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Andersen, Jesper Levring; Nielsen, Max

Publication date:
2024

Document version
Publisher's PDF, also known as Version of record

Citation for published version (APA):
Andersen, J. L., & Nielsen, M. (2024). *The economics of the Danish sandeel fishery and fishmeal and fish oil factories*. Department of Food and Resource Economics, University of Copenhagen. IFRO Commissioned Work No. 2024/16

DEPARTMENT OF FOOD AND RESOURCE ECONOMICS
UNIVERSITY OF COPENHAGEN

IFRO Commissioned Work

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Jesper Levring Andersen
Max Nielsen

2024 / 16

IFRO Commissioned Work 2024/16

(IFRO Udredning 2024/16)

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Authors: Jesper Levring Andersen, Max Nielsen

Internal scientific quality assurance: Peder Andersen has commented on the manuscript. The responsibility for the published content, however, lies entirely with the authors.

This work has been commissioned by the Ministry of Food, Agriculture and Fisheries of Denmark as part of the agreement for scientific consultancy between the Ministry of Environment of Denmark, the Ministry of Food, Agriculture and Fisheries of Denmark and the Department of Food and Resource Economics.

Published July 2024

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Department of Food and Resource Economics (IFRO)
University of Copenhagen
Rolighedsvej 23
DK-1958 Frederiksberg
www.ifro.ku.dk/english/

Preface

The Ministry for Food, Agriculture and Fisheries of Denmark has asked the Department of Food and Resource Economics (IFRO), University of Copenhagen, to describe the fleet structure and economics of the Danish fishing vessels conducting sandeel fishery in the United Kingdom Economic Exclusive Zone as well as the potential economic consequences following an access restriction to this zone. The potential economic consequences for the Danish fish processing sector have also been addressed in this note.

The note has been prepared as part of IFRO's public consultancy contract with the Ministry for Food, Agriculture and Fisheries of Denmark to advise within fisheries economics and management.

Associate Professor Jesper Levring Andersen has authored the first three sections regarding the fleet analysis, while Associate Professor Max Nielsen has authored the fourth section. Professor Emeritus Peder Andersen has undertaken the internal scientific quality assurance of the note. The Ministry for Food, Agriculture and Fisheries of Denmark has commented on the final draft.

Contents

Introduction

On 26 March 2024, the United Kingdom initiated a closure of the sandeel fishery in the United Kingdom Economic Exclusive Zone (UK EEZ) of the North Sea and all Scottish waters. The EU questions the compatibility of the full and permanent closure of the fishery with the principles and obligations under the TCA and has therefore initiated proceedings under the TCA's dispute settlement mechanism (European Commission 2024).

The sandeel fishery in the UK EEZ is primarily undertaken by Danish fishermen, who in 2023 had access to 93.45 per cent of the Total Allowable Catch (TAC) set for sandeel. Swedish, German and British fishermen had access to respectively 3.44 per cent, 0.14 per cent and 2.97 per cent of the TAC, but this will change in the coming years following the Brexit agreement. Almost all landings of sandeel from these fishermen are processed by Danish fishmeal and fish oil factories.

To undertake the analysis, it was necessary to use several data sources. The Danish Fisheries Agency supplied us with information from their logbook, sales note, Vessel Monitoring System (VMS) and vessel registers. Landings information was obtained from the logbook and sales note registers. However, these data were not detailed enough to give the exact position of each vessel when fishing. Therefore, it was necessary to combine the landings information with data from the VMS register to determine in which EEZ the fishing activity takes place. The VMS sends the position of a vessel to a central database every 30 minutes. DTU Aqua[1] has combined the data from the logbook, sales note and VMS registers for the entire period from 2011 to 2023 to have a consistent approach to this. Furthermore, we combined this extended landings information with information from the vessel register to include information about vessels in the analysis. For landings by Swedish fishermen in Denmark, similar numbers were provided by the Swedish Agency for Marine and Water Management. Landings of foreign, non-Swedish fishermen in Denmark feature in the data from the Danish Fisheries Agency, but the exact catch area is not known and therefore estimated.

Information about fleet costs was obtained from Statistics Denmark (2024a) and combined with the above fleet and landings information to determine the economic consequences for the Danish fleet conducting sandeel fishery. Moreover, information on the turnover and costs of Danish fishmeal and fish oil factories is available in Nielsen (2022).

In the present note, the importance of sandeel for Danish fishermen with a focus on the fishery in the UK EEZ is described in section 1, while section 2 presents the approach and assumptions related to calculating the potential economic consequences of the closure of sandeel fishery for Danish fishermen. Section 3 presents the economic consequences for the most affected fishing fleets. Finally, section 4 analyses the potential effects on Danish fishmeal and fish oil factories dependent on sandeel.

[1] DTU Aqua provides stock assessment advice based on many years' combined information from the Danish Fisheries Agency's logbook, sales note and VMS registers. For more information, see their website: https://www.aqua.dtu.dk/english/advice.

1. The importance of the Danish sandeel fishery

Sandeel fishery is a seasonal fishery which primarily takes place in April, May and June. Primarily larger trawlers conduct this type of fishery in the North Sea. The landings are used by fishmeal factories to produce fishmeal and fish oil used in for instance aquaculture as further described in section 4.

Historically, sandeel fishery has been important for Danish fishermen, and on average, it made up 22 per cent of the total Danish landings measured in weight and 8 per cent measured in value in the period 2011-2023. However, this type of fishery fluctuates due to sandeel's nature as a short-lived species. Therefore, the importance of sandeel fluctuated from 4 per cent and 2 per cent of the total Danish landings measured in weight and value respectively in 2016 to 40 per cent measured in weight in 2017 and 15 per cent measured in value in 2013. Table 1 shows the development in the total Danish sandeel quota in the North Sea, Skagerrak and Kattegat, which is the primary reason for many of the fluctuations observed for this type of fishery.

Table 1. *Danish North Sea sandeel quotas, including quota exchanges (tonnes), 2011-2023*

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Total quota	300,979	51,337	223,270	171,638	305,166	72,264	429,974	217,392	115,886	205,276	88,145	77,536	181,637

Source: Danish Fisheries Agency (2024).

Table 2 below shows the number of fishing vessels that have landed sandeel within each year in the period 2011-2023. In the table, the total number of registered Danish fishing vessels is also shown, and, thus, not all Danish fishing vessels conduct sandeel fishing but only approximately 3 per cent. On average, 74 vessels landed sandeel each year with the highest number in 2013 and the lowest in 2019. In 2023, the 62 sandeel vessels made up 5.4 per cent of the total number of fishing vessels in Denmark with a registered value of landings within that year. On average, each year 11 vessels had a value dependency on sandeel of below 10 per cent, while the remaining vessels had an average value dependency of 33 per cent with value dependencies ranging from 10 per cent to 99 per cent.

Table 2. *Number of Danish fishing vessels conducting sandeel fishery, 2011-2023*

Length group	Gear group	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022[2]	2023[2]
12-15 m	Multipurpose		4	5	5	6	3	2	2	1	4	4		
	Danish seiners			1	1	1		1	1		1	1	1	1
	Trawlers		9	13	12	7	5	2	4	2	2	1	7	7
15-18 m	Multipurpose	5	3	5	5	2	1		2		2	1		
	Danish seiners				1									
	Trawlers	17	16	20	17	15	11	19	17	12	22	21	22	19
18-24 m	Multipurpose					1	1	1	1	1	1	1		
	Trawlers	18	12	21	16	15	9	13	9	5	10	8	9	10
24-40 m	Industrial trawlers[1]	3	4	7	6	5	3	2	2	1	3	3	2	1
	Other trawlers	5	4	4	5	5	1	5	2	3	3	3	4	2
> 40 m	Industrial trawlers[1]	16	10	16	15	16	11	14	13	12	13	10	9	8
	Purse seiners and other trawlers	12	11	13	12	13	9	16	14	12	10	9	5	8
Licensed fishery	Shrimp beam trawlers	5	4	5		4	1			2	3	1	2	6
	Mussel dredgers										1			
Total		81	77	110	95	90	55	75	67	51	75	63	61	62
Total number of Danish fishing vessels		2,773	2,729	2,616	2,426	2,347	2,256	2,195	2,119	2,053	1,994	1,921	1,839	1,732

Note: [1]: Industrial trawlers account for at least 80 per cent of the total landings value consisting of industrial species (for example sandeel, Norway pout, blue whiting, sprat, horse mackerel, etc.). [2]: A change in gear group classification was made in 2022. Thus, all multipurpose vessels have been classified in accordance with the most frequently used gear group during a specific year.
Source: Data from the Danish Fisheries Agency's logbook, sales note and VMS registers combined by DTU Aqua and furthermore coupled with data from the Danish Fisheries Agency's vessel register.

Besides sandeel, these vessels primarily land sprat, herring and mackerel. Especially the smaller vessels also land a range of consumption species, such as Nephrops, plaice and cod. Looking at the value of sandeel, Table 3 shows the total value of sandeel landings within the European Union Exclusive Economic Zone (EU EEZ), the UK EEZ and other Exclusive Economic Zones (EEZs) as well as the relative importance of the EEZs. Besides sandeel, the sandeel vessels in the UK EEZ also primarily catch mackerel and herring to a varying degree.

Table 3. *Value of Danish sandeel landings (1,000 DKK) and importance of EEZs (per cent), 2011-2023*

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Value, EU EEZ	64.4	34.4	162.9	147.8	63.6	22.2	155.6	95.2	94.1	183.0	41.0	133.5	133.3
Value, UK EEZ	371.2	64.6	287.6	61.8	210.6	38.3	237.6	201.3	86.3	156.5	149.4	9.8	136.8
Value, other EEZs	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.2	0.0	0.9	0.0	0.2	0.0
Total value	435.6	99.0	450.4	210.0	274.3	60.5	3931	296.7	180.4	340.4	190.4	143.5	270.1
Importance of EU EEZ	14.8	34.8	36.2	70.4	23.2	36.7	39.6	32.1	52.2	53.8	21.6	93.0	49.3
Importance of UK EEZ	85.2	65.2	63.8	29.4	76.8	63.3	60.4	67.8	47.8	46.0	78.4	6.8	50.7
Importance of other EEZs	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.1	0.0	0.3	0.0	0.1	0.0

Source: Data from the Danish Fisheries Agency's logbook, sales note and VMS registers combined by DTU Aqua and furthermore coupled with data from the Danish Fisheries Agency's vessel register.

Looking at the number of vessels conducting sandeel fishery in the UK EEZ, in Table 4 below, one can observe that on average, there were around 32 vessels from 2011 to 2021 but that this number then dropped to 9 in 2022, followed by an increase to 21 vessels in 2023.

Table 4. *Number of Danish fishing vessels conducting sandeel fishery in the UK EEZ, 2011-2023*

Length group	Gear group	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022[2]	2023[2]
15-18 m	Multipurpose											1		
	Trawlers									1		4		
18-24 m	Multipurpose					1	1	1	1	1	1	1		
	Trawlers	1		1	1	1		1	1		1	5		3
24-40 m	Industrial trawlers[1]	2	3	4	4	5	1	2	2	1	3	3	1	1
	Other trawlers	1	4	2	3	3	1	2		3	1	3		1
> 40 m	Industrial trawlers[1]	16	10	16	14	16	9	14	13	12	13	10	6	8
	Purse seiners and other trawlers	12	11	13	12	13	9	16	14	12	10	9	2	8
Licensed fishery	Shrimp beam trawlers									2		1		
Total		32	28	36	34	39	21	36	31	32	29	37	9	21

Note: [1]: Industrial trawlers account for at least 80 per cent of the total landings value consisting of industrial species (for example sandeel, Norway pout, blue whiting, sprat, horse mackerel, etc.). [2]: A change in gear group classification was made in 2022. Thus, all multipurpose vessels have been classified in accordance with the most frequently used gear group during a specific year.
Source: Data from the Danish Fisheries Agency's logbook, sales note and VMS registers combined by DTU Aqua and furthermore coupled with data from the Danish Fisheries Agency's vessel register.

Looking at the vessel dependency on sandeel fishery in the UK EEZ, Table 5 shows the number of vessels that obtain at least 10 per cent of their total landings value from sandeel in the UK EEZ. From 2011 to 2021, on average, 21 vessels had a dependency on this fishery of above 10 per cent, 1 in 2022 and then 12 in 2023. Thus, the same development as previously is observed but with lower numbers.

Table 5. *Number of Danish fishing vessels with above 10 per cent of their total landings value from sandeel fishery in the UK EEZ, 2011-2023*

Length group	Gear group	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022[2]	2023[2]
18-24 m	Multipurpose						1			1		1		
	Trawlers										1	2		
24-40 m	Industrial trawlers[1]	2	1	3		4	1	2	2	1	3	2		1
	Other trawlers	1	2	1	1	1	1	1		1	1			1
> 40 m	Industrial trawlers[1]	16	9	16	4	16	3	14	13	6	12	10	1	8
	Purse seiners and other trawlers	12	5	13	3	10	2	14	9	1	3	5		2
Total		31	17	33	8	31	8	31	24	10	20	20	1	12

Note: [1]: Industrial trawlers account for at least 80 per cent of the total landings value consisting of industrial species (for example sandeel, Norway pout, blue whiting, sprat, horse mackerel, etc.). [2]: A change in gear group classification was made in 2022. Thus, all multipurpose vessels have been classified in accordance with the most frequently used gear group during a specific year.
Source: Data from the Danish Fisheries Agency's logbook, sales note and VMS registers combined by DTU Aqua and furthermore coupled with data from the Danish Fisheries Agency's vessel register.

No fishing vessels had a dependency on sandeel caught in the UK EEZ of above 15 per cent of their total landings value in 2022 and 2023. In 2021, 7 vessels above 40 meters had a dependency higher than 15 per cent, while in 2019 and 2020, it was 2 and 3 vessels respectively.

2. Method used to calculate the potential economic consequences of a closure of sandeel fishery in the UK EEZ for Danish fishermen

As shown in the previous section, the number of vessels conducting sandeel fishery and the available quota varies a lot between the years. Thus, to calculate the potential economic consequences of a closure of sandeel fishery in the UK EEZ for Danish fishermen, the consequences are considered for each year from 2011 to 2023 instead of considering average figures for a selected period of years.

The analysis is conducted by removing the landings values of sandeel originating from the UK EEZ but assuming that other types of income from other activities are unchanged. Several costs are considered correlated with the fishing activity. Thus, fuel costs, ice and provision costs, sales costs and crew payments are reduced with the same proportion as the one observed for the landings values, while costs related to maintenance, insurance, onshore property and various service costs are considered fixed no matter the level of vessel activity.

The economic consequences are described using three measures:

- Landings value
- Earning capability
- Gross profit

The earning capability is the amount left after the variable and fixed costs have been paid. Thus, the earning capability is what is left to pay for the use of labour and capital. The gross profit is calculated by further deducting crew payments and the calculated payment to the owner and thus shows the remaining amount available for capital rent or excess payment of labour (for example an extra payment to the owner).

This corresponds to the method used in Andersen and Nielsen (2012).

Cost data are obtained from Statistics Denmark (2024a). However, because the average landings value for a vessel within the respective length and gear groups differs from the average landings value of the vessels conducting sandeel fishery in the UK EEZ, all cost figures from Statistics Denmark are scaled with the proportion between these two for every cost component observed for each relevant fleet. This method implies linearity between the landings value and costs, an assumption that may not necessarily be correct. Given that these vessels generally are larger measured by landings value than the average vessel within the fleet, they might also be better at optimising and using large-scale advantages, thus implying a non-linear scaling of the cost components. However, there is no available information regarding which scaling factor that would be relevant to use instead.

Also, 2023 cost statistics are not available yet; only landings values are. Therefore, the cost figures for 2023 have been estimated using a three-year average (from the period 2020-2022) and then adjusted with the development in fuel prices for fuel costs and inflation using the harmonised index of consumer price (Statistics Denmark 2024b) for ice and provisions costs, maintenance costs, insurance costs, the cost related to onshore property and various service costs. The sales costs and crew payments are generally a proportion of the landings value and have therefore been determined using the landings value for 2023 multiplied with the three-year average proportion for sales costs and crew payments.

The approach to estimating the 2023 cost figures follows the approach used in Andersen et al. (2012).

Due to the low, infrequent number of vessels conducting sandeel fishery in the UK EZZ in the fleets between 15 and 18 meters and licensed fishery, these fleets are not included in the economic analysis in section 3.

3. The economics of the Danish sandeel fishery

Based on the method explained in section 2, the economic consequences following a closure of catching sandeel in the UK EEZ for Danish fishing vessels are considered in this section. The consequences will only be considered under the assumption that none of the sandeel caught in the UK EEZ can instead be caught in other fishing areas, for instance the EU EEZ. Thus, the economic figures might overestimate the consequences, but on the other hand, given the considerable variation in the sandeel catches between the EU EEZ and the UK EEZ, cf. Table 3, situations might arise where in some years a higher proportion of sandeel can only be caught in the UK EEZ.

Table 6, 7 and 8 below show the reduction in the landings value, earning capability and gross profit following a closure of fishing for sandeel in the UK EEZ for those fleets active in the UK EEZ, assuming that all their other fishing activities remain unchanged in the various years. In the tables, one can observe that especially trawlers between 24 meters and 40 meters will be affected by the closure but also that industrial trawlers above 40 meters are impacted significantly. These vessels also have the highest proportion of the Danish sandeel landings from the UK EEZ. Despite the fact that lower activity gives rise to lower costs, these are not enough to offset the reduction, also due to the fact that some costs are not expected to be reduced following the lower activity as explained in the method in section 2. Therefore, reductions in the earning capability and gross profit are also observed.

Table 6. *Change in total yearly vessel landings value due to a closure of sandeel fishery in the UK EEZ (per cent), 2011-2023*

Length group	Gear group	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022[2]	2023[2]	Average 2011-2023
18-24 m	Multipurpose					-4	-15	-7	-5	-12	-9	-20			-10
	Trawlers	-9		-5	-6	-9		-7	-6		-13	-8		-5	-7
24-40 m	Industrial trawlers[1, 3]	-57	-7	-27	-5	-17	-12	..	..	..	..	..	..	..	-20
	Other trawlers	-37	-8	-21	-5	-9	-16	-41	-26	-25	-37	-30	-5	-45	-26
> 40 m	Industrial trawlers[1]	-45	-19	-35	-7	-19	-7	-32	-31	-11	-18	-30	-4	-16	-23
	Purse seiners and other trawlers	-19	-5	-17	-7	-12	-3	-15	-11	-5	-7	-10	-2	-6	-10

Note: [1]: Industrial trawlers account for at least 80 per cent of the total landings value consisting of industrial species (for example sandeel, Norway pout, blue whiting, sprat, horse mackerel, etc.). [2]: A change in gear group classification was made in 2022. Thus, all multipurpose vessels have been classified in accordance with the most frequently used gear group during a specific year. [3]: ".." indicates that cost statistics are not available due to discrepancy issues but that the industrial trawlers have been included in the fleet *Other trawlers* in the calculations.
Source: Data from the Danish Fisheries Agency's logbook, sales note and VMS registers combined by DTU Aqua and furthermore coupled with data from the Danish Fisheries Agency's vessel register and Statistics Denmark (2024a) as well as the author's own calculations.

Table 7. *Change in total yearly vessel earning capability due to a closure of sandeel fishery in the UK EEZ (per cent), 2011-2023*

Length group	Gear group	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022[2]	2023[2]	Average 2011-2023
18-24 m	Multipurpose					-5				-14	-10	-26			-12
	Trawlers	-12		-6	-8	-11		-9	-7		-16	-11		-5	-8
24-40 m	Industrial trawlers[1, 3]	-72	-3	-32	-5	-20	-21	..	..	..	..	..	..	..	-20
	Other trawlers	-46	-10	-25	-7	-11	-19	-49	-31	-31	-41	-34	-6	-49	-32
> 40 m	Industrial trawlers[1]	-53	-18	-25	-7	-18	-9	-36	-36	-13	-18	-27	-5	-17	-23
	Purse seiners and other trawlers	-20	-6	-18	-7	-11	-3	-16	-10	-5	-7	-11	-2	-6	-10

Note: [1]: Industrial trawlers account for at least 80 per cent of the total landings value consisting of industrial species (for example sandeel, Norway pout, blue whiting, sprat, horse mackerel, etc.). [2]: A change in gear group classification was made in 2022. Thus, all multipurpose vessels have been classified in accordance with the most frequently used gear group during a specific year. [3]: ".." indicates that cost statistics are not available due to discrepancy issues but that the industrial trawlers have been included in the fleet *Other trawlers* in the calculations.
Source: Data from the Danish Fisheries Agency's logbook, sales note and VMS registers combined by DTU Aqua and furthermore coupled with data from the Danish Fisheries Agency's vessel register and Statistics Denmark (2024a) as well as the author's own calculations.

Table 8. *Change in total yearly vessel gross profit due to a closure of sandeel fishery in the UK EEZ (per cent), 2011-2023*

Length group	Gear group	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022[2]	2023[2]	Average 2011-2023
18-24 m	Multipurpose					-6				-18	-12	-36			-13
	Trawlers	-15		-10	-10	-14		-10	-9		-21	-17		-5	-10
24-40 m	Industrial trawlers[1, 3]	-87	-2	-38	-5	-23	-62	..	..	..	..	..	..	..	-19
	Other trawlers	-58	-13	-31	-8	-13	-21	-58	-38	-38	-46	-40	-9	-52	-37
> 40 m	Industrial trawlers[1]	-58	-18	-22	-7	-18	-10	-39	-39	-13	-18	-26	-6	-18	-23
	Purse seiners and other trawlers	-20	-6	-18	-8	-11	-3	-16	-10	-5	-8	-11	-2	-6	-10

Note: [1]: Industrial trawlers account for at least 80 per cent of the total landings value consisting of industrial species (for example sandeel, Norway pout, blue whiting, sprat, horse mackerel, etc.). [2]: A change in gear group classification was made in 2022. Thus, all multipurpose vessels have been classified in accordance with the most frequently used gear group during a specific year. [3]: ".." indicates that cost statistics are not available due to discrepancy issues but that industrial trawlers have been included in the fleet *Other trawlers* in the calculations.
Source: Data from the Danish Fisheries Agency's logbook, sales note and VMS registers combined by DTU Aqua and furthermore coupled with data from the Danish Fisheries Agency's vessel register and Statistics Denmark (2024a) as well as the author's own calculations.

To summarise the economic consequences for the Danish fishery following a closure of the sandeel fishery in the UK EEZ, Table 9 shows the expected changes if this had been the situation in each of the years from 2011 to 2023. On average, the landings value would have been reduced with 159 million DKK, the earning capability with 123 million DKK and the gross profit with 92 million DKK, corresponding to 21.23 million euros, 16.51 million euros and 12.35 million euros respectively, using an average exchange rate of 7.45 DKK per euro.

Table 9. *Total values of economic measures with or without a closure of sandeel fishery in the UK EEZ (million DKK), 2011-2023*

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	Average 2011-2023
Landings value														
- with fishery in the UK EEZ	1,413	865	1,345	933	1,583	1,024	1,389	1,453	1,376	1,529	1,053	408	1,601	1,229
- without fishery in the UK EEZ	1,042	800	1,057	872	1,373	986	1,139	1,251	1,281	1,356	891	398	1,454	1,069
Expected change (%)	-26.3	-7.5	-21.4	-6.6	-13.3	-3.7	-17.9	-13.9	-6.9	-11.4	-15.3	-2.4	-9.2	-13.0
Earning capability														
- with fishery in the UK EEZ	1,079	663	1,080	658	1,250	821	1,060	1,184	1,046	1,198	801	264	1,283	953
- without fishery in the UK EEZ	783	613	865	611	1,088	793	864	1,034	974	1,062	682	257	1,162	830
Expected change (%)	-27.5	-7.6	-19.9	-7.1	-12.9	-3.4	-18.5	-12.6	-6.9	-11.3	-14.8	-2.6	-9.4	-12.9
Gross profit														
- with fishery in the UK EEZ	831	512	838	478	986	663	815	943	811	910	560	185	960	730
- without fishery in the UK EEZ	610	475	677	443	859	642	667	830	757	810	479	180	871	638
Expected change (%)	-26.6	-7.1	-19.2	-7.4	-12.8	-3.3	-18.1	-12.0	-6.6	-11.0	-14.5	-2.7	-9.3	-12.6

Source: Data from the Danish Fisheries Agency's logbook, sales note and VMS registers combined by DTU Aqua and furthermore coupled with data from the Danish Fisheries Agency's vessel register and Statistics Denmark (2024a) as well as the author's own calculations.

A closure of the possibility to catch and land sandeel from the UK EEZ will have important negative economic implications for the Danish fishing vessels conducting this type of fishery. The implications will of course vary with the individual dependency on the UK EEZ but also with the possibility to use the fishing vessel in other types of fisheries, so the capacity utilisation is not reduced. With the significant fluctuations observed between the sandeel landings originating from the EU EEZ and UK EEZ, there may be years where the closure does not have an effect but also years where it will have even more severe implications than estimated above.

4. The economics of the Danish fishmeal and fish oil factories

Danish fishmeal and fish oil factories coproduce fishmeal and fish oil based on fish for reduction. Fishmeal and fish oil are mainly applied as ingredients in feed for aquaculture and mixed with different types of plant-based elements, although parts are also applied for feed for small pigs. The mixing typically takes place in aquaculture feed companies, either in Denmark or elsewhere. These are the largest direct buyers of fishmeal and fish oil. Fishmeal and oil are applied for feed in aquaculture and the global aquaculture industry relies on the supply of fishmeal and fish oil together with plant-based sources such as soy.

Key numbers for the Danish fishmeal and fish oil factories are shown in Table 10, which shows the turnover, earning capability and gross profit respectively to measure the economic performance of the companies. The earning capability is defined as the amount left after the variable and fixed costs have been paid. The earning capability is thus what is left to be paid for the use of labour and capital. The gross profit is calculated by further deducting salary and personnel costs. As for the Danish sandeel fishery, the period 2011-2023 is considered, but economic statistics have only been published until 2021.

Table 10. *Key numbers for Danish fishmeal and fish oil factories, 2011-2021*

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Number of firms	6	5	5	6	6	6	6	5	4	5	5
Number of employees	277	262	356	272	290	333	348	359	348	298	255
Turnover, million DKK	2,526	3,348	3,884	3,503	4,728	4,770	3,861	3,830	3,770	3,352	2,837
Earning capability, million DKK	244	156	61	349	493	292	571	515	185	136	79
Gross profit, million DKK	81	14	-106	181	305	87	339	274	-50	-79	-98

Source: Nielsen (2022).

Between four and six fishmeal and fish oil firms were in existence within the period with an annual turnover of between 2.5 billion DKK (2011) and 4.8 billion DKK (2016), indicating that a substantial variation prevailed. The earning capability was between 61 million DKK in 2013 and 571 million DKK in 2017, while the gross profit varied between a deficit of 106 million DKK in 2013 and a surplus of 339 million DKK in 2017. The years with the highest earning capability and highest gross profit were 2017 and 2018, while the gross profit was negative in 2013 and again in the period 2019-2021.

Fish for reduction was the main raw material, consisting of mainly sandeel, sprat, blue whiting, Norway pout, boarfish and capelin. The size of production depended on the landings of fish for reduction in Denmark by Danish and foreign fishermen only, since land-based transport is expensive. Minor elements of cutoffs from the human consumption fishing industry were also applied as raw material, but as cutoffs are of lower quality and used in minor quantities, they are not included in this analysis.

The total landings of fish for reduction in Denmark in the period 2011-2023 are shown in table 11.

Table 11. *Quantity (1,000 tonnes) and value (million DKK) of landings of fish for reduction by Danish (DEN) and foreign (FOR) fishermen in Denmark, 2011-2023*

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Quantity, DEN	437	203	357	413	545	341	582	485	366	476	240	251	321
Quantity, FOR	183	121	212	281	336	271	337	372	311	250	255	171	239
Total quantity	620	324	569	693	880	612	919	856	676	726	495	422	560
Value, DEN	742	428	712	619	939	696	699	840	714	937	547	590	938
Value, FOR	336	227	463	420	586	568	446	615	571	522	507	367	711
Total value	1,078	675	1,175	1,038	1,524	1,264	1,145	1,455	1,285	1,459	1,054	957	1,649

Source: Data for Danish and foreign fishermen (excluding Swedish fishermen) are from data from the Danish Fisheries Agency's logbook, sales note and VMS registers combined by DTU Aqua and furthermore coupled with data from the Danish Fisheries Agency's vessel register. Data for Swedish fishermen were obtained by directing a special request to the Swedish Agency for Marine and Water Management.

The total landings of fish for reduction fluctuated substantially with the largest landings of 919,000 tonnes in 2017 and the smallest landings of 324,000 tonnes in 2012. Prices also fluctuated with a lowest price of 1.25 DKK per kilo in 2017 and a highest price of 2.95 DKK per kilo in 2023.

Following the analysis of the previous sections for the fishery, the economic effects of the closure of sandeel fishing in the UK EEZ for the Danish fishmeal and fish oil factories are identified. It is calculated how much the turnover, earning capability and gross profit would have been reduced in each of the years 2013-2021 if there had been no landings of sandeel caught in the UK EEZ by Danish and foreign fishermen in Denmark. For each year, it is assumed that production is reduced with the value of sandeel caught in the UK EEZ's share of

the total landings value of fish for reduction. It is further assumed that all variable costs are reduced with that share. Finally, fixed costs are assumed to remain unchanged.

Data on landings of sandeel in Denmark originating in the UK EEZ are available when caught by Danish and Swedish (SW) fishermen. However, data on the allocation of sandeel caught by foreign fishermen (except Swedish) and landed in Denmark are not available. It is, however, known that landings of sandeel by foreign, non-Swedish fishermen in Denmark are all caught in the EU EEZ, except for minor amounts landed by Norwegian fishermen in Denmark. The amount of sandeel caught by foreign, non-Swedish fishermen in the UK EEZ is calculated, assuming that the share of total landings originating in the UK EEZ is the same as for Danish fishermen.

The landings in Denmark of sandeel from the EU and UK EEZs appear in Table 12, while the corresponding landing values appear in Table 13.

Table 12. *Landings of sandeel by Danish (DEN), Swedish (SW) and other (OTH) fishermen in Denmark, allocated to catches in the UK EEZ and EU EEZ (1,000 tonnes), 2011-2023*

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
UK EEZ, DEN	230	35	131	44	132	18	220	121	46	76	53	5	60
UK EEZ, SW	31	4	20	5	13	1	23	12	7	14	13	2	14
UK EEZ, OTH[1]	19	1	8	8	17	4	11	8	7	20	11	0	2
UK EEZ, all	280	40	159	57	162	23	254	141	60	110	77	7	76
EU EEZ, DEN	40	18	77	105	40	11	134	56	48	93	17	69	59
EU EEZ, SW	1	0	8	14	20	2	18	4	5	10	2	10	11
EU EEZ, OTH[1]	3	1	4	18	5	3	6	3	8	24	4	0	1
EU EEZ, all	44	19	89	137	65	16	158	63	61	127	23	79	71
Total, DEN	270	53	207	148	172	29	354	177	93	169	70	73	118
Total, SW	32	4	28	19	34	4	41	17	12	24	15	12	25
Total, OTH	22	2	12	26	22	7	17	11	15	44	15	0	3
Total, all	324	59	247	193	228	40	412	205	120	237	100	85	146

Note: [1]: The allocation of the landings in Denmark by foreign non-Swedish vessels is estimated. It is assumed that the catches of sandeel in the UK EEZ's share of the total catches of sandeel landed in Denmark is the same as for the Danish vessels.
Source: Data for Danish and foreign fishermen (excluding Swedish fishermen) are from data from the Danish Fisheries Agency's logbook, sales note and VMS registers combined by DTU Aqua and furthermore coupled with data from the Danish Fisheries Agency's vessel register. Data for Swedish fishermen have been obtained by directing a special request to the Swedish Agency for Marine and Water Management.

Table 13. *Landings values of sandeel by Danish (DEN), Swedish (SWE) and other (OTH) fishermen in Denmark, allocated to catches in the UK EEZ and the EU EEZ (million DKK), 2011-2023*

	2011	2012[1]	2013[1]	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
UK EEZ, DEN	374	65	289	62	212	39	239	203	87	158	150	10	138
UK EEZ, SW	50	5	43	7	18	2	26	20	12	28	34	4	32
UK EEZ, OTH	30	2	17	12	29	10	12	12	15	51	25	0	5
UK EEZ, total	454	72	349	81	259	51	277	235	114	237	209	14	175
EU EEZ, DEN	65	35	164	149	64	22	157	96	95	185	41	135	134
EU EEZ, SW	13	1	26	24	38	6	34	15	16	43	17	26	56
EU EEZ, OTH	5	1	9	29	9	6	8	6	17	60	7	0	4
EU EEZ, total	83	37	199	202	111	34	199	117	128	288	65	161	194
Total, DEN	439	100	453	211	276	61	396	299	182	343	192	144	272
Total, SW	63	6	69	30	56	8	61	35	28	71	51	31	88
Total, OTH	36	4	26	41	38	16	20	18	32	111	32	0	9
Total, all	538	110	548	282	370	85	477	352	242	525	275	175	369

Notes: [1]: For 2011-2012, landings values are not known for foreign, non-Swedish vessels. Therefore, they are estimated assuming the same price as for Danish fishermen.
Source: Data for Danish and foreign fishermen (excluding Swedish fishermen) are from data from the Danish Fisheries Agency's logbook, sales note and VMS registers combined by DTU Aqua and furthermore coupled with data from the Danish Fisheries Agency's vessel register. Data for Swedish fishermen were obtained by directing from a special request to the Swedish Agency for Marine and Water Management.

Landings of sandeel in Denmark fluctuated over time, from a low of 40,000 tonnes in 2016 to ten times as much in 2017, 412,000 tonnes. Landings of sandeel in Denmark originating from the UK EEZ also varied from 7,000 tonnes in 2022 to 280,000 tonnes in 2011. The landings value also varied from a low of 85 million DKK (11.4 million euros) in 2016 to a high of 538 million DKK (72.1 million euros) in 2013.

Table 12 and 13 indicate that Danish fishmeal and fish oil factories would have been able to purchase less fish for reduction if they had not been able to source sandeel from the UK EEZ. The landings value of sandeel from the UK EEZ's share of the total landings value of fish for reduction in Denmark measures the importance of sandeel from the UK EEZ for the production in Danish fishmeal and fish oil factories. The share is shown in Table 14.

Table 14. *Effect of a ban on sandeel fishing in the UK EEZ on the raw material supply of fish for reduction and raw material costs (1,000 tonnes), 2011-2023*

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Sandeel, UK EEZ	454	72	349	81	259	51	277	235	114	237	209	14	175
Fish for reduction	1,078	675	1,175	1,038	1,524	1,264	1,145	1,455	1,285	1,459	1,054	957	1,649
Share (%)	42.1	10.7	29.7	7.8	17.0	4.0	24.2	16.2	8.9	16.2	19.8	1.5	10.6

Source: The author's own calculations.

The landings value of sandeel from the UK EEZ's share of the total landings value of fish for reduction was 19 per cent on average, varying from 1.5 per cent in 2022 to 42.1 per cent in 2011.

Danish fishmeal and fish oil factories are affected by the closure of the UK EEZ for sandeel fishing in the sense that they have reduced access to raw materials. The effect is calculated assuming that: (i) the fishmeal and fish oil factories must reduce their activity by the landings value of sandeel from the UK EEZ's share of the total landings value of fish for reduction, (ii) the turnover is reduced with that share, (iii) the variable costs

are reduced with that share and (iv) fixed costs are constant. Under these assumptions, the turnover, earning capability and gross profit are calculated, all other things equal, without access to sandeel from the UK EEZ. In Table 15, the new turnover, earning capability and gross profit are calculated for the period 2011-2021. Reductions in these numbers are also shown.

Table 15. *Economics of Danish fishmeal and fish oil factories without sandeel from the UK EEZ, absolute numbers and losses (million DKK), 2011-2021*

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Absolute numbers											
- Turnover	1,463	2,990	2,730	3,230	3,924	4,579	2,927	3,209	3,435	2,809	2,276
- Earning capability	61	69	2	307	390	271	346	373	140	65	3
- Gross profit	-33	-58	-116	152	234	74	170	171	-74	-116	-139
Reduction											
- Turnover	1,064	358	1,153	273	804	191	934	620	336	543	562
- Earning capability	183	86	59	43	103	21	225	143	45	71	76
- Gross profit	114	71	9	29	71	13	169	103	24	36	41

Source: The author's own calculations.

Without access to sandeel from the UK EEZ, the turnover would all other things equal have been between 1.5 billion DKK and 4.6 billion DKK (2011 and 2016, respectively 196 million euros and 614 million euros), corresponding to a reduction in turnover of 191 million DKK and 1,153 million DKK (2016 and 2013, respectively 25.6 million euros and 154.6 million euros). On average, the annual reduction is 622 million DKK (83.4 million euros). Moreover, without access to sandeel from the UK EZZ, the earning capability would have been between 2 million DKK and 390 million DKK (2013 and 2015, respectively 0.3 million euros and 52.3 million euros), corresponding to an annual reduction in earning capability of between 21 million DKK and 225 million DKK (2016 and 2017, respectively 2.8 million euros and 30.2 million euros). On average, the annual reduction is 96 million DKK (12.9 million euros). Finally, without access to sandeel from the UK EEZ, the gross profit would have been between a deficit of 139 million DKK (18.6 million euros) and a surplus of 234 million DKK (31.4 million euros) with deficits in 6 of the 11 years. This corresponds to an annual reduction in gross profit of between 9 million DKK and 169 million DKK (2013 and 2017, respectively 1.2 million euros and 22.7 million euros), corresponding to average of 62 million DKK annually (8.3 million euros).

The annual loss of gross profit for Danish fishmeal and fish oil factories, which on average is 62 million DKK (varying between 9 million DKK and 169 million DKK), is identified assuming that it is not possible for the vessels to catch more sandeel outside the UK EEZ. If the vessels can catch sandeel outside the UK EEZ, the losses are overestimated. Moreover, in the calculations, it has been assumed that fish for reduction is the only source of raw material for Danish fishmeal and fish oil factories. It is known that minor quantities of cutoffs from factories that produce fish for human consumption are also applied as raw material. If it is possible to increase the quantities of cutoffs, this can offset some of the economic losses, but this will on the other hand require increased landings of fish for human consumption.

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