Department
for Environment,
Food & Rural Affairs

Evidence update: North Sea sandeels

Evidence report

April 2025

Natural England, Cefas, JNCC

We are responsible for improving and protecting the environment. We aim to grow a green economy and sustain thriving rural communities. We also support our world-leading food, farming and fishing industries.

Defra is a ministerial department, supported by 34 agencies and public bodies.

© Crown copyright 2025

This information is licensed under the Open Government Licence v3.0. To view this licence, visit www.nationalarchives.gov.uk/doc/open-government-licence/

Where we have identified any third party copyright information you will need to obtain permission from the copyright holders concerned.

This publication is available at www.gov.uk/defra

Contents

Executive summary

In 2023, Defra launched a public consultation on spatial management measures for industrial sandeel (*Ammodytes spp.*) fishing in UK waters of the North Sea. The consultation was informed by a scientific report, written by Natural England, Cefas, and JNCC, which was published and made available to the public alongside the consultation. Since 2023, additional evidence has been published which builds upon the evidence included in the 2023 report.

This evidence update reviews and summarises additional scientific evidence and management advice published following the commission of Natural England/Cefas/JNCC report. New studies support previous findings on the ecological importance of sandeels, particularly their role as prey for seabirds, marine mammals, and fish. New studies also draw attention to the increasing vulnerability of sandeels to pressures such as fishing and environmental change.

Updates to International Council for the Exploration of the Sea (ICES) stock assessments have reduced assessment uncertainty in recent years, though low recruitment and continued environmental variability remain key challenges. For 2025, ICES advises cautious catch limits or zero catch across multiple sandeel management unit areas, driven by low biomass and recruitment indicators. In addition, the 2024 closure of UK waters of the North Sea to sandeel fishing led to changes in fishing distribution and catch-at-age composition, with a high proportion of age-0 fish caught. To account for these changes and data impacts, the ICES assessment model was modified to include changes in selectivity pattern and declining catch per fishing day. While improving the overall model fit, abrupt changes in fishing distribution led to higher uncertainty in estimated fishing mortality in 2023 and 2024 compared to previous years.

Key messages:

- New evidence further confirms our understanding of sandeels' central role in North Sea food webs and their importance to predator species.
- New studies link breeding success in seabirds, including black-legged kittiwake (*Rissa tridactyla*) and Atlantic puffin (*Fratercula arctica*), to sandeel abundance, timing, and availability.
- Modelling studies indicate that sandeel size has declined, particularly in the western North Sea, with projected risks heightened under ongoing environmental change scenarios.
- A recent ICES benchmark (2021-2023) improved the robustness of stock assessments, but uncertainty persists around stock boundaries, age-0 dynamics, and recruitment variability.
- For 2025, ICES advise reduced catches or zero catch for all North Sea stocks, citing poor recent recruitment and limited short-term recovery prospects.

1. Introduction

This report provides an updated review of the best available scientific evidence relevant to the ecosystem role, status, and management of sandeels (*Ammodytes spp.*) in the North Sea. It is intended to provide a resource to inform decision makers when considering the prohibition of industrial sandeel fishing in English waters of the North Sea. The report builds upon the previous Natural England/Cefas/JNCC evidence review[1] (published in March 2023 to accompany the Defra public consultation for sandeel closure) by incorporating new literature, recent ICES stock assessments and advice, and updates from other management processes. In March 2023, Defra launched a consultation on spatial management measures for industrial sandeel fishing. Following the English consultation to prohibit sandeel fishing in English waters of the North Sea, Scotland pursued a similar measure for the prohibition of sandeel fishing in all Scottish waters. As with the English consultation, the Scottish consultation was accompanied by evidence to inform the management decision[2]. Both the English and Scottish reports highlight the important ecosystem role of sandeels. The Scottish report, published later, included new scientific evidence not available at the time of the English report. This follow-up report now considers that additional evidence.

The aim of this report is to determine if there are any updates to the evidence base in relation to the findings of the 2023 Natural England/Cefas/JNCC evidence review, which highlighted the ecological importance of sandeels in the North Sea food web, the impacts of environmental change on their productivity, and the potential environmental implications of changes in their availability, particularly for predator species such as seabirds, marine mammals, and commercially important fish. The report is structured as follows:

- **Section 2** summarises new literature published since the 2023 consultation, which generally focuses on predator-prey interactions, ecosystem function, and the vulnerability of sandeels to environmental change.
- **Section 3** summarises new outputs from the International Council for the Exploration of the Sea (ICES), including updates from a sandeel benchmark workshop and annual catch advice for 2022 to 2025.
- **Section 4** outlines recent advice from the Norwegian Institute of Marine Research on sandeel stocks in the Norwegian Exclusive Economic Zone.

[1] The 2023 Natural England/Cefas/JNCC science report can be found here: https://www.gov.uk/government/publications/evidence-report-on-the-ecosystem-impacts-from-industrial-sandeel-fishing

[2] The full Scottish review of scientific evidence can be found here: https://www.gov.scot/publications/sandeel-consultation-review-scientific-evidence/

Together, these sections provide an integrated overview of new evidence to inform decisions regarding the prohibition of sandeel fishing in English waters of the North Sea.

2. Updates from published literature

2.1. Evidence review

An evidence review was conducted to identify and synthesise recent scientific studies published since the 2023 Natural England/Cefas/JNCC report on sandeel fishing and ecosystem impacts. The review addressed the question of how sandeels function ecologically in the North Sea, examining peer-reviewed articles and grey literature on their role in the ecosystem, key predators, environmental drivers of change, and the implications for management.

2.1.1. Methodology

We used Google Scholar for the evidence review due to its broad coverage, accessibility, and ability to capture grey literature and diverse sources. While it has limitations compared to subscription databases (e.g., coverage and recall; Gusenbauer & Haddaway, 2020), its performance is broadly comparable to other search systems, supporting its use as an acceptable platform for evidence reviews (Martín-Martín et al., 2018; Haddaway et al., 2015; Gehanno et al., 2013).The search was performed in April 2025, and was limited to publications published between January 1st 2022 and April 10th 2025. In total, 27 new papers were identified to be included in the review of updated evidence.

2.2. Literature summary

Since the 2023 Natural England/Cefas/JNCC scientific report on the ecosystem risks and benefits of a full prohibition of industrial sandeel fishing in UK waters, a growing body of research has reinforced and expanded our understanding of the importance of sandeel to the ecosystem. Evidence continues to support the report's conclusion that sandeels are a vital forage species linking lower and higher trophic levels, and that predator groups, particularly seabirds and marine mammals, stand to benefit most from an increased availability of sandeels. The literature also provides evidence of the impacts of environmental stressors, changes to sandeel prey, and subsequent impacts to sandeel ecology and dynamics. The studies identified in the evidence review are summarised below and further detailed in **Table 1**.

2.2.1. Seabirds

Multiple studies have reinforced the link between sandeel availability and seabird breeding outcomes. Searle et al. (2023) and Régnier et al. (2024) both found that higher abundance and seasonal availability of 0-group sandeels (sandeels at age 0) were strongly associated with improved breeding success in species such as kittiwakes, puffins, and common guillemots (*Uria Aalge*). These studies also indicated that increased fishing pressure reduced the proportion of sandeels in chick diets, while fishery closures could yield positive demographic responses. However, benefits may be masked by the impacts of poor environmental conditions on sandeels.

Harris et al. (2022) and Wanless et al. (2023) provided long-term perspectives, showing that sandeels were the dominant chick prey in the 1980s but declined sharply in dietary importance over time, largely due to earlier seasonal burrowing and reduced body size and quality. These changes have lowered energy transfer per feed, especially for species such as guillemots that deliver prey singly. Dunn et al. (2022) extended this understanding year-round, finding that areas of high guillemot foraging success aligned with key sandeel habitats even outside the breeding season. Fijn et al. (2022) showed a similar habitat link for Sandwich terns (*Thalasseus sandvicensis*), which targeted coarse sediments and high-salinity areas associated with sandeel presence.

2.2.1. Marine mammals

New studies provide further detail on the dependence of marine mammals on sandeels. Ransijn (2023) identified sandeels as a preferred prey for grey seals (*Halichoerus grypus*) and harbour porpoises (*Phocoena phocoena*), due to their high energy content, predictable spatial distribution, and low mobility. Both species showed a Type III functional response to sandeel availability, which indicates active prey-switching behaviour. However, Ransijn (2023) found that marine mammal consumption in the southern North Sea (i.e., ICES division IVc) was small relative to fisheries removals where marine mammal consumption tended to be <20% of the reported fisheries removals for ICES division IVc.

Robinson et al. (2023) and MacDougall & Robinson (2025) further highlighted strong spatial links between minke whales (*Balaenoptera acutorostrata*) and sandeel-rich areas. Juvenile whales targeted age-0 sandeels in early summer, while adults fed on a broader age and size range before switching to alternative prey later in the season. Booth et al. (2023) found that sandeels, due to their high energy density, formed a significant component of marine mammal diets and called for improved macronutrient data to refine intake estimates.

2.2.1. Fish and other predators

New studies support the view that sandeels are a major dietary component for a variety of demersal and pelagic fish. Ludwig et al. (2024) identified them as dominant prey (>30% by weight) in multiple demersal predator–life stage combinations, including grey gurnard (*Eutrigla gurnardus*) and whiting (*Merlangius merlangus*). Hunt et al. (2022) found similarly high reliance among flatfish species such as dab (*Limanda limanda*) and plaice (*Pleuronectes platessa*), across both short- and long-term diet windows. According to their analysis, sandeel remained prevalent in the diet even in winter.

Sandeels also featured in the diets of several cephalopod species. Oesterwind & Piatkowski (2023) documented consistent consumption by long finned squid (*Loligo forbesii*) and the European flying squid (*Todarodes sagittatus*), particularly in winter, with larger cephalopods feeding on older sandeels. These findings underscore sandeels' wide ecological reach across multiple predator groups and seasons.

2.2.1. Environmental drivers

New studies link changes in sandeel body size, condition, and availability to deteriorating environmental conditions. Olin et al. (2025) used a dynamic energy budget model to show that declining zooplankton availability, particularly in the western North Sea, has contributed to sandeel size declines, with implications for maturation and fecundity. These effects were largely driven by long-term declines in small copepods and phenological shifts, rather than temperature alone.

Utne et al. (2022) found that sandeel larvae virtually disappeared from post-smolt salmon (*Salmo salar*) diets after 2004, likely due to prey limitation linked to changing water mass characteristics and plankton communities. Di Pane et al. (2024) and Deschamps et al. (2024) both documented significant changes in mesozooplankton structure over recent decades, coinciding with forage fish recruitment failures. These shifts included declines in lipid-rich copepods and later seasonal peaks, reducing prey quality and availability during key larval sandeel feeding windows.

Olin et al. (2022) found that available prey energy for sandeels declined by up to 85% in the western North Sea between 1958 and 2018, driven by declines in small zooplankton. The timing of prey availability also became mismatched with sandeel feeding periods, particularly for 0-group fish. Henriksen et al. (2024) showed that sediment type and light conditions strongly influence sandeel burrowing preferences, with coarse sand and low light representing optimal habitat. While no links were made to potential impacts on wider stock resilience, this study highlights other variables which affect sandeels which Henriksen et al. (2024) note may better inform the management of sandeels and targeted conservation efforts.

2.2.1. Ecosystem structure

Recent modelling studies support the view of sandeels as structurally important in food webs. Fulton & Sainsbury (2024) introduced a “hub index” to quantify species' centrality in energy flow, identifying sandeels as a hub species in the North Sea. Pint et al. (2024) found, using an Ecopath with Ecosim model for the Southern Bight of the North Sea, that sandeels were ranked among the top five keystone species in the food web.

Trifonova et al. (2023) applied a Bayesian network approach to track ecological responses under climate and fishing scenarios, finding that changes in sandeel larvae abundance could influence broader food web dynamics through bottom-up forcing. Van Deurs et al. (2023) and Melià et al. (2024) explored recruitment-environment relationships and found mixed or weak links to spawner traits, but better predictive performance when incorporating environmental data. Allgayer et al. (2024) modelled sandeel spatial structure in sandeel area 4, showing that larval dispersal was highly uneven and that isolated patches were most vulnerable to depletion.

Table 1. Summary of evidence published since the sandeel consultation which is relevant to inform decision makers on the ecosystem role of sandeels and the potential impacts of the full prohibition of sandeels in English waters of the North Sea. Studies were identified via a review of available literature.

Author and Date	Theme	Evidence overview	Relevant evidence summary
Buyse et al (2022)	Sandeel dynamics	This study analysed 34 years of fish community data from the Belgian part of the North Sea to assess how demersal and benthopelagic fish assemblages have responded to climate variability. They identified three spatially distinct fish assemblages—mud, fine sand, and coarse sand—and used dynamic factor analysis to link community trends to sea surface temperature (SST), the Atlantic Multidecadal Oscillation (AMO), and the North Atlantic Oscillation (NAO).	**Buyse et al. (2022)** included both greater (*Hyperoplus lanceolatus*) and lesser sandeel (*Ammodytes tobianus*) in their analysis of fish community dynamics. Sandeels were mainly associated with the offshore coarse sand assemblage. The densities of lesser sandeels remained relatively stable until the mid-2000s but declined in the following decade. These trends were positively associated with NAO index values, suggesting that large-scale climatic conditions influenced sandeel presence. Notably, lesser sandeels showed a negative relationship with SST, AMO, and both NAO-related variables, which may reflect their sensitivity to warming and changes in water circulation.
Dunn et al (2022)	Predator needs: seabirds	This study developed a Bayesian state-space model using biologging data to estimate daily energy gain and body mass of common guillemots over a full annual cycle. It identified spatial and seasonal variation in energy balance, with higher energy gain in warmer, coastal waters and mass loss occurring at range edges, especially in late summer and early spring. The findings highlight periods and locations of potential energetic bottlenecks and offer a framework for assessing survival risk.	**Dunn et al. (2022)** found that key areas of high energy gain for common guillemots, especially along the coasts of eastern Scotland and northeast England, coincided with known sandeel habitats and a region where a commercial sandeel fishery had been closed to protect seabirds during breeding. This overlap suggested that sandeels were not only critical during the breeding season but also provided an important energy source for guillemots throughout the entire year. The spatial analysis revealed that these areas consistently supported high foraging success, underscoring the value of sandeel-rich zones as year-round foraging grounds.

Fijn et al (2022)	Predator needs: seabirds	This study used GPS tracking and Hidden Markov Models to examine how Sandwich terns adjusted their foraging behaviour during breeding in response to environmental conditions. It found that static factors, especially sediment grain size, were stronger predictors of foraging than dynamic ones like wave period or salinity. Foraging locations were not highly consistent across tidal, diurnal, or seasonal cycles, suggesting terns respond flexibly to prey availability.	**Fijn et al. (2022)** showed that sandeels were a key prey species for Sandwich terns, and their availability was inferred through habitat proxies. Sandwich terns were more likely to forage over coarse sediments, where sandeels are more abundant due to their burrowing behaviour. Higher salinity also increased the likelihood of foraging, aligning with known preferences and survival conditions for sandeels. Fijn et al. (2022) conclude that Sandwich terns rely on static habitat features, like sediment type and salinity, to locate sandeels during the breeding season, and that these static environmental variables may more strongly affect foraging behaviour of coastal seabirds than dynamic variables.
Harris et al (2022)	Predator needs: seabirds	This study analysed 38 years of chick diet data for common guillemots on the Isle of May, revealing strong within-season and long-term changes in prey composition. The proportion of sandeels in the diet declined markedly over time, with sprat becoming the dominant prey in recent decades. The paper emphasizes that sampling diet at only one point in the season can misrepresent annual trends.	**Harris et al (2022)** found that Sandeels were initially the dominant prey in guillemot chick diets during the 1980s, but their contribution declined sharply over the four decades of the study. Notably, sandeels became increasingly restricted to the early chick-rearing period, with very few observed in diets after mid-season from the 2000s onwards. This pattern is likely linked to the seasonal burying behaviour of age-1+ sandeels, which move into sediment and become less available to surface-feeding seabirds. The timing of this burying behaviour shifted earlier over time, potentially contributing to a growing mismatch between sandeel availability and guillemot chick-rearing.
Hunt et al (2022)	Predator needs: fish	This study used stomach content and stable isotope analyses to examine the trophic ecology of two flatfish species, common dab and European plaice, in four coastal bays along the Northumberland coast. It found that both species primarily fed on sandeels, bivalves, and brittle stars, with moderate to high spatial variability in diet composition.	**Hunt et al. (2022)** used stomach content and stable isotope analyses which identified sandeels as a dominant prey item for common dab and European Plaice across all study sites, especially in short-term diet analyses (upwards of 80% contribution in some areas). Stable isotope mixing models supported this, with sandeels contributing substantially to diets across most bays and time frames, especially in summer when sandeels were more accessible in dense benthic schools. Even in

			muscle tissue reflecting winter/spring diet, both species remained reliant on sandeels, suggesting seasonal availability did not fully deter their use.
Olin et al (2022)	Sandeel prey	This study used over 60 years of Continuous Plankton Recorder data to examine long-term changes in the zooplankton prey field of lesser sandeels across six areas of the northeast Atlantic. They analysed trends in total available energy, prey size, phenology, and key taxa abundances, particularly copepods. Results showed strong regional variation, with dramatic declines in prey energy and small copepods in the western North Sea, accompanied by shifts in seasonal prey availability and an increase in median prey size.	**Olin et al. (2022)** found that the quality of the zooplankton prey field available to lesser sandeels declined sharply in parts of the western North Sea, particularly on Dogger Bank and in the Firth of Forth. Available prey energy during the sandeel feeding season dropped by up to 85% between 1958 and 2018, driven mainly by a long-term decline in small copepods. The study also showed a mismatch emerging between peak prey availability and the seasonal feeding windows of sandeels, particularly for 0-group fish, which may reduce foraging success during early life stages. Increases in median prey size were observed, but this was linked to the loss of small prey rather than a rise in larger species. These shifts aligned with observed declines in sandeel size and recruitment noted in other studies, suggesting that food limitation, rather than direct temperature effects, may be a primary driver of reduced growth.
Utne et al (2022)	Predator needs: fish	This study examined how changes in the Northeast Atlantic ecosystem have influenced the diet and feeding conditions of Atlantic salmon post-smolts during their first months at sea. Using 25 years of stomach content data from over 2,500 salmon, the study identified key prey species, spatial diet patterns, and shifts in stomach fullness across time. The findings showed a sharp decline in fish larvae, especially sandeel and herring, in post-smolt diets after 2004, alongside reduced stomach fullness and condition factor. These declines were linked to changing oceanographic conditions, including reduced Arctic Water inflow, decreased zooplankton	**Utne et al. (2022)** found that sandeel larvae were a key prey for Atlantic salmon post-smolts in the late 1990s, particularly in regions west of Scotland and in the northern North Sea. Sandeel made up a significant part of the diet during the period 1995–2004 but became almost entirely absent from stomach contents in the years following 2004. This decline coincided with a sharp drop in regional sandeel landings and reflected the collapse of several sandeel populations in the area. The disappearance of sandeel larvae from post-smolt diets contributed to reduced feeding ratios and overall poorer salmon condition. Utne et al. (2022) linked these patterns to broader ecosystem changes, including altered water mass composition and a possible prey-switching dynamic with blue whiting larvae during certain years. However, sandeel loss remained a central factor in declining salmon feeding condition.

		abundance, and possible competition with expanding mackerel stocks.	
Berge (2023)	Sandeel dynamics	This thesis analysed growth, size, and condition of lesser sandeels in four management areas of the Norwegian North Sea. It used biological data from both commercial and scientific sources from 2007 to 2022. Sandeels in the southernmost area were consistently smaller. Differences in length increased with age, suggesting limited mixing between areas. Individual weight increased sharply during the fishing season.	**Berge (2023)** used length, weight, and condition data to assess sandeel growth across management areas and found that sandeel condition varied by area and age group but showed no consistent spatial pattern. Length differences between areas became more pronounced over time, suggesting limited mixing. Berge also found that older sandeels in some areas appeared to burrow earlier, leading to a drop in observed size late in the season. Weight increased two- to three-fold during the season, especially in younger age groups. He concluded that opening the fishery later would increase efficiency and reduce fishing mortality.
Booth et al (2023)	Predator needs: marine mammals	This paper reviewed current methods for estimating energy intake in marine mammals for use in bioenergetic models. It focused on the pathway from gross ingested energy to biologically useful net energy, outlining key processes such as prey acquisition, digestion, and associated energy losses. The authors highlighted that while foraging behaviour is relatively well studied, prey capture success rates and prey-specific energy losses remain poorly quantified for many species.	**Booth et al. (2023)** compiled energy density data for a wide range of marine mammal prey, including sandeels. They reported that sandeels had consistently high energy density values, making them a valuable prey type in terms of energy return. The study noted that energy density in fish, including sandeels, varied by season, body size, and other biological factors. This variation affects not only the energy gained by predators but also digestion rates and assimilation efficiency. Despite their importance in marine mammal diets, the authors pointed out that detailed macronutrient data for sandeels were still limited. They emphasised the need for better prey quality data.
Oesterwind and Piatkowski (2023)	Predator needs: other	This study explored stomach content analyses of twelve cephalopod species from the North Sea to assess their role as predators in the ecosystem. The study aimed to improve food web models by filling gaps in knowledge about cephalopod diets, especially as their biomass in the region increases. Results showed that many	**Oesterwind and Piatkowski (2023)** found that sandeels featured in the diets of several North Sea cephalopod species, particularly long-finned squid and the European flying squid. Long-finned squid consumed sandeels in both summer and winter, with larger individuals feeding more frequently on fish, including sandeels up to 160 mm in length. The European flying squid also consumed sandeels in winter samples, alongside other fish such as herring (*Clupea harengus*) and *Trisopterus*

		cephalopods, particularly larger squids like long-finned squid, fed heavily on fish, including commercially important species.	*spp*. These findings suggest that sandeels are an important prey item for mid-to-large cephalopods.
Ransijn (2023)	Predator needs: mammals	This thesis investigated Multi-Species Functional Responses (MSFR) of key marine mammal predators in the North Sea, focusing on their prey preferences and energy intake. Using Bayesian models, the thesis found that all studied predators (harbour porpoise, grey seal, and harbour seal (*Phoca vitulina*)) exhibited prey switching when prey was at low abundance, with sandeels strongly preferred by porpoise and grey seals due to their energy richness and predictable distribution. Harbour seals showed more varied diets and a greater tendency to switch prey.	**Ransijn (2023)** presented several new findings on sandeels in the context of predator-prey interactions in the North Sea. Sandeels emerged as a critical, energy-rich prey species for marine mammals, especially grey seals and harbour porpoise, due to their high calorific value, patchy but predictable distribution, and relatively low mobility, which likely makes them easier to catch. Spatial modelling revealed that the distribution of sandeels significantly influenced the availability of energetic prey for porpoise, with high energy densities concentrated in specific areas of the North Sea. Bayesian multi-species functional response (MSFR) models showed that grey seals and harbour porpoise exhibited strong preference for sandeels, displaying a Type III functional response, indicative of prey switching at low prey densities. Harbour seals, in contrast, had more diverse diets and showed a more generalist response. The study also found that while marine mammal predation on sandeels is ecologically relevant, it is relatively small compared to fisheries removals, where marine mammal consumption tended to be <20% of the reported fisheries removals.
Robinson et al (2023)	Predator needs: marine mammals	This study examined the spatial distribution and feeding behaviour of adult and juvenile minke whales in the Moray Firth, northeast Scotland, using data from over two decades of dedicated boat surveys. Juveniles were most often found in shallow, inshore waters with gentle slopes and sandy gravel sediments, while adults occurred further offshore in deeper waters and steeper habitats. Adults used a variety of active feeding methods and showed individual foraging	**Robinson et al. (2023)** found that sandeels were a key prey item for both adult and juvenile minke whales throughout the feeding season. Juveniles primarily targeted young sandeels (0–1 year, 86–118 mm), relying on passive feeding nearshore. Adults consumed a broader age (0-3) and size range of sandeels (up to 163 mm), along with juvenile herring and sprat, and shifted prey seasonally. Sandeel-rich sandy gravel sediments closely matched juvenile whale distributions, suggesting strong habitat-prey links. The study also noted an inshore shift in whale presence following the 2006 sandeel fishery closure, with visible increases in feeding activity and whale numbers

		specialisations, whereas juveniles fed almost exclusively using passive, low-energy strategies.	
Searle et al. (2023)	Predator needs: seabirds	This paper used 25 years of data from the north-western North Sea to evaluate the effects of a commercial sandeel fishery closure on the breeding success of four seabird species. It finds evidence that the closure benefited black-legged kittiwake populations, while impacts on other species were limited or unclear, highlighting the species-specific nature of responses to forage fish fisheries and the complexities of disentangling conservation outcomes from the impacts environmental change.	**Searle et al. (2023)** examined the effects of a sandeel fishery closure in the northwestern North Sea on the diet and breeding success of seabirds, specifically kittiwake, guillemot, puffin, and razorbill (*Alca torda*), over 25 years, using long-term data from multiple colonies. The study found that higher sandeel abundance, especially juvenile (0-group) sandeels, was consistently associated with improved breeding success, and that increased fishing effort reduced the proportion of sandeels in seabird diets. While kittiwakes showed a clear benefit from the closure, with breeding success improving post-closure, the effects on other species were less evident. The authors suggest that changing environmental conditions, particularly poor sandeel recruitment and declining prey quality, may have masked the potential benefits of reduced fishing pressure for species like guillemot, puffin, and razorbill. The study underscores that while fishery closures can improve ecosystem resilience, their effectiveness is strongly mediated by environmental variability, meaning they may help prevent further declines but cannot guarantee predator population recovery.
Trifonova et al. (2023)	Ecosystem function	This study applied a data-driven Bayesian network approach to assess how physical and biological indicators influence marine population trends across four regions over 30 years, in the context of climate change and offshore renewable energy (ORE) development. It revealed region-specific patterns of bottom-up and top-down effects on ecosystems and identifies habitat-dependent indicator species, offering a pragmatic tool for understanding and managing ecosystem trade-offs.	**Trifonova et al. (2023)** developed a Bayesian network approach, covering Shetland & Orkney, the West of Scotland, the Deep central North Sea, and the Shallow central North Sea to understand ecosystem trends and drivers. The approach explores the importance of multiple variables including important prey groups, one of which was sandeel larvae. The model predicted sandeel larvae trend responses with high accuracy. Sandeel larvae abundance was predicted to decline, following a scenario increase in bottom temperature and a high fishing level in the deep central North Sea. Results indicated that both bottom-up and top-down forcing can alter the ecosystem dynamics for this region through species interactions mediated by sandeel larvae, i.e., the impacts of

			fishing on sandeel larvae leads to wider ecosystem impacts for species which interact with sandeel larvae.
Van Deurs et al (2023)	Sandeel dynamics	This study assessed how the age, size, and condition of spawning fish affect recruitment success across eleven North Sea stocks, using long-term assessment data. The authors tested whether recruitment improves when spawning stocks contain more older or heavier individuals and how these traits respond to fishing pressure. While older age structure showed weak and inconsistent links to recruitment, spawner weight had more consistent positive correlations with recruitment in several species.	**Van Deurs et al. (2023)** included lesser sandeel in their multi-stock analysis and found no strong evidence that age structure influenced sandeel recruitment. The sandeel stock showed no significant correlation between recruitment and either the proportion of old spawners or average spawner age. Trends in spawner weight (a proxy for condition) were also erratic and showed no consistent link to recruitment. However, the age composition and spawner weight in sandeel did respond to changes in fishing mortality, mirroring patterns observed across other short-lived species like sprat and Norway pout. The findings highlighted that while demographic traits can be shaped by fishing pressure, they may not reliably explain recruitment variation in sandeels
Wanless et al (2023)	Predator needs: seabirds	This study investigated whether increased parental effort by common guillemots could buffer the impacts of warming sea temperatures on chick diet and demographic rates over a 38-year period on the Isle of May. They found that while parents did increase effort in warmer years, this was not enough to maintain chick energy intake. Higher effort was linked to lower chick growth, reduced fledging success, and poorer adult survival.	**Wanless et al. (2023)** showed that sandeels were the dominant prey in chick diets during the early years of the study but were gradually replaced by sprat from the early 2000s onwards. This shift was driven by rising spring sea surface temperatures, which were strongly linked to declines in sandeel availability, body size, and energy content. Sandeel length decreased by over 1 cm per degree of warming, and their relative calorific value also dropped significantly in warmer years. These changes reduced the energy delivered per feed, particularly important for guillemots that can only deliver one prey item per trip. The authors noted that this prey shift and quality decline were key drivers of reduced chick energy intake.
Allgayer et al (2024)	Sandeel dynamics	This study used an individual-based model to assess functional connectivity and demographic processes within the SA4 sandeel stock in the North Sea. By simulating larval dispersal and population dynamics across 43 sandbank	**Allgayer et al. (2024)** modelled the spatial dynamics of sandeels in the SA4 management area, treating the stock as a metapopulation made up of 43 subpopulations distributed across sandy patches. The MerMADE model incorporated larval behaviour, hydrodynamics, and life history traits to simulate dispersal and recruitment. They found that larval

		patches, the study identified areas with high origin and destination importance and evaluated how patch depletion affected stock resilience. Results showed that some patches were highly isolated, receiving little larval input, while others were key sources of dispersers. The findings emphasised that not all patches contribute equally to population stability and recovery, suggesting that stock assessment and management strategies should account for internal spatial structure and connectivity.	transport was highly asymmetrical, with certain areas like the Moray Firth acting as major sources of larvae, while others, such as the Turbot Bank, were highly isolated. Depletion of patches with low destination centrality, especially those unable to receive larvae from elsewhere, had the most severe long-term effects on overall population size. In contrast, smaller patches that regularly received incoming dispersers recovered more quickly.
Deschamps et al (2024)	Sandeel prey	This study analysed 44 years of copepod data from the time series to assess functional shifts in the southern North Sea copepod community and their environmental drivers. Using a trait-based approach, they identified a regime shift between 1986 and 1988, transitioning from a community dominated by large herbivorous, summer-peaking copepods with diapause ability, to one dominated by smaller carnivorous and detritivorous taxa with shorter development times and autumn seasonality. The shift was linked to warmer sea temperatures, increased salinity, and declining nutrient and dinoflagellate levels.	**Deschamps et al. (2024)** did not directly analyse sandeels, but their findings provide critical context for understanding sandeel recruitment dynamics. The observed copepod regime shift around 1986–1988 coincided with well-documented declines in the recruitment of forage fish, including lesser sandeels. The post-shift copepod community was smaller-bodied, less energy-rich, and peaked later in the year, reducing the availability of high-quality prey during the critical spring and early summer feeding period for larval sandeels. The decline in herbivorous, lipid-rich copepods and a shift to more autumn-dominant species may have contributed to food limitation and phenological mismatch.
Di Pane et al (2024)	Sandeel prey	This study analysed over 40 years of mesozooplankton data to identify tipping points in community structure and assess how taxonomic resolution influences shift detection. Using multivariate regression trees and principal coordinates analysis, the study identified two major regime shifts: one in the early 1980s and a	**Di Pane et al. (2024)** did not specifically study sandeels in their analysis of mesozooplankton, however they highlighted that the abrupt shift in zooplankton community structure in the 2000s likely had major consequences for higher trophic levels, including forage fish like lesser sandeels. The study linked these plankton changes to well-documented recruitment failures in multiple fish species, including herring and sandeels, between 2002 and 2010. The decline in key prey for larval and

		more pronounced shift around 2007. These changes were marked by a sharp rise and subsequent fall in total abundance and diversity.	juvenile sandeels may have directly contributed to reduced sandeel recruitment during this period. The authors supported previous findings that climate-driven changes in plankton availability can ripple through the food web.
Fulton and Sainsbury (2024)	Ecosystem function	This paper explored how Ecosystem-Based Fisheries Management (EBFM) can be strengthened by incorporating indicators of ecosystem structure, using concepts from engineering such as criticality analysis. By applying this approach to ecosystem models and long-term diet data, the study identified key "hub species" as critical ecosystem connectors that require management attention, with results varying by system.	**Fulton and Sainsbury (2024)** introduced the "hub index" as a network-based measure to identify species that play a structurally important role in food webs by connecting many other species across trophic levels. These hub species are considered critical to maintaining ecosystem integrity and function. In applying this method to diet data and food web models, the authors identify key hub species in the North Sea, which included sandeels. Their central position reflects their role as a major conduit of energy from zooplankton to a wide range of predators, including fish, seabirds, and marine mammals.
Henriksen et al (2024)	Sandeel dynamics	This study used laboratory experiments to determine how sediment type and light intensity affect the burial behaviour of sandeels. The study tested sediment mixtures with varying grain sizes and found that sandeels preferred coarse to very coarse sand (0.5–2.0 mm) over finer or much coarser substrates. Burial was almost completely avoided in sediments with medium pebble gravel (>4.0 mm). Light intensity also had a strong effect, with sandeels showing a clear preference for darker conditions.	**Henriksen et al. (2024)** used choice experiments to test burial preferences of sandeels across a range of sediment types and light levels. They found that sandeels showed a strong preference for sediments composed primarily of coarse to very coarse sand (0.5–2.0 mm grain size), with burial probability dropping sharply in substrates containing more than 30% medium gravel (>4 mm). Mixtures containing up to 65% fine gravel (2.0–4.0 mm) were tolerated, but larger grain sizes acted as a barrier to burial. Light levels had a clear influence, with sandeels consistently avoiding more brightly lit areas, even when those contained otherwise preferred sediments. The study concluded that both sediment structure and light availability strongly affect sandeel burying behaviour and that coarse substrates under dim light conditions represent optimal habitat.
Ludwig et al (2024)	Predator needs: fish	This study explored functional trait associations between demersal fish predators and their prey in	**Ludwig et al (2024)** used trait-based methods to assess predator-prey relationships of demersal fish in the southern North Sea. Sandeels are

		the southern North Sea, aiming to simplify complex food webs. The results showed that predator traits, especially tissue composition, are linked to prey energy content and mobility, supporting the use of trait-based approaches to understand selective feeding and food web dynamics under environmental change.	mentioned as prey for piscivorous species like grey gurnard and whiting. Sandeels were confirmed as a primary food source and found in large proportions (>30% weight) in 6 out of 13 predator/life-stage combinations analysed.
Melià et al (2024)	Sandeel dynamics	This report evaluated how environmental variables affect fish recruitment across European seas, using a suite of case studies from the SEAwise project. The report developed and tested predictive models for a range of stocks, incorporating climate and oceanographic data such as temperature, salinity, chlorophyll, and prey availability. Results showed that adding environmental variables improved recruitment forecasts in many cases, particularly for short-lived species.	**Melià et al. (2024)** developed stock–recruitment models for three North Sea sandeel stocks. Linear regressions revealed varying relationships between recruitment and environmental variables including temperature, salinity, currents, chlorophyll, and zooplankton. However, the models performed inconsistently, particularly when using short-term, monthly environmental averages, indicating that recruitment-environment links for sandeels may be noisy and difficult to generalise. Despite these challenges, the incorporation of environmental data did improve predictive power compared to models based solely on stock size.
Pint et al (2024)	Ecosystem function	This study details the development of an Ecopath with Ecosim food web model for the Southern Bight of the North Sea (SBNS), tailored to support ecosystem-based management of blue economy activities. The model represented the 1991 ecosystem and included 43 functional groups alongside commercial and recreational fishing fleets. Trophic flows were found to be highly complex, with strong benthic recycling and relatively high system stability. Compared to other regional models, the SBNS food web showed similar structure but greater resilience.	**Pint et al. (2024)** included sandeels as a distinct functional group in their EwE food web model of the Southern Bight of the North Sea. Sandeels had one of the highest fish biomasses in the system (4.39 t km^{-2}) and ranked among the top five keystone species, alongside phytoplankton, copepods, squid, and juvenile whiting. Their position at a mid-trophic level (3.43) made them a key link between planktonic production and higher predators. The model indicated that sandeels were influenced by interactions with juvenile whiting, which exerted negative pressure through predation and competition. Their high biomass, central role in energy transfer, and keystone status underline their critical contribution to food web structure of the Southern Bight of the North Sea.

Régnier et al (2024)	Predator needs: seabirds	This study investigated how variations in the timing and abundance of lesser sandeel (*Ammodytes tobianus*) has affected the breeding success of five seabird species. It found that temporal mismatch between prey availability and seabird breeding reduced productivity in several species, but that high sandeel abundance may sometimes offset these effects.	**Régnier et al (2024)** explored how seasonal availability and abundance of lesser sandeels affected the breeding success of five North Sea seabird species. Using 17 years of detailed field data, the authors found that mismatches between seabird breeding periods and the seasonal availability of age-0 sandeels negatively affected productivity in species like kittiwake, puffin, and guillemot, supporting the match/mismatch hypothesis (MMH). However, in line with the match/mismatch/abundance hypothesis (MMAH), high sandeel abundance was sometimes able to compensate for poor synchrony, especially in puffins and kittiwakes. The findings highlighted that both timing and abundance of prey interact in complex, species-specific ways to influence seabird demography.
MacDougall and Robinson (2025)	Predator needs: marine mammals	This study investigated how the distribution of feeding minke whales in the Southern Trench Marine Protected Area (MPA), northeast Scotland, changed seasonally in response to prey availability and environmental conditions. Using 14 years of survey data and presence–absence models, they found that whales shifted their foraging locations through the summer, initially targeting sandeel-rich areas and later preferring thermal fronts. These shifts aligned with seasonal prey availability and were best predicted by burrowed sandeel density and sea surface temperature gradients.	**MacDougall and Robinson (2025)** found that minke whale presence was strongly associated with high burrowed sandeel density (BSD) during May and June. This relationship weakened in later months as sandeels began to burrow and became less accessible in the water column. The whales then shifted their distribution towards thermal fronts, likely following the seasonal emergence of alternative prey like juvenile herring and sprat. While BSD served as a useful proxy for sandeel presence, the authors noted that it reflected benthic habitat and not real-time prey availability in the water column. Nonetheless, BSD data helped capture broad seasonal trends in foraging behaviour. The study concluded that the seasonal decline in whale use of sandeel habitat supported a prey-switching strategy.
Olin et al (2025)	Sandeel dynamics	This study investigated the causes of declining body size in lesser sandeel in the North Sea, using a dynamic energy budget model informed by long-term data. The results indicated that declining prey availability, rather than temperature alone, was the primary driver of size reductions,	**Olin et al (2025)** used a dynamic energy budget model to investigate size declines in North Sea sandeels and attributed these largely to declining zooplankton prey densities rather than temperature alone. Results suggest that sandeel sizes may decline further with continued trajectories of increasing temperatures prompting delays in phenology, increasing turbidity, and shifts in zooplankton (copepod) prey from

		though temperature interacts with prey density in complex ways. The study also highlighted the roles of early-life phenology and turbidity, emphasising the need to consider multiple interacting factors when assessing climate change impacts on fish size.	*Calanus finmarchicus* to *Calanus helgolandicus* in the northernmost areas and declining densities of small copepods in the southernmost areas. Finally, results showed that sandeel growth conditions have deteriorated in the western North Sea, which have long been important sandeel fishing grounds. Smaller sandeels have higher mortality rates, lower maturation rates and lower fecundity: authors suggest this may make the sandeel stock particularly vulnerable to additional mortality from fishing.

3. Updates from the International Council for the Exploration of the Sea (ICES)

3.1. Summary

ICES is the primary scientific body responsible for providing evidence-based advice on the sustainable management of marine resources in the Northeast Atlantic. One of ICES' core functions is to assess the status of fish stocks and issue annual catch advice to inform management decisions. Periodically, ICES carries out benchmark assessments, i.e., comprehensive technical reviews of stock assessment methods, to ensure the best available science is used to support this advice. These benchmarks involve re-evaluating data inputs, biological parameters, and modelling approaches, and are subject to peer review.

An ICES benchmark assessment for sandeels, conducted from 2021 to 2023, introduced improvements to the methodology used for assessing stocks in sandeel areas 1r, 2r, 3r, and 4 (ICES 2024). While the existing stock area boundaries were retained, the workshop acknowledged that they are management-driven and not fully aligned with biological stock structure. The benchmark achieved technical progress through enhanced catch data preparation, standardised survey inputs, updated biological parameters, and improved statistical modelling. These refinements resulted in reduced retrospective bias, particularly in recruitment estimates, thereby improving the robustness of future single-stock management advice. Benchmark reviewers identified key areas for further development, including uncertainty in the Area 4 model, the need to revisit stock boundary definitions, and the exclusion of age-0 sandeel from the assessment, which may affect estimates of recruitment and reference points. Reviewers also highlighted the importance of more systematic sensitivity analyses and greater clarity around the derivation of key reference points like Fcap[3] within Management Strategy Evaluations (MSE).

Building on the benchmark, ICES issued catch advice for 2025. For all seven North Sea sandeel stocks, advice ranged from reduced catches to zero catch, with the latter recommended for Areas 3r, 4, 5r, and 7r. Even in areas where some fishing is advised (1r,

[3] **Definition for Fcap reference point**: A capped fishing mortality (F) rate for short-lived species that limits exploitation when biomass is high. By capping the F, the escapement biomass (i.e., the portion of a fish stock that "escapes" fishing and survives to spawn) is increased in proportion to the stock size, maintaining a high probability of achieving the minimum amount of biomass left to spawn.

2r, and 6), catch limits have been reduced or kept very low. Notably, catch advice for Area 1r (Dogger Bank) was reduced by 45% due to two consecutive years of poor recruitment, despite the stock being above biomass reference points. The stock assessment advice is now caveated to highlight that the UK's full closure of its Exclusive Economic Zone (EEZ) to sandeel fishing since 2024 adds uncertainty to the stock assessments by affecting both access to data and the reliability of trend estimates.

The following sections provide more detail on the 2021-2023 sandeel benchmark and latest stock advice.

3.2. Sandeel benchmark workshop

An ICES benchmark workshop on sandeel (WKSandeel; ICES 2024) was conducted over an extended period (2021-2023) to review and agree the stock assessment methodology to be used in future update assessments of sandeels in areas 1r, 2r, 3r, and 4 (**Figure 1**). Catch numbers at age, fishing effort, maturity at age, weight at age, natural mortality at age, and survey indices were recalculated based on the latest insights and tools. The group reflected on the 2016 area delineation, concluding that it was based on management considerations rather than best available biological information on stock structure. Although the area delineation remains the same, improvements in catch data preparation, survey data standardisation, biological parameter improvements, and statistical modelling of these data in the assessment all improved compared to the previously agreed assessment methodology. This led to lower retrospective patterns[4], particularly for recruitment.

3.2.1. Future work suggested at the ICES benchmark

ICES benchmark workshops are reviewed by external experts throughout the process. The reviewers' reports note several areas where the assessments could be developed in the future:

Current models do not include catches of age-0 sandeel

There are observations of 0-year-old catches in the historical time series, however by weight it is an insignificant fraction of the total catch. Removing the fishery on that age

[4] **Retrospective patterns**: systematic and consistent differences between the estimates of stock size or fishing mortality from a stock assessment when recent years of data are successively removed, often revealing biases or instability in the model's estimates over time.

group in the model allowed for a more robust stock assessment, as it did not have to estimate fishing mortality on a group which has relatively greater natural mortality.

While not using age-0 fish may give better information about the more recent years, there was less certainty about the historical value of the information. It was advised that this should be explored because the censoring of the age-0 information could have an impact on the estimation of the stock-recruitment curve and hence reference points.

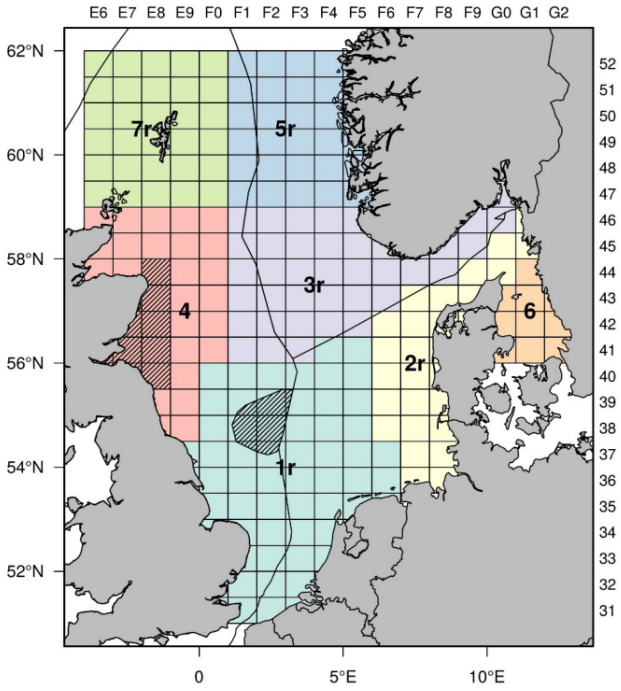

Figure 1. Sandeel in ICES Division 4 (Greater North Sea). Stock areas for the seven sandeel stocks. The closed parts of Sandeel Area 1(Dogger Bank since 2022) and 4 (since 2000) are shown with hatched markings. In 2024, the UK Exclusive Economic Zone (EEZ) was closed to sandeel fishing. The UK, EU, and Norwegian EEZs are shown. *Image taken from ICES sandeel advice sheets[5].*

Stock boundaries

Members of the benchmark reviewed whether the current sandeel stock boundaries in the North Sea (**Figure 1**) were biologically appropriate based on existing and new evidence which included genetics, otolith chemistry, larval drift, tagging, and age-length data. The current stock divisions were originally informed by larval drift models and later adjusted for growth and migration patterns (ICES 2017). The benchmark found that the current boundaries poorly reflect biological stock structure, particularly the management-driven boundary between the Norwegian EEZ and EU zone. Evidence indicated this border splits

[5] ICES 2025 sandeel advice. The following area denotations link to the corresponding 2025 advice sheets: SA1r, SA2r, SA3r, SA4, SA5r, SA6, SA7r

a biologically connected area that acts as a larval sink and shows movement of adults between areas, though not complete genetic mixing.

Three area scenarios were considered at the benchmark meeting:

- **WKSAND 2016 (Status quo)**: Maintains current, management-driven boundaries.
- **WKSAND 2022a**: Proposes seven biologically informed stock units; alters SA1–SA3 borders; splits out southern coastal areas; best aligned with biological evidence.
- **WKSAND 2022b**: Merges SA2r and SA3r into one large unit to reflect larval and adult connectivity; less supported by some analyses.

Despite strong scientific support for the WKSAND 2022a scenario, particularly regarding the removal of the Norwegian-EU boundary, assessment limitations (particularly for sandeel area 3) led to a decision to retain the 2016 boundaries for now, acknowledging that this was a management solution rather than a biological solution.

Uncertainty and sensitivity

The assessment model for sandeel area 4 produced a very uncertain assessment, however a comment was made in the benchmark report (ICES 2024) that the assessment was also uncertain at the last benchmark. One reviewer noted that future sensitivity analyses should include seasonality choices, age-0 data use, selectivity time blocks, index inclusion, and start year choice, at a minimum. These suggested sensitivity runs would help to understand the uncertainty surrounding model and data choices. In addition, reviewers recommended that 1) uncertainty should be acknowledged more holistically, 2) fixed model parameterisations should be reviewed, and 3) Finally, reduce uncertainty in reference points by better considering what constitutes a 'good' or 'large' recruitment event.

MSE and Fcap

Management Strategy Evaluation (MSE) is used to estimate the value of Fcap. While the MSE was run for 50 years, it did not completely stabilise with respect to the risk: this issue was not fully resolved and could use further exploration, including

- Exploration into recruitment distribution, sampling, and the inclusion of an upper limit on the recruitment values.
- Exploration into the life history choices to determine the most robust set of years to sample from.

- Exploration into the potential improvement in stock assessment estimation by looking at the estimation of the individual parameters and how they are changing over time.

3.3. Sandeel catch advice

ICES advised a reduced or zero catch approach for all North Sea sandeel stocks for 2025. For Area 1r (Dogger Bank), although the stock is above precautionary biomass limits, advice has been reduced by 45% to ≤72,997 tonnes following two years of poor recruitment. In Area 2r (central and southern North Sea), a catch of ≤39,159 tonnes is advised, with the stock currently below safe biomass levels but expected to recover following strong recruitment in 2024. Area 3r (northern and central North Sea and Skagerrak) has received a zero-catch recommendation, as spawning biomass remains below all reference points and recovery is not expected even with no fishing. Similarly, Area 4 (northern and central North Sea) is advised as zero catch, driven by low biomass and high uncertainty in stock assessments. Area 5r (Viking and Bergen Banks) remains closed, with advice unchanged since 2011 due to persistently low sandeel abundance. Area 6 (Skagerrak, Kattegat and Belt Sea) is data-limited and has an advised catch of ≤112 tonnes, applying a precautionary buffer. Area 7r (Shetland area) also remains under zero catch advice, consistent with recommendations since 2013. Across all areas, ICES highlights the importance of protecting sandeel habitats from degradation and notes the impact of the UK's continued closure of sandeel fisheries in its waters since 2024, which affects the reliability of assessments due to lack of fisheries-dependent data in closed areas.

As seen in previous years for Area 4, where a closed area exists prohibiting sandeel fishing, catch limits have been set by ICES as if the entire areas remain open to fishing (i.e., TACs are set based on the stock size within the entirety of each area). This means that the whole of the TAC for areas with partial closures may be harvested from the fraction which remains open, raising concerns about localised sandeel depletion. ICES advice and TAC for 2022-2025 can be found in **Table 2**.

Table 2. International Council for the Exploration of the Sea (ICES) advice for North Sea sandeel stocks from 2022-2025.

Sandeel stock	Year	ICES advice basis	Catch advice (tonnes)	TAC (tonnes)
san.sa.1r	2022	MSY approach: zero catch	0	5,000
	2023	MSY approach: allow for sufficient stock (MSY Bescapement) to remain for successful recruitment	≤120,482	116,815

Sandeel stock	Year	ICES advice basis	Catch advice (tonnes)	TAC (tonnes)
	2024	MSY approach: allow for sufficient stock (MSY Bescapement) to remain for successful recruitment	≤132,315	128,346
	2025	MSY approach: allow for sufficient stock (MSY Bescapement) to remain for successful recruitment	≤72,997	70,807
san.sa.2r	2022	MSY approach: allow for sufficient stock (MSY Bescapement) to remain for successful recruitment	≤71,859	71,859
	2023	MSY approach: allow for sufficient stock (MSY Bescapement) to remain for successful recruitment	≤40,997	40,997
	2024	MSY approach: allow for sufficient stock (MSY Bescapement) to remain for successful recruitment	≤35,925	35,925
	2025	MSY approach: allow for sufficient stock (MSY Bescapement) to remain for successful recruitment	≤39,159	39,159
san.sa.3r	2022	MSY approach: allow for sufficient stock (MSY Bescapement) to remain for successful recruitment	≤85,559	6,845 (EU +UK zone), 95,000 (Norwegian zone)
	2023	MSY approach: allow for sufficient stock (MSY Bescapement) to remain for successful recruitment	<30,570	2,446 (EU +UK zone), 60,000 (Norwegian zone)
	2024	MSY approach: zero catch	0	5,000 (EU +UK zone), 19,000 (Norwegian zone)
	2025	MSY approach: zero catch	0	0
san.sa.4	2022	MSY approach: zero catch	0	5,000
	2023	MSY approach: allow for sufficient stock (MSY Bescapement) to remain for successful recruitment	≤35,020	33,969
	2024	MSY approach: zero catch	0	0
	2025	MSY approach: zero catch	0	0
san.sa.5r	2022	Precautionary approach	0	0
	2023	Precautionary approach	0	0

Sandeel stock	Year	ICES advice basis	Catch advice (tonnes)	TAC (tonnes)
	2024	Precautionary approach	0	0
	2025	Precautionary approach	0	0
san.sa.6	2022	Precautionary approach	≤140	140
	2023	Precautionary approach	≤140	140
	2024	Precautionary approach	≤140	140
	2025	Precautionary approach	≤112	112
San.sa.7r	2022	Precautionary approach	0	0
	2023	Precautionary approach	0	0
	2024	Precautionary approach	0	0
	2025	Precautionary approach	0	0

4. Updates from Norwegian sandeel management (2025)

Norway's Institute of Marine Research (IMR) has issued preliminary advice recommending zero catch of sandeel in 2025 within the Norwegian economic zone, due to critically low stock biomass across all management areas[6]. The 2025 report shows that the stock has been in steady decline since its peak in 2020, despite very low catches in recent years. The 2024 survey indicated a weak incoming year class, and the 2024 acoustic survey confirmed that total biomass was at a historically low level for the time series, with remaining sandeel primarily concentrated in one area. Based on this, IMR advised that all areas remain closed to fishing until at least 15 May 2025, when updated advice will be provided following a new acoustic survey.

A key concern was that recent recruitment predictions have been overly optimistic, even when based on conservative assumptions. The survey, designed to provide early signals of good recruitment, has limited predictive power in poor recruitment years, consistently overestimating the number of young fish entering the stock. The IMR suggested that

[6] IMR 2025 sandeel report: https://www.hi.no/hi/nettrapporter/rapport-fra-havforskningen-2025-9

predation and environmental factors may be playing a bigger role than expected: increased predation pressure from rising haddock (*Melanogrammus aeglefinus*) and whiting populations may be contributing to higher sandeel natural mortality. Given these factors and the continued uncertainty, the recommendation reflects a precautionary approach aimed at preventing further depletion and giving the stock a chance to recover.

5. Conclusion

This evidence update has reviewed the scientific and management evidence published since the 2023 Natural England/Cefas/JNCC report on the ecosystem risks and benefits of a full prohibition of industrial sandeel fishing in UK waters of the North Sea. New published studies, updated ICES stock assessments, and other sources have expanded the evidence base and provided further clarity on the ecological role of sandeels, their environmental vulnerability, and the effects of management interventions.

The new evidence supports the original report's conclusions. No studies were identified that contradict the previous assessment of the ecological importance of sandeels. The weight of evidence continues to support the view that sandeels are a structurally important forage species in the North Sea. This is particularly so for dependent seabird, marine mammal, and fish predators playing a key role as a conduit of energy through the ecosystem from plankton through to large predators. Evidence also continues to demonstrate that the availability of sandeels to predators (encompassing sandeel location, timing, abundance and quality) is increasingly shaped by environmental variability and the availability of prey for sandeels themselves.

Improvements in the underlying ICES stock assessment methodology, particularly guided by the 2021–2023 ICES benchmark, include improved catch data preparation, survey data standardisation, biological parameter improvements, and the resulting statistical modelling which has led to lower retrospective patterns. However, key uncertainties remain, including the spatial structure of stocks, the role of age-0 sandeel in assessments, and the reliability of recruitment forecasts under changing environmental conditions.

6. References

Allgayer, R.L., Fernandes, P.G., Travis, J.M. and Wright, P.J., 2023. Spatial patterns of within-stock connectivity provide novel insights for fisheries management. Marine Ecology Progress Series.

Berge, D.S., 2023. Spatiotemporal variation in the growth and size distributions of lesser sandeel (Ammodytes marinus) in the north-eastern North Sea (Master's thesis, The University of Bergen).

Booth CG, Guilpin M, Darias-O'Hara A-K, Ransijn JM, Ryder M, Rosen D, Pirotta E, Smout S, McHuron EA, Nabe-Nielsen J, Costa DP (2023) Estimating energetic intake for marine mammal bioenergetic models. Conserv Physiol 11(1): coac083; doi:10.1093/conphys/coac083.

Boyse, E., Robinson, K.P., Beger, M., Carr, I.M., Taylor, M., Valsecchi, E. and Goodman, S.J., 2023. Environmental DNA reveals fine scale spatial and temporal variation of prey species for marine mammals in a Scottish marine protected area. bioRxiv, pp.2023-12.

Buyse, J., Hostens, K., Degraer, S. and De Backer, A., 2022. Long-term series demonstrate small-scale differences in trends within fish assemblages explained by climate variability. Estuarine, Coastal and Shelf Science, 264, p.107663.

Deschamps, M.M., Boersma, M., Meunier, C.L., Kirstein, I.V., Wiltshire, K.H. and Di Pane, J., 2024. Major shift in the copepod functional community of the southern North Sea and potential environmental drivers. ICES Journal of Marine Science, 81(3), pp.540-552.

Di Pane, J., Boersma, M., Marques, R., Deschamps, M., Ecker, U. and Meunier, C.L., 2024. Identification of tipping years and shifts in mesozooplankton community structure using multivariate analyses: a long-term study in southern North Sea. ICES Journal of Marine Science, 81(3), pp.553-563.

Dunn, R.E., Green, J.A., Wanless, S., Harris, M.P., Newell, M.A., Bogdanova, M.I., Horswill, C., Daunt, F. and Matthiopoulos, J., 2022. Modelling and mapping how common guillemots balance their energy budgets over a full annual cycle. Functional Ecology, 36(7), pp.1612-1626.

Fijn, R.C., Thaxter, C.B., Aarts, G., Adema, J., Middelveld, R.P. and van Bemmelen, R.S., 2022. Relative effects of static and dynamic abiotic conditions on foraging behaviour in breeding Sandwich terns. Marine Ecology Progress Series, 692, pp.137-150.

Fulton, E.A. and Sainsbury, K., 2024. Food web structure, the hub index and identifying species of ecological significance. Ecological Indicators, 166, p.112378. https://doi.org/10.1016/j.ecolind.2024.112378

Gehanno, J.F., Rollin, L. and Darmoni, S., 2013. Is the coverage of Google Scholar enough to be used alone for systematic reviews. BMC medical informatics and decision making, 13, pp.1-5.

Gusenbauer, M. and Haddaway, N.R., 2020. Which academic search systems are suitable for systematic reviews or meta-analyses? Evaluating retrieval qualities of Google Scholar, PubMed, and 26 other resources. Research synthesis methods, 11(2), pp.181-217.

Harris, M.P., Albon, S.D., Newell, M.A., Gunn, C., Daunt, F. and Wanless, S., 2022. Long-term within-season changes in the diet of Common Guillemot (Uria aalge) chicks at a North Sea colony: implications for dietary monitoring. Ibis, 164(4), pp.1243-1251.

Haddaway N.R., Collins A.M., Coughlin D., Kirk S. 2015. The Role of Google Scholar in Evidence Reviews and Its Applicability to Grey Literature Searching. PLOS ONE 10(9): e0138237. https://doi.org/10.1371/journal.pone.0138237

Henriksen, O., Moran, N.P., Veilex, L.A., Behrens, J.W., Nielsen, A., Mildenberger, T.K., Wright, P.J., Jensen, H. and van Deurs, M., 2024. Effects of sediment type and light availability on the burying behaviour of small sandeel (Ammodytes tobianus). Journal of Experimental Marine Biology and Ecology, 577, p.152020.

Hunt, G.L., Cobain, M.R., McGill, R.A., Pinnegar, J.K., Engelhard, G.H., Wigham, B.D. and Polunin, N.V., 2023. Quantifying spatio-temporal consistency in the trophic ecology of two sympatric flatfishes. Journal of Fish Biology, 103(2), pp.378-392.

ICES. 2017. Report of the Benchmark on Sandeel (WKSand 2016), 31 October - 4 November 2016, Bergen, Norway. ICES CM 2016/ACOM:33. 319 pp. https://doi.org/10.17895/ices.pub.7718

ICES. 2024. Benchmark workshop on sandeel (ammodytes spp.) (Outputs from 2022 and 2023 meetings) (WKSANDEEL). ICES Scientific Reports. 6:10. 328 pp. https://doi.org/10.17895/ices.pub.21581151

Ludwig, K.E., Singer, A., Kröncke, I. and Sell, A.F., 2024. Predator-prey trait associations and feeding preferences of demersal fishes in the southern North Sea. Marine Ecology Progress Series, 739, pp.173-190. https://doi.org/10.3354/meps14597

MacDougall, D.A. and Robinson, K.P., 2025, March. Following the Food: Dynamic, Seasonal Changes in the Fine-Scale Distribution of Foraging Minke Whales Within a Scottish Marine Protected Area (MPA). In Oceans (Vol. 6, No. 1, p. 18). MDPI.

Martín-Martín, A., Orduna-Malea, E., Thelwall, M. and López-Cózar, E.D., 2018. Google Scholar, Web of Science, and Scopus: A systematic comparison of citations in 252 subject categories. Journal of informetrics, 12(4), pp.1160-1177.

Melià, P., Schiavo, A., Ojaveer, H., Einberg, H., Rubene, G., Putnis, I., Neuenfeldt, S., Voss, R., Kühn, B., Taylor, M. and Kempf, A., 2025. SEAwise Report on improved predictive models of recruitment under different habitat scenarios and incorporating experimental results.

Oesterwind, D. and Piatkowski, U., 2023. Stomach content analysis of North Sea cephalopods: often-overlooked predators with direct impact on commercially used fish species?. Marine Biology, 170(8), p.101.

Olin, A.B., Banas, N.S., Heath, M.R., Wright, P.J., MacDonald, A., Wanless, S., Daunt, F., Speakman, J.R. and Nager, R.G., 2025. Changing food conditions and size declines in a North Sea forage fish. bioRxiv, pp.2025-03. https://doi.org/10.1101/2025.03.25.643521

Olin, A.B., Banas, N.S., Johns, D.G., Heath, M.R., Wright, P.J. and Nager, R.G., 2022. Spatio-temporal variation in the zooplankton prey of lesser sandeels: species and community trait patterns from the Continuous Plankton Recorder. ICES Journal of Marine Science, 79(5), pp.1649-1661.

Pint, S., Stevens, M., Musimwa, R., Standaert, W., De Troch, M., van Oevelen, D., Heymans, J.J. and Everaert, G., 2024. A food web model of the Southern Bight of the North Sea. Ocean & Coastal Management, 255, p.107256.

Ransijn, J., 2023. Marine mammal predator-prey interactions in the North Sea (Doctoral dissertation, The University of St Andrews). https://doi.org/10.17630/sta/346

Régnier, T., Wright, P.J., Harris, M.P., Gibb, F.M., Newell, M., Eerkes-Medrano, D., Daunt, F. and Wanless, S., 2024. Effect of timing and abundance of lesser sandeel on the breeding success of a North Sea seabird community. Marine Ecology Progress Series, 727, pp.1-17. https://doi.org/10.3354/meps14520

Robinson, K.P., MacDougall, D.A., Bamford, C.C., Brown, W.J., Dolan, C.J., Hall, R., Haskins, G.N., Russell, G., Sidiropoulos, T., Sim, T.M. and Spinou, E., 2023. Ecological habitat partitioning and feeding specialisations of coastal minke whales (Balaenoptera acutorostrata) using a recently designated MPA in northeast Scotland. PloS one, 18(7), p.e0246617.

Searle, K. R., Regan, C. E., Perrow, M. R., Butler, A., Rindorf, A., Harris, M. P., Newell, M. A., Wanless, S., & Daunt, F. 2023. Effects of a fishery closure and prey abundance on seabird diet and breeding success: Implications for strategic fisheries

management and seabird conservation. Biological Conservation 281. https://doi.org/10.1016/j.biocon.2023.109990

Trifonova, N.I. and Scott, B.E., 2023. Ecosystem indicators: predicting population responses to combined climate and anthropogenic changes in shallow seas. Ecography, 2024(3), p.e06925. https://doi.org/10.1111/ecog.06925

Utne, K.R., Skagseth, Ø., Wennevik, V., Broms, C.T., Melle, W. and Thorstad, E.B. 2022. Impacts of a Changing Ecosystem on the Feeding and Feeding Conditions for Atlantic Salmon During the First Months at Sea. Front. Mar. Sci. 9:824614. https://www.frontiersin.org/journals/marine-science/articles/10.3389/fmars.2022.824614/full

Van Deurs, M., Jacobsen, N.S., Behrens, J.W., Henriksen, O. and Rindorf, A. 2023. The interactions between fishing mortality, age, condition and recruitment in exploited fish populations in the North Sea. Fisheries Research, 267, 106822. https://doi.org/10.1016/j.fishres.2023.106822

Wanless, S., Albon, S.D., Daunt, F., Sarzo, B., Newell, M.A., Gunn, C., Speakman, J.R. and Harris, M.P. Increased parental effort fails to buffer the cascading effects of warmer seas on common guillemot demographic rates. Journal of Animal Ecology, 92:1622–1638. https://doi.org/10.1111/1365-2656.13944