Summary review of the evidence presented by respondents to the consultation to prohibit industrial fishing in UK waters.

Natural England, Cefas, and JNCC have reviewed the responses to the sandeel consultation which provided evidence-based arguments that challenged Defra's proposal for full prohibition of industrial sandeel fishing in English waters. The arguments put forward by respondents tend to focus on (1) issues with the expectation that benefits may arise, (2) what may be seen as a move away from ICES advice for North Sea sandeel fisheries, and (3) the proportionality of a full prohibition. Both the scientific report prepared by Defra Arms Length Bodies[1] (hereafter referred to as ALB science report) and the challenges put forward by respondents draw from a common evidence pool. Therefore, consensus is generally found between the ALB science report and consultation respondents regarding the effects of environmental variation on sandeel production and the varied impacts of changing sandeel biomass on predator production. Although scientific literature drawn on is largely similar, the manner in which the evidence is used differs. The ALB report attempts to quantify the potential impacts of a sandeel fishery closure whereas the respondents draw on the complexity and contrast within the available scientific literature to highlight the uncertainty in potential impacts (including a wider range of literature than the ALB report uses).

The following sections provide a brief review of the evidence brought forward by consultation respondents.

Consultation response comments on the links between sandeels and environmental variation

- Multiple consultation responses referenced discourse in the literature regarding environmental impacts on sandeel production and the heterogeneity of predator responses to changes in sandeel abundance.
    - The impact of environmental variation on sandeel recruitment and survival is well studied. The section of the ALB science report "*Influence of environmental variation and risk to realising potential benefits*" provides a brief review of the existing literature on this topic. Environmental links include the impacts of bottom temperature on sandeel abundance, the impact of high spring temperatures on sandeel emergence, and how this can lead to mismatch between the development time of sandeels and when key copepod prey is available. Some respondents highlighted additional links, including the influence of ocean currents noting that some sandeel-environment links

[1] Scientific report delivered by Natural England, Cefas, and JNCC for publication alongside Defra's consultation on the prohibition of industrial fishing in English waters of the North Sea: What are the ecosystem risks and benefits of full prohibition of industrial Sandeel fishing in the UK waters of the North Sea (ICES Area IV)?

which were reported for the North Sea, have not been consistently observed across sub-populations.

The influence of environmental variability on sandeel survival and recruitment means that, even under any prohibition of industrial fisheries, sandeel biomass will still fluctuate and potentially decline following periods of adverse environmental conditions.

Consultation response comments on the link between sandeels and seabirds

- The ALB science report concludes that seabirds would benefit most from the closure of sandeel fisheries. Consultation respondents have argued that this may only hold true for kittiwakes.
    - The ALB science report comments that the bulk of the available evidence suggests that kittiwakes are the key species for which there is substantial concern regarding sandeel fishing effort. In a paper published since the release of the consultation, Searl et al. (2023) found that fishing effort was associated with reduced kittiwake breeding success and a lower proportion of age-0 sandeel in their diets, despite the fishery targeting age 1+. The same study found no evidence to suggest the fishery closure has, to date, been effective in safeguarding the breeding success of guillemot, razorbill or puffin. However, it was suggested that this may be due to the impacts of climate and prey availability on sandeel populations, and that such shifts in sandeel phenology, alongside declines in sandeel abundance and quality, may have masked any potential closure-related benefits to breeding success in these three auk species. This aligns with the core advice of the ALB science report which highlighted that adverse environmental conditions could dampen potential ecosystem benefits.
- Respondents commented that there is no direct competition between kittiwakes and the sandeel fishery as kittiwakes target the age 0 group while fisheries harvest the age 1+ group.
    - This is not entirely correct, as breeding adult kittiwakes eat sandeels aged one year or older during April and May and then switch to the younger age class in June and July, as juvenile sandeels become available (Harris & Wanless 1997; Lewis et al., 2001). As fisheries target 1+ group sandeels, they can directly compete with breeding kittiwakes in the months of March to July. The timing of the fishery relative to the timing of the switch in breeding kittiwake diet from 1+ group to 0 group sandeels can therefore be crucial in determining impacts on both kittiwake breeding success and adult overwinter survival in the current year. Effects in subsequent years are also likely to accrue through the overall reduction in the abundance of older sandeels. If fishing reduces the spawning stock to the point where egg production limits the numbers of 0-group fish, recruitment of 0-group sandeels may be reduced in subsequent years, explaining therefore the two-year lag effect observed in Flamborough and Filey Coast SPA (Carroll et al., 2017).

- One respondent commented that the factors effecting the breeding success of kittiwake may be linked to the impacts of environmental change on sandeel emergence or other temperature related effects.
    - Environmental and fishery effects can interact in a complex manner, so that individual effects can be difficult to tease apart. Some studies found support for additive effects of climate change (through increases in sea surface temperature and advancement of timing of the spring bloom) and the presence of active sandeel fisheries on kittiwake breeding success (Frederiksen et al., 2004; Scott et al., 2006) and adult survival (Frederiksen et al., 2004). It is therefore possible that in some circumstances both effects interact, such that when environmental conditions are poor, fisheries could exacerbate a difficult situation for seabirds by further reducing the biomass of available 1+ group fish (Rindorf et al., 2000). In the example provided in the statement above (Searle et al., 2023), the fact that kittiwake breeding success did not increase to pre-fishery levels may indicate indeed that other factors are at play, one of them being the indirect effect of climate change on prey availability.
- One respondent suggests that the current ICES advice falls in line with the suggestion that management leave a 'third for the birds', which is based on the evidence delivered by Cury et al. (2010).
    - The argument being put forward by the respondent is that the current level of the ICES $B_{escapement}$ reference point used in the management of sandeel fisheries in SA1r is only just below (27%) the recommended "thirds for the birds" rule of thumb. On that basis, the maximum spawning stock biomass in SA1r is given as 527,551t in 1998 and so 27% of that is 142,439t which is still a shortfall of >30K t compared to the "thirds for the birds" assumption. Currently, in SA4, the value (43%) is above the "third for the birds" rule.
    - However, it is important to state that the maximum spawning stock biomass is based on a reference baseline set for the years following the "regime shift" in the North Sea in 1994. Regime shifts are driven by abrupt changes in plankton communities that drive wider ecosystem change (including maximum sustainable biomass of prey fish species). Prior to 1994, the maximum recorded spawning stock biomass in SA1r was just below 1,000,000t, so, although the current maximum sustainable biomass for sandeel may be appropriate to underpin current $B_{escapement}$ threshold values, it highlights the susceptibility of such thresholds to variable and often unpredictable ecosystem-wide pressures. Adopting a more precautionary approach to management could provide greater ecological resilience in the face of such variability.

- Finally, one respondent has commented that the responses of eastern English kittiwake colonies are not consistently related to each other, indicating that they are not reacting to a common factor such as sandeel abundance in area SA1r.
    - The fact that inter-annual variation in breeding success (e.g., high chick survival in year one vs. low chick survival in year two) is not synchronised between colonies from the same region does not necessarily mean that these colonies are not responding to the same pressures. For example, low sandeel availability could be a main factor driving low breeding success across colonies from the same region while other ecological and/or environmental factors could exacerbate the negative effect of food depletion in some localised areas (e.g., nest predation, adverse weather conditions). It is therefore important to consider both additive and cumulative effects of various pressures, operating at different spatial scales.

Consultation response comment on the use of ecosystem models

- One respondent raised concerns with the application of the ecosystem models. They suggested that, in mass balanced models, a change in the production of prey produces a like-for-like response in the production of predators.
    - The mass balanced model (Ecopath with Ecosim) does not simulate like-for-like increases in production/biomass between predators and prey. Changes in primary production or prey biomass lead to differential increases (and decreases) throughout the simulated food web. It is often the case that simulations estimate greater percentage increases in predators relative to prey production. However, this response can be greatly reduced or eliminated through the inclusion of carrying capacity (which is the standard, not exception, when calibrating Ecopath with Ecosim models) or by representing species as multiple age groups (e.g., juveniles and adults). In this case, there is an is an emergent stock-recruitment relationship that limits abundance of juveniles which in turn can limit adult biomass responses. Juvenile limitation, despite overall increase in production of the prey of the juveniles, can occur due to foraging area limitations on access by the juveniles to their food resource (spatially/temporally restricted foraging by the juveniles).
- Concerns were also raised over the use of constant fishing mortality as a management strategy.
    - Fishing mortality was held constant in model simulations, not as a management strategy, but as a commonly employed modelling mechanism/baseline to reach ecosystem equilibrium under alternate pressure states. The objective was not to implement Management Strategy Evaluation, rather to simulate an ecosystem under alternate levels of sandeel depletion to quantify the response of ecosystem components and thus determine the relative importance of sandeels for ecosystem function and structure.

- It is noted in the ALB science report that "*while fishing mortality was used to drive the depletion of sandeels in the model simulations, outputs have been presented in a way that they could also be viewed more generally as "what might happen if the sandeel stock declines". Sandeel depletion could occur in response to multiple drivers of mortality, such as climate change or changes in food availability".*

- Finally, one respondent raised the point that studies of harbour porpoise in the southern North Sea have shown that sandeels are a less prominent feature of their diets. The respondent has suggested that the model estimate for sandeel consumption by toothed whales has therefore been overestimated.

    - The version of the North Sea Ecopath with Ecosim model used to produce ecosystem simulations was the ICES 'key run'[2]. While the model was extended to the year 2020, the base parameters were not altered to keep in alignment with the model reviewed by the ICES Working Group on Multispecies Assessment Methods (WGSAM). In this version of the model, toothed whale diet was informed by evidence collected in Scottish waters by Santos et al. (1994, 1995, and 2004). In the 2004 study it is estimated that sandeels make up 25% of the overall weighted diet of harbour porpoises. It is likely that this estimate exceeds what is commonly observed in the southern North Sea. This uncertainty is accounted for using Monte Carlo simulations: diet parameters, as well as vital rates, are assigned confidence intervals based on data uncertainty. Model permutations are created where the base parameters are resampled within the plausible parameter space to provide a range of model simulations. Mammal diets are assigned large confidence intervals (i.e., assuming low confidence) during this procedure due to their origin and variability in literature.

Consultation response comment on the inclusion of predators in the ICES stock assessment

- Multiple respondents argued that the current ICES stock assessments for sandeels already sufficiently prioritise predator needs.

    - The ICES stock assessments for sandeels in the North Sea provides advice that prioritises the status of the sandeel stocks and aims to maintain sandeel biomass at a level that enables successful recruitment ($B_{escapement}$). Predator needs (expressed as rates of consumption of sandeels and derived from multispecies assessment) are incorporated into the SMS (stochastic multi-species) model used for stock assessment. These rates, along with fishing pressure are used to estimate historic sandeel stock dynamics. Note that the assumption in the multispecies model is that

[2] An ICES 'key run' refers to a model parameterisation and output which is accepted as a standard by the ICES Working Group on Multispecies Assessment Methods (WGSAM). Such 'key run' models thus serve as a quality assured reference for scientific input to ICES advice products: ICES, 2015. Report of the Working Group on Multispecies Assessment Methods (WGSAM). International Council for the Exploration of the Sea, Woods Hole, USA.

predators will, somehow, always get enough food and that an absence of sandeel would be met by finding other food sources rather than starving/failing to breed.

- The needs of predators may be indirectly met through this approach if sandeel biomass remains at levels capable for successful recruitment and that the biomass of all other alternative prey species is also at the required level. However, this approach is not the same as an approach which *directly prioritises the needs of predators* by building in an understanding of the status of predators or how alternate catch options may impact predator production. Such an approach has recently been adopted for the management of Atlantic menhaden (an important forage fish on the U.S. East Coast), where a trade-off is established between menhaden harvest and the predicted biomass of striped bass (a key predator). Acknowledging the trade-offs between prey harvest and predator needs represents a shift toward ecosystem-based fisheries management.

Consultation response on the proportionality of a full closure

- Some respondents commented that a full prohibition would be 'disproportionate' and 'discriminatory'.
    - As stated in the ALB science report and re-iterated by some consultation respondents, sandeel stocks experience high levels of natural fluctuation due to their short lifecycle and the influence of fluctuating environmental variables on sandeel recruitment and production. Although there is evidence to indicate that a full prohibition of sandeel fishing from UK waters has the potential to benefit dependent predators and provide greater ecosystem resilience, it is also the case that environmental variability could offset or reduce some of the expected benefits. Due to the high levels of natural variation in stock size and the complexity in patterns of predator dependence, there will be substantial uncertainty in forecast outcomes from new management actions. Ultimately any decision on the trade-offs between fisheries and biodiversity objectives, and what is therefore considered to be proportional, is likely to be driven by appetite for risk and prioritisation of different marine policy objectives.
- Finally, one respondent raises concerns that the DEFRA consultation document does not consider other options such as a partial closure of industrial sandeel fishing in English waters of the North Sea.
    - The consultation states, "*partial closures of the same waters proposed in the consultation are assumed to have similar but smaller impacts*". The ALB science report suggests similar outcomes, with simulated impacts (be it positive or negative biomass responses) generally increasing as sandeel depletion is reduced. However, as noted by the respondents and caveated in the ALB science report, the model operates at the level of the North Sea and does not simulate specific site attachment. Benefits of the fishery closure may therefore be disproportionately greater in areas

with greater predator dependence or forage overlap. The ALB science report also acknowledges the risk that partial closures may lead to displacement of sandeel fishing within UK waters, and therefore negate any sought-after wider ecosystem benefits. For example, closure of the UK part of the Dogger Bank SAC still leaves areas open to fishing effort, particularly those closer to the Yorkshire seabird colonies. This may lead to higher localised fishing intensity as the current ICES advice does not take closed areas into consideration when estimating total allowable catch. In addition, there is high inter-annual variation in the offshore foraging dispersion of kittiwakes from the Flamborough and Filey Coast SPA, encompassing areas outside of Dogger Bank, which suggests that a more extensive closure would have higher chances of success when prioritising the need for seabird recovery.

Future monitoring

- Respondents raised concerns over the cessation of sandeel monitoring that would occur if the fishery was closed.
    - Monitoring of the sandeel stock in the event of a closure of English (or UK) grounds to sandeel fishing would need to be reconsidered.
    - There would be no need to undertake assessments for the purpose of forecasting potential catch in SA4 so a full age-based assessment may not be required although this may have knock-on implications for current multispecies/ecosystem modelling frameworks within ICES.
    - For SA1r the situation is more complex because only the UK side of the stock area would be closed to fishing, but stock status across the whole stock may still be desired for determining fishing opportunities in the remaining areas. In this case, information on the abundance and size/age structure might be sought from the UK side and the mechanisms for generating such information would need to be considered.
    - Therefore, the approach, precision, and frequency of assessment of sandeel stocks required for ecosystem monitoring and any remaining fisheries will require further consideration depending on the UK governments response to the consultation.