378	15548	25362	15593	10812	3343	1048	1595
2014	6225	29785	14623	17450	19683	11351	4710	2038	2090
2015	7705	48349	53345	15714	10220	14163	5068	2086	2222
2016	17208	27639	36165	36788	9129	7813	6046	2548	1761
2017	28724	27355	27315	24442	18432	4176	2421	2683	2545
2018	15656	17302	41274	26023	17040	6786	1437	1013	1040
2019	4515	29380	24143	39669	17364	7151	3087	1063	904
2020	26813	41940	32019	29992	19892	6596	2286	640	203
2021	35094	27281	57391	21520	12296	8836	3265	898	155

Figure A8.4.8. Whiting in 4 and 7d: Standardised one observation ahead residuals from the 2022 SAM model for North Sea whiting with a plus group at age 8.

Addressing model issues: change in model settings

Since the retrospective patterns were caused by low abundance at older ages, and that the estimated catch numbers for these old ages are quite uncertain due to poor sampling (i.e., less individuals to sample from), the first step in attempting to correct the retrospective patterns was to change the model settings in order to allow the model to estimate a separate catch variance parameter for the plus group. This change to the model settings resulted in lower F and higher SSB estimates, and much better retrospective patterns. However, the leave-one-out runs indicated that removing either the Q1 or Q3 survey indices would result in the high F and low SSB previously observed (Fig. A8.4.9). In other words, the model needed both survey time series included in order to "correct" for the high F and low SSB resulting from the low catch numbers in the plus group.

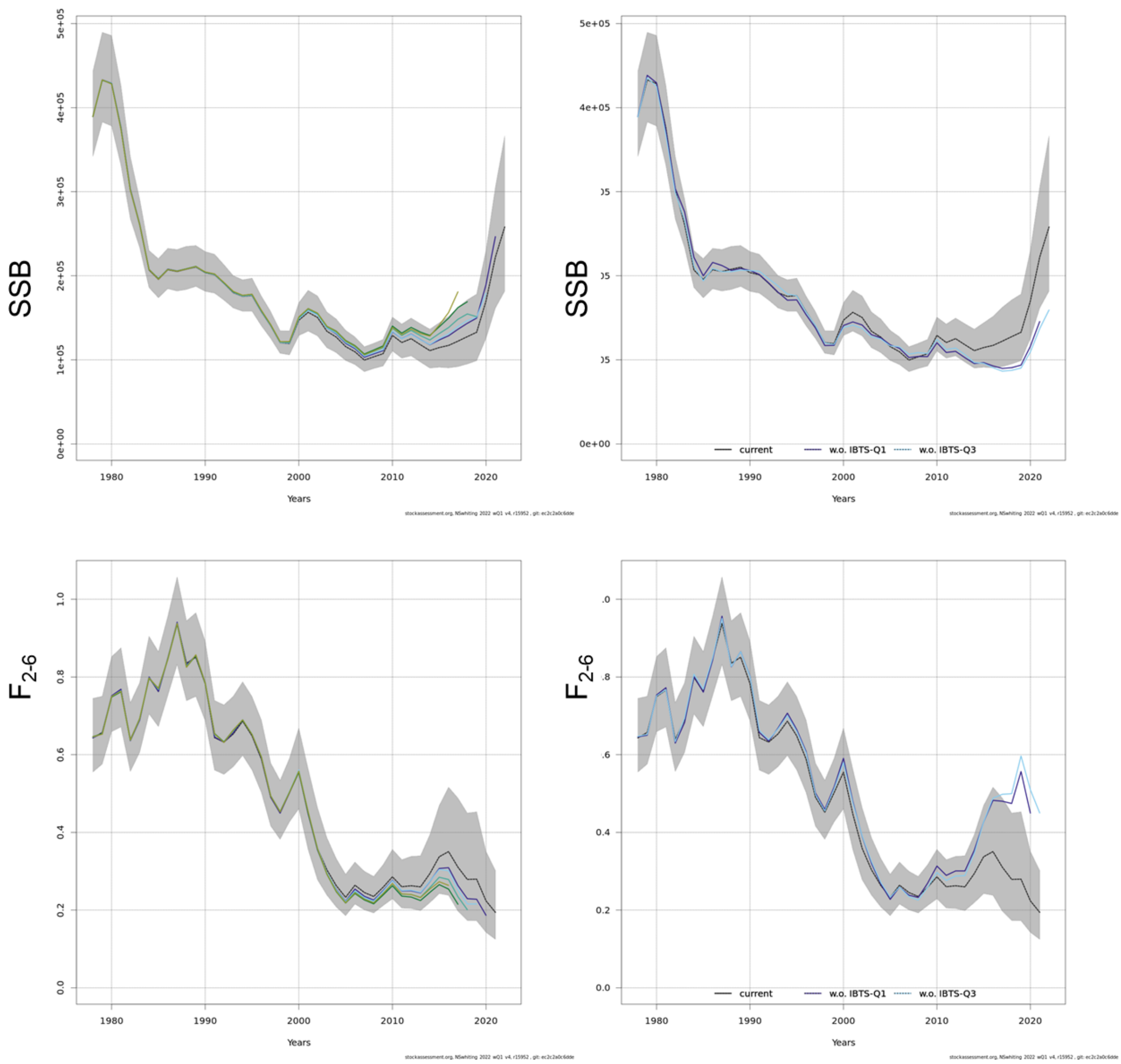

Figure A8.4.9. Whiting in 4 and 7d: SSB (top) and F (bottom) retrospective (left) and leave-one-out (right) runs from the 2022 SAM model for North Sea whiting with a plus group at age 8 and a catch variance parameter estimated separately for age 8+.

Addressing model issues: change in plus group

Since the low abundance at old ages is causing issues with the assessment model, and that abundances for these older age classes have been decreasing over several years, it was agreed with 2022 WGNSSK participants to reduce the plus group to age 6, and to average F across ages 2 to 5 (so as to not include the plus group). It was also agreed that the catch variance parameter should be estimated separately for the plus group since abundance estimates at old ages are more uncertain. This new model resulted in SSB and F estimates on par with previous assessments, and most importantly in much better retrospective patterns compared to the original model (Fig. A8.4.10). It should be noted that the F estimated with this new model is lower than in previous assessments owing to being averaged across ages 2 to 5 instead of 2 to 6, but the trend is highly similar to what was observed previously. The Mohn's rho value for SSB is 0.152 which falls below the threshold of 0.2 set by WKFORBIAS, and only one peel (one with the most data years removed) falls outside the confidence interval when up to two peels is acceptable according to WKFORBIAS (ICES, 2019). In addition, the leave-one-out runs for this model indicate that while removing the Q3 survey would result in lower SSB and higher F estimates, removing Q1 survey would have little impact (Fig. A8.4.10), an observation consistent with previous assessments (ICES, 2021c). However it should be noted that, while the retrospective patterns have improved significantly, reducing the plus group to age 6 had little impact on residuals. In fact, the strong negative pattern observed at age 8+ in the standardised one observation ahead residuals for the past few years can still be seen at age 6+ (Fig. A8.4.11). Lastly, the model parameters obtained with a plus group at age 6 (Table A8.4.2) and a plus group at age 8 (Table A8.4.3) are highly similar (both models have a separate catch variance estimate for the plus group).

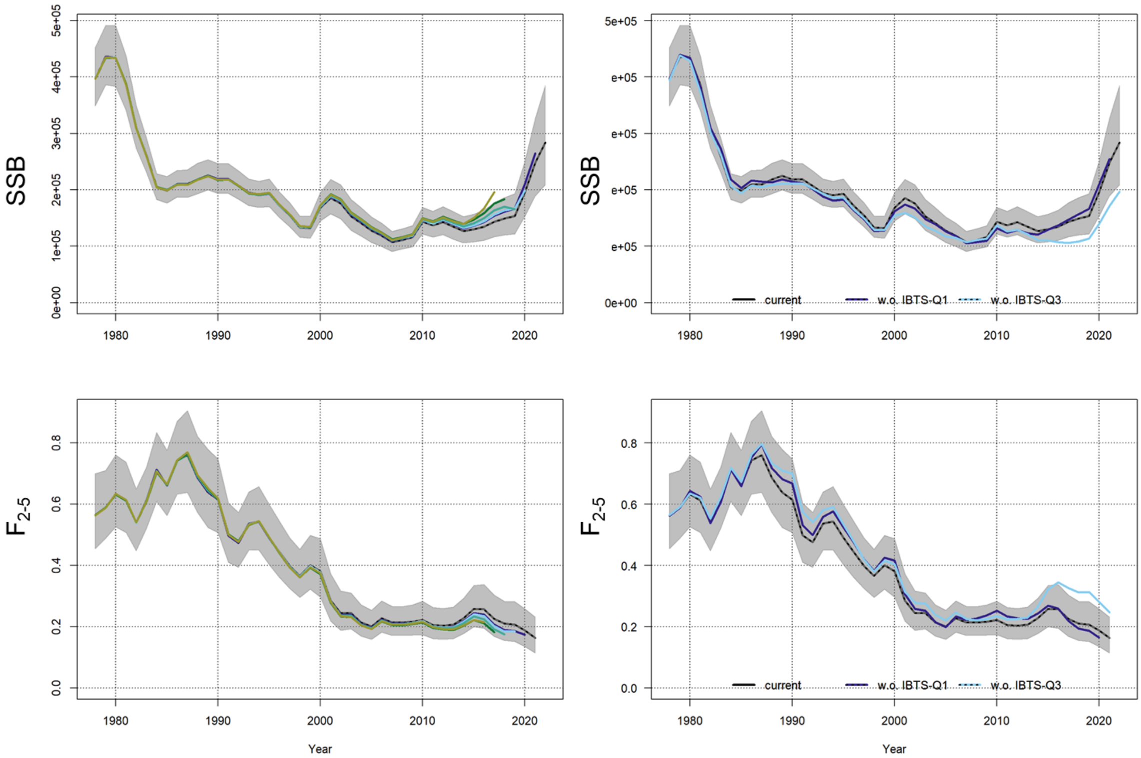

Figure A8.4.10. Whiting in 4 and 7d: SSB (top) and F (bottom) retrospective (left) and leave-one-out (right) runs from the 2022 SAM model for North Sea whiting with a plus group at age 6 and a catch variance parameter estimated separately for age 6+.

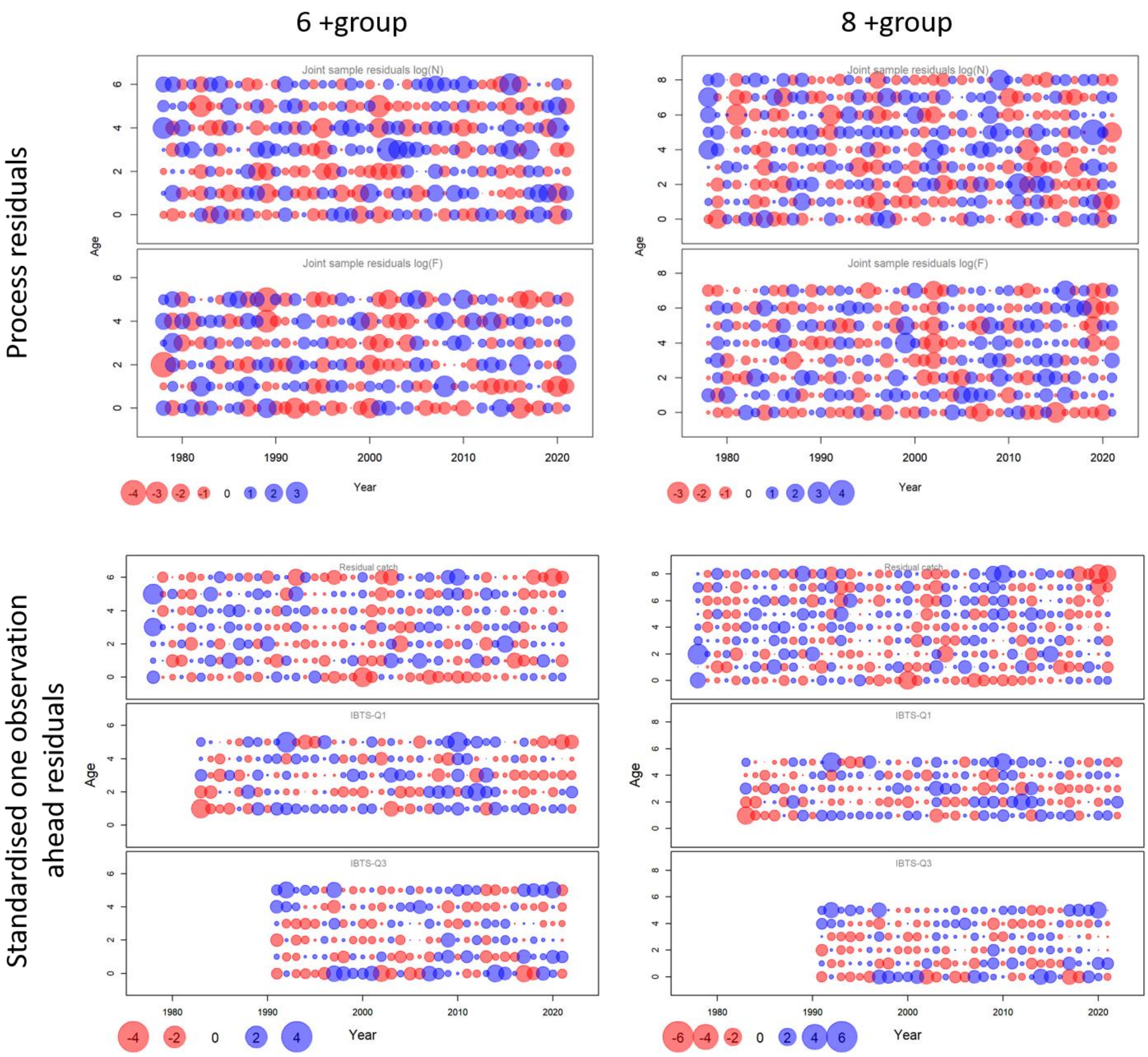

Figure A8.4.11. Whiting in 4 and 7d: Side-by-side comparison of process residuals (top) and standardised one observation ahead residuals (bottom) between the model with a plus group at age 6 (left) and 8 (right). Both models have a separate catch variance estimate for the plus group.

Table A8.4.2. Whiting in 4 and 7d: Table of model parameters for the model with a plus group at age 6 and a separate catch variance parameter for the plus group.

Parameter name	par	sd(par)	exp(par)	Low	High
logFpar_0	-13.172	0.078	0.000	0.000	0.000
logFpar_1	-12.053	0.078	0.000	0.000	0.000
logFpar_2	-11.988	0.080	0.000	0.000	0.000
logFpar_3	-12.192	0.085	0.000	0.000	0.000
logFpar_4	-13.333	0.098	0.000	0.000	0.000
logFpar_5	-12.250	0.098	0.000	0.000	0.000

logFpar_6	-12.022	0.099	0.000	0.000	0.000
logFpar_7	-12.218	0.104	0.000	0.000	0.000
logFpar_8	-12.314	0.115	0.000	0.000	0.000
logSdLogFsta_0	-1.744	0.155	0.175	0.128	0.239
logSdLogN_0	-1.076	0.135	0.341	0.260	0.447
logSdLogN_1	-2.747	0.413	0.064	0.028	0.146
logSdLogObs_0	0.200	0.126	1.222	0.950	1.570
logSdLogObs_1	-1.598	0.094	0.202	0.168	0.244
logSdLogObs_2	-0.873	0.079	0.418	0.357	0.489
logSdLogObs_3	-0.763	0.080	0.466	0.398	0.547
logSdLogObs_4	-1.125	0.172	0.325	0.230	0.458
transfIRARdist_0	-0.393	0.232	0.675	0.424	1.074
transfIRARdist_1	0.988	0.458	2.686	1.075	6.707
transfIRARdist_2	-1.014	0.283	0.363	0.206	0.639
itrans_rho_0	0.971	0.202	2.641	1.764	3.954

Table A8.4.4. Whiting in 4 and 7d: Table of model parameters for the model with a plus group at age 8 and a separate catch variance parameter for the plus group

Parameter name	par	sd(par)	exp(par)	Low	High
logFpar_0	-13.103	0.084	0.000	0.000	0.000
logFpar_1	-11.974	0.082	0.000	0.000	0.000
logFpar_2	-11.891	0.083	0.000	0.000	0.000
logFpar_3	-12.060	0.087	0.000	0.000	0.000
logFpar_4	-13.262	0.103	0.000	0.000	0.000
logFpar_5	-12.174	0.102	0.000	0.000	0.000
logFpar_6	-11.921	0.103	0.000	0.000	0.000
logFpar_7	-12.084	0.106	0.000	0.000	0.000
logFpar_8	-12.120	0.114	0.000	0.000	0.000
logSdLogFsta_0	-1.679	0.140	0.187	0.141	0.247
logSdLogN_0	-1.126	0.154	0.324	0.238	0.442
logSdLogN_1	-2.342	0.216	0.096	0.062	0.148
logSdLogObs_0	0.203	0.124	1.225	0.955	1.572
logSdLogObs_1	-1.673	0.099	0.188	0.154	0.229

logSdLogObs_2	-0.808	0.080	0.446	0.380	0.523
logSdLogObs_3	-0.736	0.087	0.479	0.403	0.569
logSdLogObs_4	-0.709	0.186	0.492	0.339	0.713
transfIRARdist_0	-0.303	0.345	0.739	0.371	1.472
transfIRARdist_1	-0.612	0.259	0.542	0.323	0.910
transfIRARdist_2	0.946	0.461	2.576	1.025	6.471
transfIRARdist_3	-0.860	0.296	0.423	0.234	0.765
itrans_rho_0	1.105	0.161	3.018	2.185	4.169

Conclusion

In conclusion, the SAM model with a plus group at age 6, F averaged across ages 2 to 5, and catch variance parameter estimated separately for age 6+ met the acceptable standards set by WKFORBIAS (ICES, 2019) and was considered to be satisfactory by the 2022 WGNSSK participants. As a result, this new model was used for the 2022 assessment of North Sea whiting. New references points were calculated using outputs from this new model (see Working Document 5). Neither the inclusion of the poorly sampled 2022 Q1 NS-IBTS data nor the use of the new maturity ogive were found to impact the model results, and both these data sources were used in the assessment.

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Working document 5: New reference points for North Sea Whiting in area 27.4 and 7d

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The SAM model used to assess the North Sea whiting stock was updated during 2022 WGNSSK to correct retrospective pattern in SSB and F due to uncertainty in catch numbers at older ages (WD 4). EqSim was run on the new SAM assessment results to determine new reference points which were compared to the previous reference points obtained during the last interbenchmark in 2021. The EqSim was run with the average of the last 10 years of biological data and the last 3 years of fishing selectivity data, the default value of sigmaSSB (0.2), and autocorrelation in recruitment, were used as was done in the interbenchmark. The suggested new reference point F_{MSY} for North Sea whiting was 0.393, compared to 0.371 obtained in the last interbenchmark.

Introduction

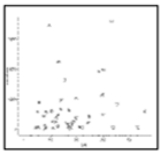
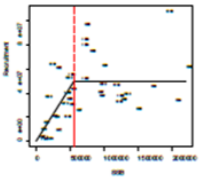
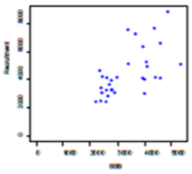
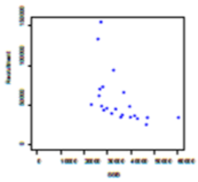
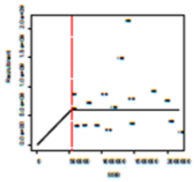
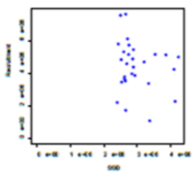
New reference points were estimated for the new SAM assessment model results using the new plus group at age 6. This was done in a stepwise process, using the EqSim analysis (standardized ICES code) and ICES technical guidelines (ICES, 2015, 2021a), detailed in the sections below. These new reference points were then compared to the ones obtained during the last interbenchmark (ICES, 2021b).

Methods

Estimating B_{lim} and PA reference points

B_{lim} is an important reference point from which other precautionary reference points are derived. To determine B_{lim}, the full assessment data series should be used to determine stock type in terms of the SSB-recruitment relationship (Table A8.5.1).

Table A8.5.1. Whiting in 4 and 7d: Categorization of stock types as presented in ICES Technical Guidelines (ICES, 2021a).

Stock characteristics			Limit point estimation options dependent on data and specific stock information	
Stock type	S–R plot characteristics	Sample S–R plot	B_{lim} estimation possible according to standard method	B_{lim} estimation possible on the basis of stock-specific method or judgement
Type 1	Spasmodic stocks – stocks with occasional large year classes.		B_{lim} is based on the lowest SSB, where large recruitment is observed – unless F has been low throughout the observed history, in which case B_{loss} = B_{pa}.	
Type 2	Stocks with a wide dynamic range of SSB, and evidence that recruitment is or has been impaired.		B_{lim} = segmented regression change point.	
Type 3	Stocks with a wide dynamic range of SSB, and evidence that recruitment is or has been impaired, with no clear asymptote in recruitment at high SSB.			B_{lim} may be close to the highest SSB observed. The estimate depends on an evaluation of the historical fishing mortality.
Type 4	Stocks with a wide dynamic range of SSB, and evidence that recruitment increases as SSB decreases.			No B_{lim} from this data, only the PA reference point. (B_{loss} would be a candidate for B_{pa}).
Type 5	Stocks showing no evidence of impaired recruitment or with no clear relation between stock and recruitment (no apparent S–R signal).		B_{lim} = B_{loss}	
Type 6	Stocks with a narrow dynamic range of SSB and showing no evidence of past or present impaired recruitment.			No B_{lim} from this data, only the PA reference point (B_{loss} could be a candidate for B_{pa}, however, this is dependent on considerations involving historical fishing mortality).

B_{pa} was estimated based on B_{lim} as follows, where the default value of 0.2 was used for sigmaSSB, as decided during the last interbenchmark (ICES, 2021b):

$B_{pa}=B_{lim}*exp(1.645*sigmaSSB)$

To estimate F_{lim}, EqSim was run without assessment/advice error and without advice rule (without $B_{trigger}$), using a segmented regression with breakpoint fixed at B_{lim}, as per the ICES guidelines (ICES, 2021a), to model the spawning stock recruitment relationship, in order to get the F (F_{50}) that ensures a 50% probability for SSB to remain above B_{lim}.

According to the latest ICES Technical Guidelines (ICES, 2021a), F_{pa} is no longer estimated from F_{lim} (F_{pa}=F_{lim}*exp(-1.645*sigmaF) but instead should be set to $F_{P.05}$.

Estimating F_{msy}, MSY $B_{trigger}$

F_{MSY} was initially calculated based on an EqSim with assessment/advice error, which should give maximum yield, and without advice rule (without MSY $B_{trigger}$). For the spawning stock recruitment relationship, a segmented regression was used with a freely estimated breakpoint.

To include assessment and advice error, the values $\left(F_{cv}, F_{phi}\right) = (0.212, 0.423)$, the default values suggested by WKMSYREF4 (ICES, 2015).

To ensure consistency between the precautionary and the MSY frameworks, F_{MSY} is not allowed to be above F_{pa}; therefore, if the initial F_{MSY} value is above F_{pa}, F_{MSY} is reduced to F_{pa}.

MSY $B_{trigger}$ is a lower bound of the SSB distribution when the stock is fished at F_{MSY} (ICES, 2021a). To set MSY $B_{trigger}$ the flowchart in Figure A8.5.1 is followed together with recent fishing mortality estimates.

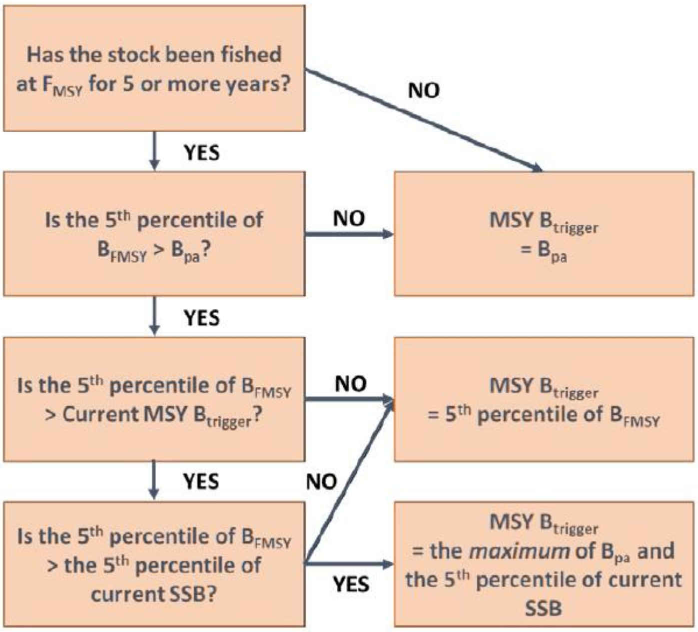


Figure A8.5.1. Whiting in 4 and 7d: Flow chart to set MSY $B_{trigger}$ as given by ICES Advice Technical guidelines (ICES, 2021a).

Calculations for MSY $B_{trigger}$ were based on EqSim runs without assessment/advice error and without advice rule, using segmented regression with a freely estimated breakpoint.

When applying the advice rule (AR), F was reduced when SSB falls below this threshold. Using the advice rule, it should be checked that when fishing at F_{MSY} the probability of falling below B_{lim} remains smaller than 5%. Therefore, it should be ensured that the initially calculated F_{MSY} was at or below $F_{P.05}$.

EqSim settings

The sigmaSSB for the new SAM model was 0.136. Since the value was below 0.2, the default values of 0.2 was used instead, as decided during the last interbenchmark (ICES, 2021b). For fisheries selectivity, an average of the most recent 3 years was found to be representative and was used throughout (Fig. A8.5.2). It should be noted that the highest selectivities seen on Figure 2 were all observed in the early part of the time series (prior 1985). For weights-at-age, an average of the most recent 10 years was found to be representative and was used throughout (Fig. A8.5.3). As in the last benchmark, the time series since 1983 are included for estimation of stock-recruitment relationship, excluding the years 1978-1982 (years without survey data in the assessment model).

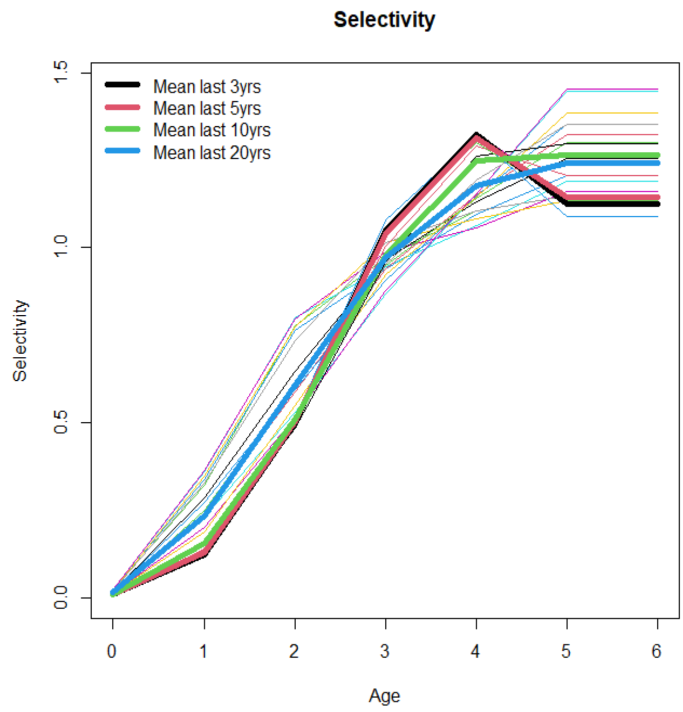


Figure A8.5.2 Whiting in 4 and 7d: Fisheries selectivity at age by year and averages for recent 3, 5, 10, 20 years.

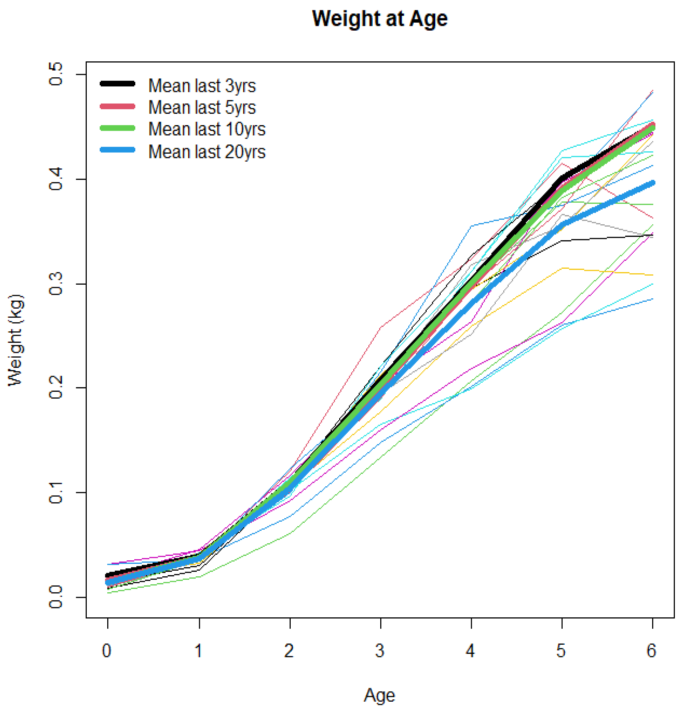


Figure A8.5.3. Whiting in 4 and 7d: Weights-at-age by year and averages for the recent 3, 5, 10, 20 years.

Autocorrelation in recruitment was significant at lag 1 and was included (Fig. A8.5.4).

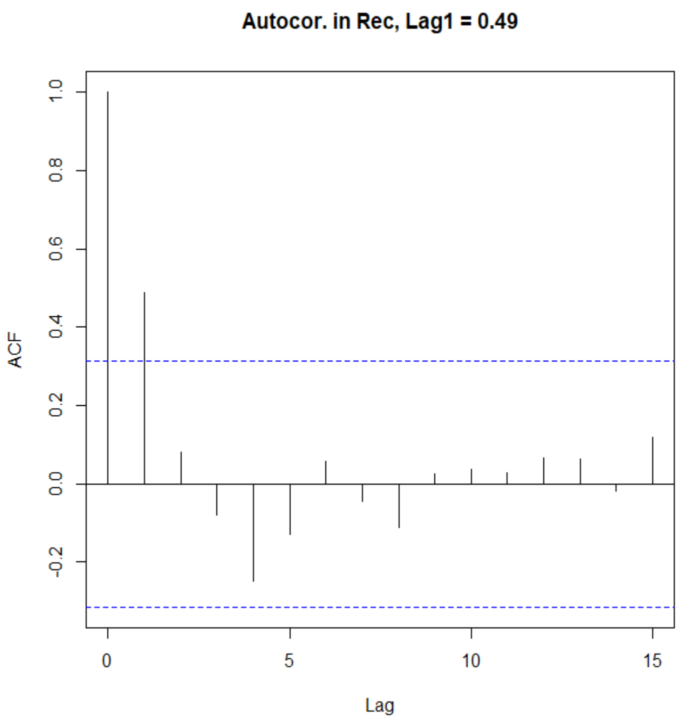


Figure A8.5.4. Whiting in 4 and 7d: Autocorrelation in recruitment.

Results

B_{lim}, F_{lim}, and B_{pa}

No clear relation between SSB and recruitment could be seen, with no identifiable SSB level at which recruitment was impaired (Fig. A8.5.5). Following ICES technical guidelines, we are therefore in a Type 5 stock situation, and B_{lim} should be equal to B_{loss} which is the lowest SSB observed historically. Based on the results from the new SAM model, the lowest SSB was observed in 2007 and was 107146 tonnes. Therefore, here B_{lim} = 107146 tonnes. A segmented regression was used (Table A8.5.1).

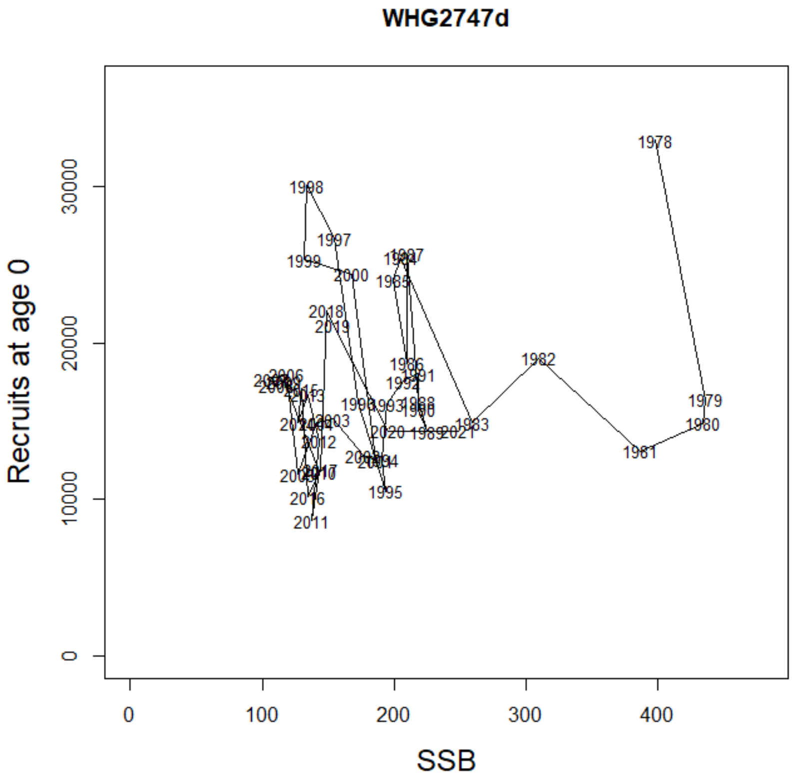


Figure A8.5.5. Whiting in 4 and 7d: Plot of age 0 recruits against SSB.

To estimate F_{lim}, EqSim was run without assessment/advice error and without the advice rule. A segmented regression with breakpoint fixed at B_{lim} for the was used to model the spawning stock recruitment relationship in EqSim, as recommended by the guidelines (ICES, 2021a). The resulting F_{lim} (F_{50}) obtained was 0.935 (Table A8.5.2).

Table A8.5.2. Whiting in 4 and 7d: EqSim run without advice/assessment error and without advice rule, to determine F_{lim} (segmented regression with a breakpoint fixed at B_{lim}).

	catF	lanF	catch	landings	catB	lanB
F05	0.559245	NA	69608.95	NA	151018.4	NA
F10	0.635705	NA	72440.29	NA	142079.6	NA
F50	**0.934542**	NA	73201.14	NA	107152.1	NA
medianMSY	NA	0.643644	NA	34643.87	NA	141216.4
meanMSY	0.77	0.62	75500.83	34626.42	127839	143830.5
Medlower	NA	0.416416	NA	32926.19	NA	172179.4
Meanlower	NA	0.409369	NA	33490.62	NA	NA
Medupper	NA	0.863864	NA	32922.97	NA	117251.6
Meanupper	NA	0.817658	NA	33497.26	NA	NA

The B_{pa} value obtained based on B_{lim} was B_{pa} = 148888 tonnes.

Unconstrained F_{MSY}

To estimate the unconstrained F_{MSY}, the EqSim was run without the advice rule (i.e. no MSY $B_{trigger}$), with assessment and advice error using the default values $(F_{cv}, F_{phi}) = (0.212, 0.423)$ as suggested by WKMSYREF4 (ICES, 2015), and with a segmented regression with a freely estimated breakpoint (Fig. A8.5.6). The resulting unconstrained F_{MSY} obtained (median MSY for lanF) was F_{MSY} = 0.393 (Table A8.5.3). The corresponding equilibrium plots are shown in Figure A8.5.7.

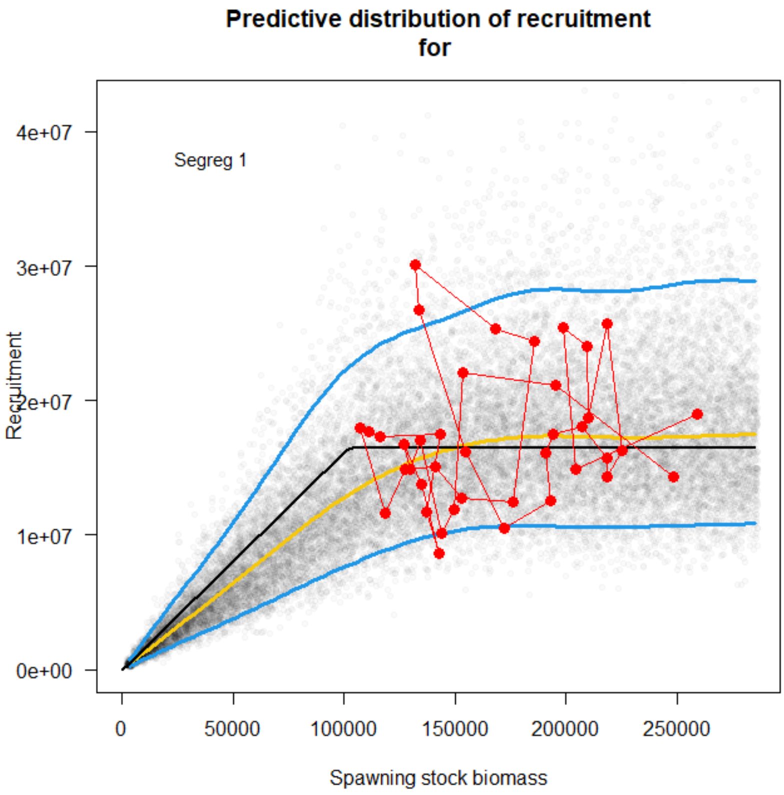


Figure A8.5.6. Whiting in 4 and 7d: Segmented regression using a freely estimated breakpoint to fit the spawning stock recruitment relationship.

Table A8.5.3. Whiting in 4 and 7d: EqSim run with advice/assessment error and without advice rule, to determine unconstrained F_{MSY} (segmented regression with freely estimated breakpoint).

	catF	lanF	catch	landings	catB	lanB
F05	0.375943	NA	61102.73	NA	185365.8	NA
F10	0.418323	NA	62346.57	NA	173414.6	NA
F50	0.616739	NA	51126.32	NA	107092.7	NA
medianMSY	NA	**0.393393**	NA	33120.14	NA	180465.3
meanMSY	0.41	0.37	62197.23	33035.35	175773.8	187070.7
Medlower	NA	0.292292	NA	31481.73	NA	209546.9
Meanlower	NA	0.281532	NA	32538.05	NA	NA
Medupper	NA	0.492492	NA	31473.27	NA	151130
Meanupper	NA	0.457928	NA	32557.34	NA	NA

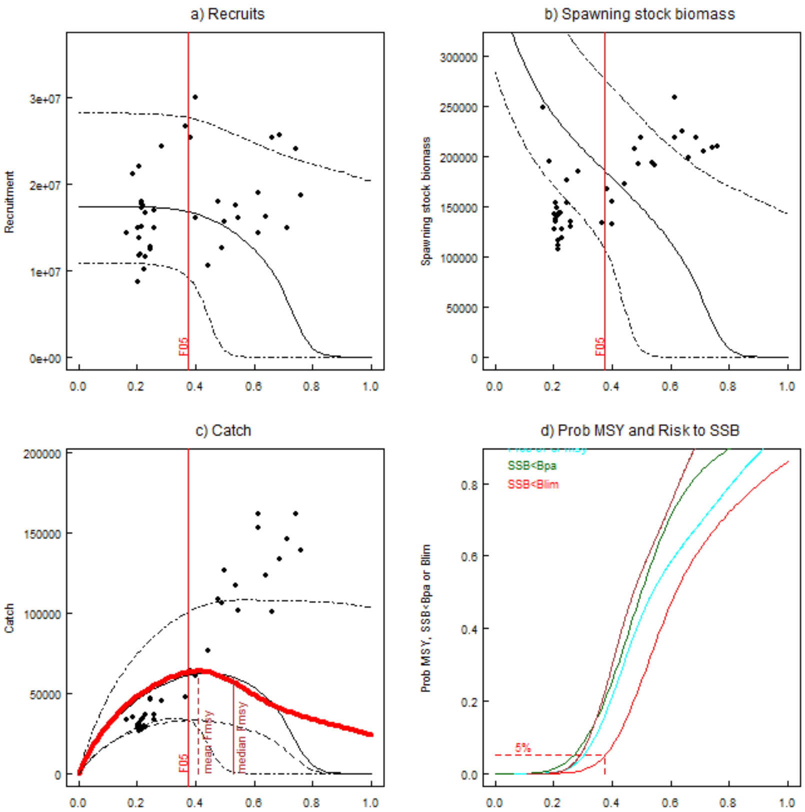


Figure A8.5.7. Whiting in 4 and 7d: Equilibrium plots for the estimation of the initial (unconstrained) F_{MSY} (EqSim with assessment/advice error, and without advice rule, and with a segmented regression with freely estimated breaking point).

MSY $B_{trigger}$

For most stocks that lack data on fishing at F_{MSY}, MSY $B_{trigger}$ is set at B_{pa}. However, as a stock starts to be fished consistently with F_{MSY}, a value for MSY $B_{trigger}$ could be set to reflect the 5th percentile definition of MSY $B_{trigger}$. Here, the stock has been fished below F_{MSY} (0.393) for the last 5 years (Table A8.5.4). The 5th percentile of B_{Fmsy} was calculated running an EqSim without assessment/advice error and without advice rule, using a segmented regression with freely estimated break-point (Fig. A8.5.8). The 5th percentile of B_{Fmsy} is estimated to be 109833 tonnes which is less than B_{pa} (148888 tonnes). Therefore, according to Figure A8.5.1 our MSY $B_{trigger}$ is B_{pa}, and MSY $B_{trigger}$ = 148888 tonnes.

Table A8.5.4. Whiting in 4 and 7d: Summary table (last 5 years only) of the new SAM assessment model results

	R(age 0)	Low	High	SSB	Low	High	Fbar(2-5)	Low	High
2017	10133907	7717908	13306204	143654	116464	177193	**0.226**	0.168	0.303
2018	11885469	8860050	15943971	149239	119870	185804	**0.21**	0.155	0.283
2019	22090037	15855554	30775952	153550	122037	193202	**0.207**	0.152	0.282
2020	21131946	14464246	30873310	195513	152679	250363	**0.188**	0.136	0.259
2021	14371814	8648430	23882836	248436	189206	326207	**0.163**	0.115	0.232
2022				283605	208997	384846			

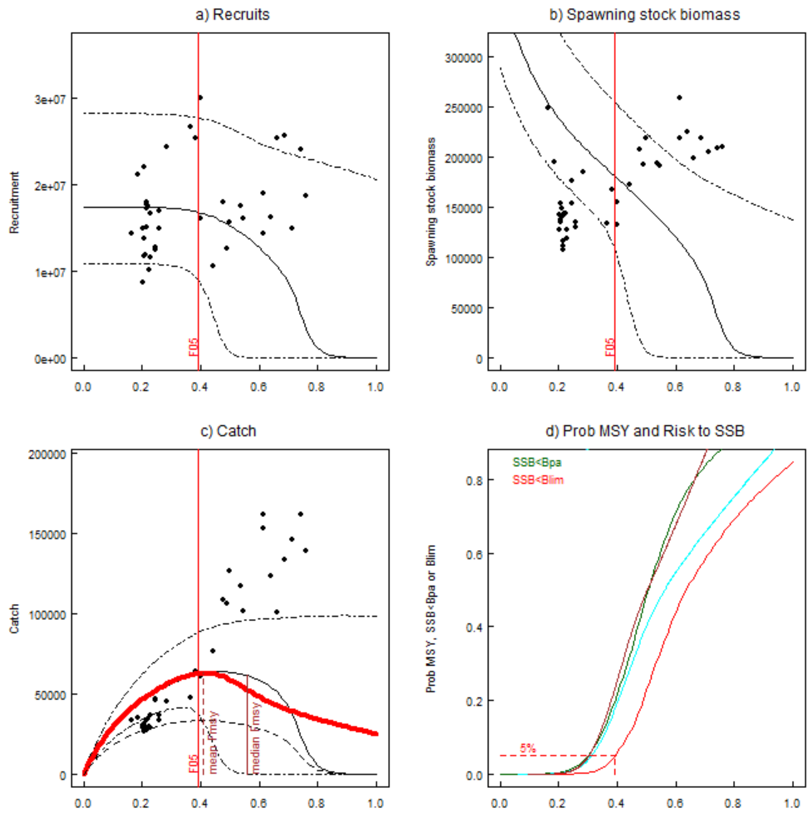


Figure A8.5.8. Whiting in 4 and 7d: EqSim without assessment/advice error and without $B_{trigger}$, with a freely estimated breaking point of segreg to estimate the 5th percentile of B_{Fmsy}.

$F_{p.05}$ and F_{pa}

$F_{p.05}$ was calculated by running EqSim with assessment/advice error and with advice rule to ensure that the long term risk of SSB<B_{lim} of any F used does not exceed 5% when applying the advice rule (Fig. A8.5.9).

$F_{P.05}$ was estimated to be 0.473 (Table A8.5.5). Therefore, as explained in section 1.3 above, F_{pa} = 0.473.

Since F_{MSY} (0.393) is smaller than F_{pa} (0.473), F_{MSY} remains uncapped at 0.393.

Table A8.5.5. Whiting in 4 and 7d: EqSim run with assessment/advice error, with advice rule to test whether F_{MSY} was at or below $F_{P.05}$ (segmented regression with freely estimated breakpoint).

	catF	lanF	catch	landings	catB	lanB
F05	**0.472638**	NA	65329.52	NA	165635.7	NA
F10	0.545704	NA	66379.38	NA	152607.1	NA
F50	0.964729	NA	58089.61	NA	107132.1	NA
medianMSY	NA	0.453453	NA	33893.33	NA	169552.8
meanMSY	0.57	0.45	66390.74	33886.88	148664.1	170210.6
Medlower	NA	0.318318	NA	32220.39	NA	201893.6
Meanlower	NA	0.31027	NA	33386.75	NA	NA
Medupper	NA	0.648649	NA	32206.6	NA	137592.5
Meanupper	NA	0.646216	NA	33391.26	NA	NA

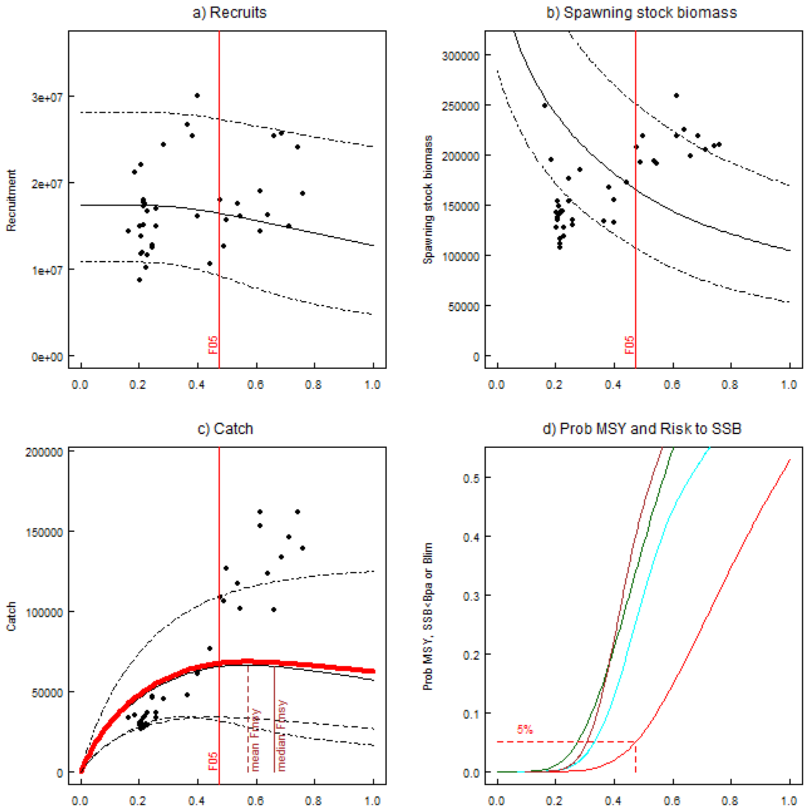


Figure A8.5.9. Whiting in 4 and 7d: EqSim with assessment/advice error and $B_{trigger}$, and a freely estimated breakpoint for segreg to estimate $F_{p.05}$

Reference points summary table

Table A8.5.6 Whiting in 4 and 7d: Reference points from final EqSim settings.

	$B_{trigger}$	B_{pa}	B_{lim}	F_{pa}	F_{lim}	$F_{P.05}$	$F_{MSY\_unconstr}$	F_{MSY}
Value	148888	148888	107146	0.473	0.935	0.473	0.393	0.393

MSY ranges

The initially estimated F_{MSY} (0.393) was lower than $F_{P.05}$ (0.473). F_{MSY} is therefore uncapped at 0.393. However, the $F_{MSYupper}$ (0.493) obtained by estimating MSY and F_{MSY} without an MSY $B_{trigger}$ but including advice error in the evaluation was greater than $F_{P.05}$ (Fig. 10). Following the guidelines, if the estimated $F_{MSYupper}$ exceeds the estimated $F_{P.05}$, $F_{MSYupper}$ is capped and specified as $F_{P.05}$, which was estimated with error and advice rule (ICES, 2015). As a result, F_{MSY} ranges are as follows:

Table A8.5.7 Whiting in 4 and 7d: MSY ranges

Reference point	Value	Technical basis
$F_{MSYlower}$	0.292	$F_{MSYlower}$ (EqSim)
F_{MSY}	0.393	F_{MSY} (EqSim)
$F_{MSYupper}$	0.473	$F_{P.05}$

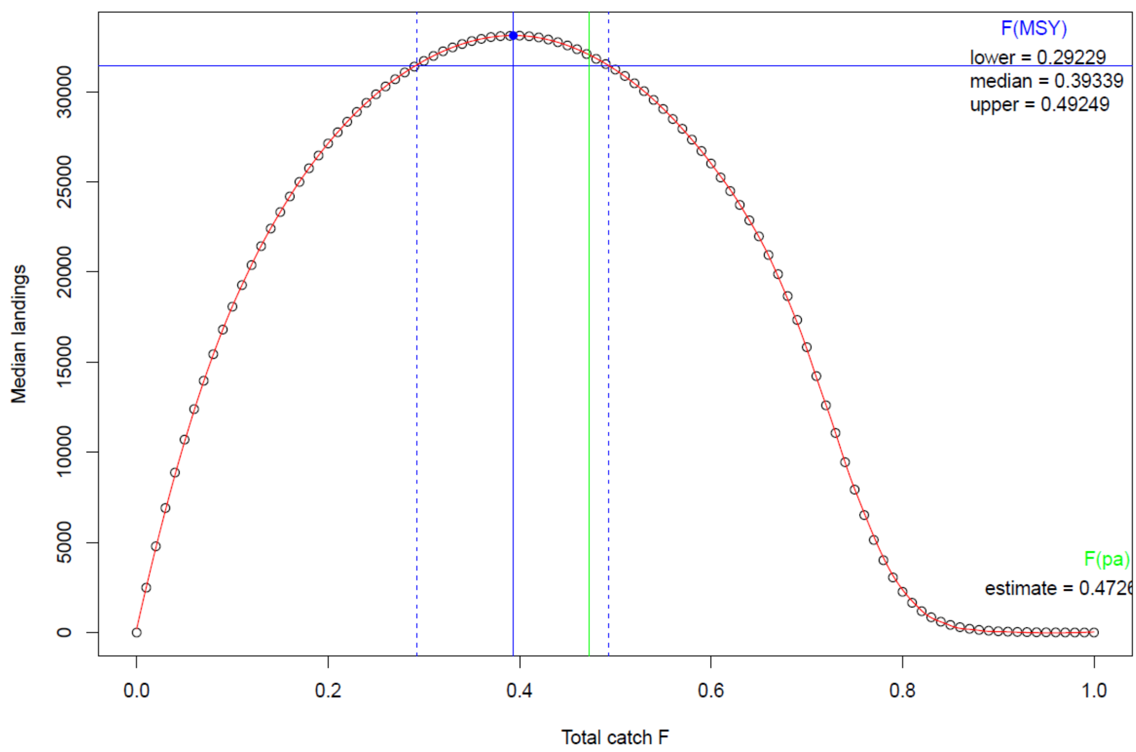


Figure A8.5.10. Whiting in 4 and 7d: Median yield curve and upper and lower ranges (vertical dashed lines) for F_{MSY}=0.393, as well as F_{pa} =$F_{P.05}$ (calculated with AR and errors) (green).

Comparison with previous reference points

In the last interbenchmark, the F_{MSY} estimated was found to be below $F_{P.05}$ and F_{MSY} was uncapped, however $F_{MSYupper}$ was capped at $F_{p.05}$. Following the SAM model update the situation is similar: F_{MSY} is uncapped but $F_{MSYupper}$ is capped at $F_{p.05}$. In summary both the F_{MSY} and $F_{MSYupper}$ obtained here are larger than the ones previously estimated in the last interbenchmark (Table A8.5.8). B_{pa} and B_{lim} also increased compared to the last interbenchmark.

Table A8.5.8. Whiting in 4 and 7d: New reference points obtained with the new plusgroup compared to the previous ones.

Reference point	New values	Values from 2021 interbenchmark
$F_{MSYlower}$	0.292	0.293
F_{MSY}	0.393	0.371
$F_{MSYupper}$	0.473	0.385
$B_{trigger}$	148888	143905
B_{pa}	148888	143905
B_{lim}	107146	103560
F_{pa}	0.473	0.385
F_{lim}	0.935	0.718
$F_{P.05}$	0.473	0.385
$F_{msy\_unconstr}$	0.393	0.371

References

ICES. 2015. Report of the Workshop to consider FMSY ranges for stocks in ICES categories 1 and 2 in Western Waters (WKMSYREF4): 187.

ICES. 2021a. Technical Guidelines - ICES fisheries management reference points for category 1 and 2 stocks (2021). ICES. https://www.ices.dk/sites/pub/Publication Reports/Forms/DispForm.aspx?ID=37356 (Accessed 11 February 2022).

ICES. 2021b. Inter-benchmark Protocol of North Sea Whiting. ICES. https://ices-library.figshare.com/articles/_/18620768 (Accessed 3 May 2022).

Annex 9: Approaches to missing data

This section contains reports for stocks on deviations from stock annexes caused by missing information from Covid-19 disruption and/or survey issues in 2021/2022.

cod.27.47d20 (cod)

1. Stock: cod.27.47d20

2. Missing or deteriorated survey data: (Also indicate also the reliance of the assessment on this data i.e. which other survey data was available)

A combination of several major storms and mechanical issues with some vessels resulted in a reduction in the sampling coverage in the NS–IBTS–Q1 survey in 2022, particularly in the central and northern North Sea. Therefore, only a partial dataset was available to generate the NS–IBTS–Q1 index for the assessment.

The indices for North Sea cod are calculated with delta-GAM and comprise a high resolution stationary spatial model with low resolution yearly independent deviations and include year, ship, depth, time of day and haul-duration effects. Increased uncertainty from the reduced coverage in the NS–IBTS–Q1 survey in 2022 was reflected by higher estimated index variances for that year, which are carried through to and included in the SAM assessment.

No deviations from the stock annex with regards to generation of indices.

3. Missing or deteriorated catch data: (Indicate proportion of total catch reported/sampled, by métier if appropriate)

Lower discard ratio coverage (57% of the landings in 2021 compared to 76% in 2019), particularly in Subarea 4 in Q1 (18% of the landings compared to >50% in other quarters). Lower proportion of landings sampled for age (78% in 2021 vs 89% in 2019). A high proportion of discard strata were sampled for age although lower in Subarea 4 in Q1 (30% compared to >75% for the other quarters).

No deviations from the stock annex with regards to InterCatch raising.

4. Missing or deteriorated commercial LPUE/CPUE data: (where commercial LPUE/CPUE are used in the assessment indicate the impact of the disruption on these data)

N/A

5. Missing or deteriorated biological data: (e.g. maturity data)

Biological sampling of the NS-IBTS-Q1 in the South was low (241 fish compared to >500 fish in other sub-areas), although this is not unique to 2022 and could be a consequence of reduced abundance of cod in that area. Samples from the South were pooled with the Northwest according to the stock annex for low sample size (as has been done in other years). Raw maturities calculated for 2022 were very low and could be a consequence of covid or reduced abundance in some subareas. The SAM assessment estimates maturity, rather than taking it as a fixed input, and is therefore able to compensate for this to some extent.

No deviations from the stock annex with regards to maturity calculations.

6. Brief description of methods explored to remedy the challenge:

N/A

7. Suggested solution to the challenge, including reason for this selecting this solution: (clearly document changes from the normal procedures in the stock annex)

N/A

8. Was there an evaluation of the loss of certainty caused by the solution that was carried out? (Please describe)

N/A

had.27.46a20 (haddock)

1. Stock: had.27.46a20

2. Missing or deteriorated survey data: (Also indicate also the reliance of the assessment on this data i.e. which other survey data was available)

A combination of severe weather and vessel issues in Q1 of 2022 resulted in a reduction in the sampling coverage of the Q1 NS-IBTS survey and the cancellation of the Q1 UK-SCOWCGFS. The Q1 index used in the haddock stock assessment is a combined North Sea-West Coast index which is modelled using the delta-GAM method. Therefore, only a partial dataset from the North Sea, and no data at all from the West Coast were available to generate this index.

3. Missing or deteriorated catch data: (Indicate proportion of total catch reported/sampled, by métier if appropriate)

The discard observer programmes for most countries continued to be limited by covid-19 during 2021. The majority of the haddock catch is taken by Scotland and so changes in the Scottish sampling programme are the primary driver for sampling coverage. In 2021, the Scottish observer programme were unable to conduct any discard sampling in Q1 of 2021. However, discard sampling across the rest of the year continues at levels similar to those seen in 2020 and sampling coverage of the catches remained fairly high (see table below). Close consideration by Scottish data submitters has led to the conclusion that discard estimates remain sufficiently representative to be used in the assessment. The sampling coverage of BMS landings (a small component of the total catch) were much lower than usual in 2021 though the age compositions submitted were considered to be representative.

The following text table summarises the proportion reported/sampled*:

Catch category	Raised or imported	Sampled or estimated	Weight (tonnes)	Proportion
Logbook registered discards	Imported	Estimated	0	NA
Landings	Imported	Sampled	22792	81
Landings	Imported	Estimated	5337	19
Discards	Imported	Sampled	10802	66
Discards	Raised	Estimated	4340	27
Discards	Imported	Estimated	1125	7
BMS landings	Imported	Estimated	154	87
BMS landings	Imported	Sampled	22	13

*** discard estimates were reported for 86% of reported landings**

4. Missing or deteriorated commercial LPUE/CPUE data: (where commercial LPUE/CPUE are used in the assessment indicate the impact of the disruption on these data)

These data are not considered in the haddock stock assessment or advice.

5. Missing or deteriorated biological data: (e.g. maturity data)

Maturity data for haddock is derived from the Q1 survey data (NS IBTS and UK-SCOWCGFS) which were affected by severe weather and vessel issues in 2022. However, the analysis of the maturity data uses a GAM smoother as a final step to reduce the effect of interannual variability in the time series. Though the raw estimates of maturity for 2022 were considered to be slightly lower than might be expected, the smoothing step resulted in final maturity estimates that were considered to be suitably representative for use in the assessment.

6. Brief description of methods explored to remedy the challenge:
7. Suggested solution to the challenge, including reason for this selecting this solution: (clearly document changes from the normal procedures in the stock annex)
8. Was there an evaluation of the loss of certainty caused by the solution that was carried out?

Since the discard and maturity estimates were considered to be sufficient for use no remedy was needed for these data.

The reduced sampling in the NS IBTS Q1 survey and the complete absence of survey data from the West Coast of Scotland in Q1 of 2022 was judged to be significant enough that it would likely have affected the quality of the modelled survey indices. A sensitivity analysis was conducted by replicating the reduced sampling coverage in previous years to evaluate the impact on the resulting indices. The reduction in sampling will likely have altered the "true" index value by +/- 10%. The solution presented recommends the use of coefficients of variation associated with the modelled indices as an additional input to the assessment model. This represents a deviation from the assessment model inputs agreed at the recent benchmark. Further details of this sensitivity analysis can be found in Working Document-1 (Annex 8).

lem.27.3a47d (lemon sole)

1. Stock: Lemon sole 3a47d

2. Missing or deteriorated survey data: (Also indicate also the reliance of the assessment on this data i.e. which other survey data was available)

The IBTS Q1 survey was compromised in 2022 by weather and vessel issues, meaning that several hauls in the central northern North Sea could not be completed. The Q1 index used in the generation of lemon sole advice (under the WKLIFE X approach) uses the delta-GAM method to interpolate likely abundance data across missing areas. From survey distribution plots (and delta-GAM diagnostics), there are no indications that the IBTS Q1 survey data for 2022 for lemon sole was significantly affected by the missing hauls, and consequently they were used as normal.

3. Missing or deteriorated catch data: (Indicate proportion of total catch reported/sampled, by métier if appropriate)

The discard observer programmes for most countries were limited by covid-19 during 2021. Close consideration by data submitters has led to the conclusion that discard estimates remain sufficiently representative to be used in the assessment for NS lemon sole.

The following text table summarises the proportion reported/sampled:

CatchCategory	RaisedOrImported	CATON	perc
BMS landing	Imported_Data	0.029	100
Discards	Imported_Data	378.1	76
Discards	Raised_Discards	118.4	24
Landings	Imported_Data	2092	100
Logbook Registered Discard	Imported_Data	0	NA

4. Missing or deteriorated commercial LPUE/CPUE data: (where commercial LPUE/CPUE are used in the assessment indicate the impact of the disruption on these data)

These data are not considered in the lemon sole assessment or advice.

5. Missing or deteriorated biological data: (e.g. maturity data)

Maturity is currently assumed to be fixed through time. Length data were available as usual.

6. Brief description of methods explored to remedy the challenge:
7. Suggested solution to the challenge, including reason for this selecting this solution: (clearly document changes from the normal procedures in the stock annex)
8. Was there an evaluation of the loss of certainty caused by the solution that was carried out?

There was considered to be no significant problem for NS lemon sole, and hence no remedy was required.

ple.27.7d (plaice in the eastern English Channel)

1. Stock: **ple27.7d**

2. Missing or deteriorated survey data: (Also indicate also the reliance of the assessment on this data i.e. which other survey data was available)
There is no missing data in 2021. However in 2020, Because of the COVID-19 pandemic, only the French waters of the English Channel were sampled during the 2020 CGFS survey, which has an impact on the FR GFS index used in the assessment. In addition, issues in the calculation of the survey index were reported due to some survey hauls dropped during the calculation of the index.

3. Missing or deteriorated catch data: (Indicate proportion of total catch reported/sampled, by métier if appropriate)
No deterioration

4. Missing or deteriorated commercial *LPUE/CPUE* data: (where commercial LPUE/CPUE are used in the assessment indicate the impact of the disruption on these data)
Not relevant

5. Missing or deteriorated biological data: (e.g. maturity data)
Not relevant (constant ogive).

6. Brief description of methods explored to remedy the challenge:
A new index (a delta GAM index) was presented during 2022 WGNSSK meeting. An estimation of reference points for 7.d plaice stock was carried out during WGNSSK meeting (20-29 April) after the update of the FR CGFS Index

7. Suggested solution to the challenge, including reason for this selecting this solution: (clearly document changes from the normal procedures in the stock annex)
This solution was selected to fix two problems: 1/ issues in the calculation of the index and 2/ the lack of sampling in UK waters during the 2020 CGFS survey. A working document is included in the report (ICES, 2022) to present in details the procedure.

8. Was there an evaluation of the loss of certainty caused by the solution that was carried out? (Please describe)

The effect of these issues has been investigated in 2021 (ICES 2021) and did not show significant impacts on assessment outputs.

pok.27.3a46 (saithe)

1. Stock: **Pok.27.3a46**

2. Missing or deteriorated survey data: (Also indicate also the reliance of the assessment on this data i.e. which other survey data was available)

No missing survey data / negligible impact (IBTS Q3)

3. Missing or deteriorated catch data: (Indicate proportion of total catch reported/sampled, by métier if appropriate)

Lower proportion of landings sampled for age (62% in 2021 and <70% in 2020 vs. >90% in 2019 and before). No impact on raising strategy though.

Still high proportion of discard strata sampled for age (Scotland and Denmark, where most of the discards originate). But based on very few actual samplings, so most unsampled strata not matchable on area and quarter.

4. Missing or deteriorated commercial LPUE/CPUE data: (where commercial LPUE/CPUE are used in the assessment indicate the impact of the disruption on these data)

No deterioration

5. Missing or deteriorated biological data: (e.g. maturity data)

Not relevant (constant ogive).

No foreseeable future impact (benchmark, etc.): IMR spawning saithe survey going on as expected.

6. Brief description of methods explored to remedy the challenge:

Unsampled discards for areas 3a and 6 matched on all available data for raising age structure and weights (same strategy as in 2021, for 2020 data).

7. Suggested solution to the challenge, including reason for this selecting this solution: (clearly document changes from the normal procedures in the stock annex)

No change suggested.

8. Was there an evaluation of the loss of certainty caused by the solution that was carried out? (Please describe)

No, but can speculate that likely very low. Mostly affected discard sampling while discards are typically low (<2% in 2021). Weight-at-age for discards in ranges previously estimated.

whg.27.47d (whiting)

1. Stock: whg.27.47d

2. Missing or deteriorated survey data: (Also indicate also the reliance of the assessment on this data i.e. which other survey data was available)

Due to a combination of mechanical problems, COVID restrictions, and severe storms during the 2022 NS-IBTS Q1, 26 rectangles were not sampled and many were sampled with only one tow. This resulted in incomplete survey coverage, especially in the central and northern North Sea.

In order to investigate whether this incomplete dataset would impact the outputs of the SAM assessment model, the model was run both with and without indices for 2022 Q1 NS-IBTS to compare the outputs. Outputs from both runs were almost identical and it was decided to include for 2022 Q1 NS-IBTS indices in the model.

3. Missing or deteriorated catch data: (Indicate proportion of total catch reported/sampled, by métier if appropriate)

COVID restrictions led to reduced sampling in 2020 (50% landings sampled across 9 metiers) and a simpler raising procedure was used in intercatch. But normal sampling coverage seems to have resumed in 2021 (67% landings sampled across 11 metiers). As a result the normal raising procedure was used in intercatch for 2021 data: discards raised by gear type and quarter, age allocation for landings and discards by gear type and half year (only TR1 raised separately for discards).

4. Missing or deteriorated commercial LPUE/CPUE data: (where commercial LPUE/CPUE are used in the assessment indicate the impact of the disruption on these data)

N/A

5. Missing or deteriorated biological data: (e.g. maturity data)

N/A

6. Brief description of methods explored to remedy the challenge:

N/A

7. Suggested solution to the challenge, including reason for this selecting this solution: (clearly document changes from the normal procedures in the stock annex)

N/A

8. Was there an evaluation of the loss of certainty caused by the solution that was carried out? (Please describe)

N/A

nep.fu.32 (Norway lobster)

1. Stock: nep.fu.32
2. Missing or deteriorated survey data: (Also indicate also the reliance of the assessment on this data i.e. which other survey data was available)
   NO MISSING SURVEY DATA. ASSESSMENT NOT RELIANT ON SURVEY DATA
3. Missing or deteriorated catch data: (Indicate proportion of total catch reported/sampled, by métier if appropriate)
   THIS IS IN GENERAL NOT A WELL SAMPLED STOCK, AND THE SAMPLING IN 2021 WAS NEITHER BETTER NOR WORSE THAN IN ORDINARY YEARS
4. Missing or deteriorated commercial *LPUE/CPUE* data: (where commercial LPUE/CPUE are used in the assessment indicate the impact of the disruption on these data)
   NO MISSING LPUE/CPUE DATA. THESE INDICES ARE ONLY INCLUDED AS INDICATORS AND ARE NOT PART OF THE ASSESSMENT
5. Missing or deteriorated biological data: (e.g. maturity data)
   NO BIOLOGICAL DATA FROM THIS STOCK
6. Brief description of methods explored to remedy the challenge:
   NOT RELEVANT
7. Suggested solution to the challenge, including reason for this selecting this solution: (clearly document changes from the normal procedures in the stock annex)
   NOT RELEVANT
8. NOT RELEVANT