Small but mighty: managing Northeast Atlantic forage fish to sustain marine life

Credits

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Table of Content

Executive summary

Forage fish are small to medium-sized species that are often found in large aggregations, feeding on plankton and other small aquatic organisms. They play a crucial role in the ocean as a vital link in the food web, supporting marine wildlife, including marine mammals, seabirds, and fish species.[1,2,3,4] However, the management of fisheries targeting these keystone species currently fails to adequately account for the interaction among species throughout the food web, or the ecosystem at large.[5,6,7,8,9]

In the Northeast Atlantic, notable examples of forage fish species include sandeel, sprat, herring, mackerel, Norway pout, and horse mackerel. Sandeel, for example, occurs in the records of over 60% of all predatory fish diets analysed in this report and plays a vital role in many seabird diets. The abundance and distribution of forage fish stocks tend to fluctuate significantly due to various factors, such as changing ocean temperatures and reproductive success, with fishing pressure exacerbating fluctuations.[10,11]

over **60%**

of all predatory fish diets analysed in this report were found to contain sandeel

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For instance, fishing amplifies stock variability by reducing stock sizes, thereby compromising stocks' resilience to environmental changes, including climate change.[12,13,14,15,16]

In response to the European regulatory framework and international commitments, current fisheries management of fish stocks in the Northeast Atlantic focuses on sustainably maximising the catches of individual fish stocks (i.e. Maximum Sustainable Yield[a] (MSY)). Adopting an Ecosystem-Based

[a] MSY refers to the largest level of catch (measured in quantity or weight) that can be harvested from a stock over the long term without depleting the stock under constant environmental conditions.

Fisheries Management (EBFM) approach, which is also a legal requirement under the regulatory framework, provides a clear opportunity to factor broader ecosystem dynamics into the management of these species, though its practical implementation is still lagging.[17,18]

Management of forage fish necessitates the availability of comprehensive data, a requirement that is not consistently met in the region. Even among scientifically assessed forage fish stocks, determining their abundance or exploitation rate remains challenging, making them susceptible to inappropriate management decisions. Among the 32 forage fish stocks analysed in this report, only 31% (ten stocks) are identified as being sustainably exploited ($F<F_{MSY}$); 47% (15 stocks) are deemed to have a healthy size ($B>B_{MSY}$); and only 16% (five stocks) meet both conditions, in line with MSY management objectives.

Despite this situation, forage fish are of great importance in terms of both volume and value in the European fisheries sector. There is, however, considerable variation among species as regards volume and value of forage fish landings, with herring standing out as contributing the most to volume (632 100 tonnes), while mackerel contributes most to value (€399 million). Most forage fish are caught using demersal trawlers/seiners (>400 vessels), purse seiners (>400 vessels) and pelagic trawlers (>200 vessels), and their catches are intended for direct human consumption and industrial use (e.g. for fishmeal and fish oil production). The capture of forage fish for non-human consumption has raised questions, given the reliance of wild predators on forage species as a food source.

32

forage fish stocks analysed in this report

only **31%**

are identified as being sustainably exploited

47%

are deemed to have a healthy size

only **16%**

meet both conditions

To benefit the most from an EBFM approach for forage fish in the Northeast Atlantic, a strategic policy framework should prioritize:

1. **Incorporating ecosystem considerations into management decisions:** the adoption of management decisions such as catch limits should be based on scientific advice that encompasses comprehensive ecosystem considerations, acknowledging species' interdependence and accounting for environmental influences.

2. **Enforcing long-term management strategies:** putting in place adaptive management strategies that integrate EBFM objectives, and regularly testing and updating them through management strategy evaluations.

3. **Improving protection of habitats and the greater ecosystem:** better protecting essential forage fish habitats, by restricting activities that have a negative impact on them and requiring thorough impact assessments of forage fish fisheries on ecosystems.

Embracing an EBFM approach to forage fish would enable them to maintain healthy abundance levels and sustain their integral role as prey to many species in marine ecosystems. At the same time, this approach helps preserve the marine environment in a better state for fishing communities and society at large, with the benefits that go with it.

"Embracing an EBFM approach...helps preserve the marine environment in a better state for fishing communities and society at large"

1. Preserving the ecosystem through fisheries

Sustainable fisheries management underscores its commitment to preserving fish stocks for the health of the ocean, coastal communities, and the wider society.[19] While current exploitation of European marine resources has had a positive outcome for numerous fish stocks in the Northeast Atlantic,[20,21] concerns arise about the management of forage fish stocks and their ability to effectively maintain their pivotal role in sustaining marine ecosystems.[22]

Despite the ecological significance of forage fish, the current management approach prioritizes maximizing catches of individual fish stocks over maintaining their crucial ecosystem role. This approach might be unsustainable for the greater ecosystem, including the species that rely on them. Reassessing forage fish management is thus crucial.

Northeast Atlantic coastal states have a legal obligation to implement EBFM.[19] This approach includes the intricate relationships between species and their environment, recognizing that the good status of one species is interlinked with that of others. Given their keystone role in marine ecosystems, forage fish are ideally suited to be managed through this approach. However, despite their importance, there have been limited efforts to implement EBFM for forage fish stocks.

To ensure the responsible exploitation of forage fish in Europe, there is a pressing need for improved and updated scientific advice that considers their role in the marine ecosystem. This will include considering species' interdependence within the marine food web and environmental influences, beyond protecting a single target stock. Failing this, adopting a precautionary approach becomes imperative.

The challenges concerning forage fish management warrant a shift in approach in Europe. Embracing EBFM would mean harmonizing fisheries management with broader objectives, including achieving Good Environmental Status and minimizing the degradation of marine ecosystems. This approach would benefit forage fish stocks, species reliant on them, and the marine environment at large.

This report outlines the role and significance of forage fish in the Northeast Atlantic ecosystem. It summarizes the status, exploitation, and management of the main forage fish stocks caught using catch limits. The report concludes with recommendations to enhance EBFM.

7

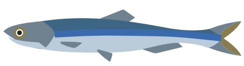
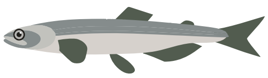
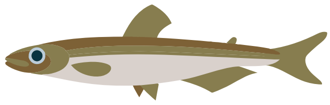
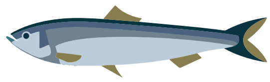
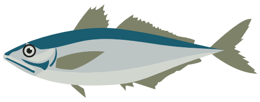
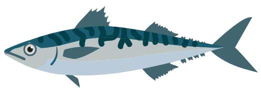
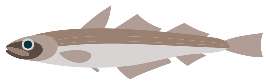
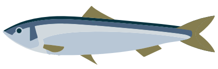
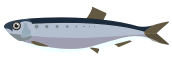
2. Forage fish species in the Northeast Atlantic

Forage fish, small to medium-sized and schooling species, play a significant role in pelagic ecosystems. They greatly influence the diets of larger marine predators, acting as crucial components of the marine food web. Consuming both phytoplankton and zooplankton, they effectively transfer energy and nutrients from the foundation of the food-web to higher trophic levels, sustaining marine life, like marine mammals, seabirds, and fish species.[23]

While some studies have questioned the direct impact of forage fish stock size on predator numbers, the reliance of marine predators on forage fish groups is evident.[24] Local density of prey and dynamic differences among forage fish species might have a more significant influence on predator success than a straightforward connection between forage fish and predator population sizes.[25,26]

Forage fish species possess short lifespans, prolific reproduction, and substantial populations. These traits, along with the ever-changing dynamics of the ocean, climate, and food availability, lead to variable populations each year, irrespective of fishing pressure. The reliance on foundational elements like plankton, which are sensitive to climate change, make these species vulnerable to plankton-related climate impacts[27,28]. Stock shifts compounded by fishing underline the need for attentive forage fish management, given their considerable influence on ecosystem health and higher trophic levels.[5,16,29,30] Moreover, they serve as primary targets for fisheries, contributing significantly to global catches.

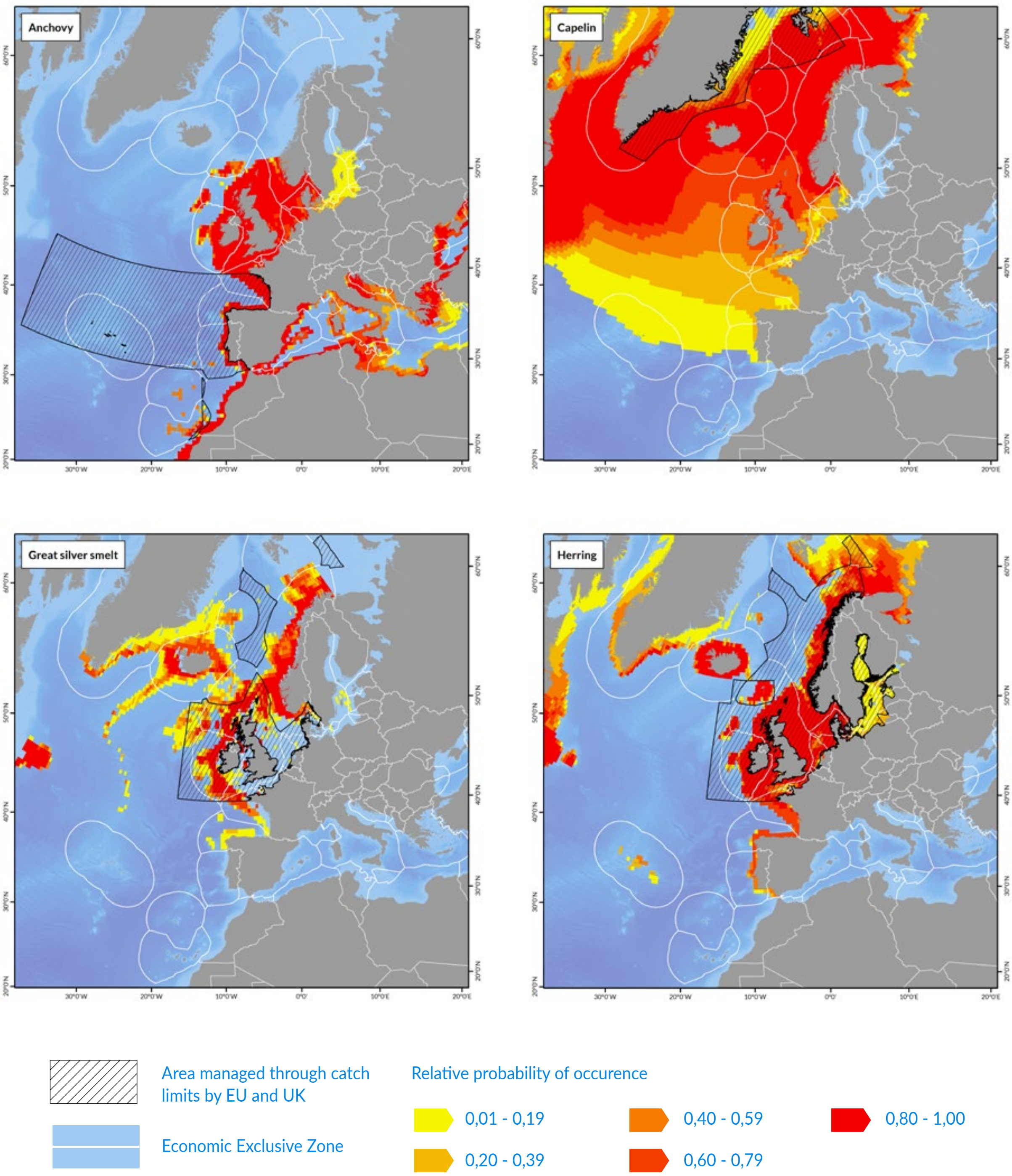
This report focuses on ten primary forage fish species in the Northeast Atlantic (see **Table 1**). However, other forage fish species like blue whiting (*Micromesistius poutassou*), boarfish (*Capros aper*), garfish (*Belone belone*) and European smelt (*Osmerus eperlanus*) have not been covered in this study. In addition, important forage species like krill, copepods, and small pelagic molluscs are also not included in the report.

	Common name	Scientific name	⇔ Common length in cm (max length)	▲ Trophic level
	**Anchovy**	*Engraulis encrasicolus*	13.5 (20.0)	3.1 ± 0.4
	**Capelin**	*Mallotus villosus*	15.0 (20.0)	3.2 ± 0.1
	**Great silver smelt**	*Argentina silus*	26.0 (70.0)	3.3 ± 0.3
	**Herring**	*Clupea harengus*	30.0 (45.0)	3.4 ± 0.1
	**Horse mackerel**	*Trachurus trachurus*	22.0 (70.0)	3.7 ± 0.0
	**Mackerel**	*Scomber scombrus*	30.0 (60.0)	3.6 ± 0.2
	**Norway pout**	*Trisopterus esmarkii*	19.0 (35.0)	3.2 ± 0.0
	**Sandeel**	*Ammodytes spp.*	13.5 (20.0)	3.1 ± 0.1
	**Sardine**	*Sardina pilchardus*	20.0 (27.5)	3.1 ± 0.1
	**Sprat**	*Sprattus sprattus*	12.0 (16.0)	3.0 ± 0.1

Legend:
Common name *Scientific name*
⇔ Common length in cm (max length)
▲ Trophic level

Table 1 List of the forage fish species covered in this study. Data source: FishBase[31]

The distribution of forage fish species in the Northeast Atlantic depends on environmental factors, oceanographic conditions, and species-specific preferences. Their presence is widespread in the region and in some cases also occurs in other adjacent waters, such as the Mediterranean Sea, the Black Sea, the Baltic Sea and the Arctic (see **Figure 1**). Their preferred habitats often coincide with zones of high productivity, such as upwelling zones, where nutrient-rich waters support abundant plankton, a key food source. Some species, like mackerel, undertake seasonal migrations based on temperature and food availability, while others, like herring and sprat, exhibit vertical migrations during day and night.[32,33]



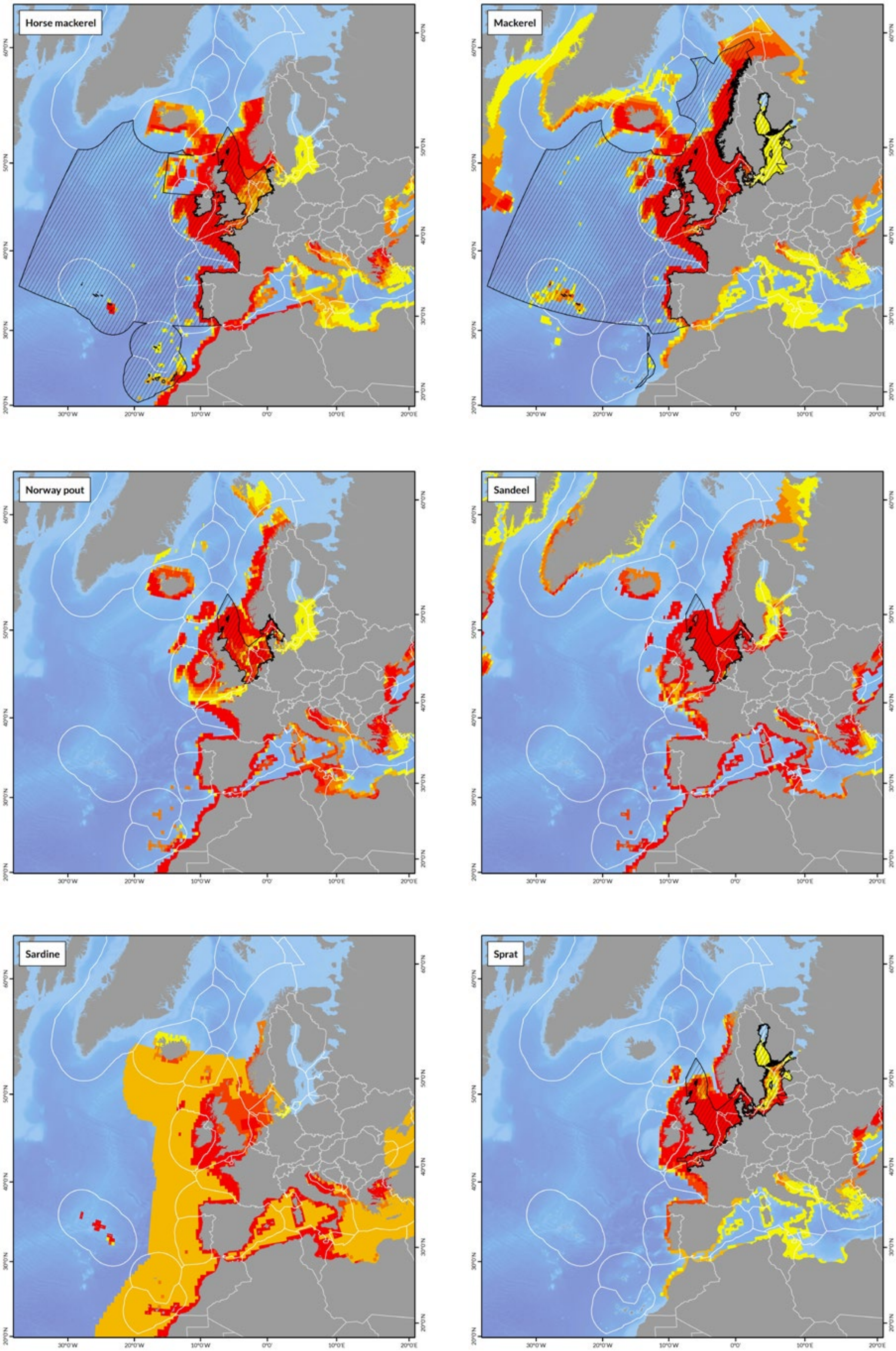


Figure 1 Distribution maps for the forage fish species included in this study. Note that for sardine, there is no area managed through catch limits. Data sources: FishBase[31] and AquaMaps[34] for species distribution, and EU fishing opportunities regulations for areas managed through catch limits

Numerous predators rely on forage fish species in the Northeast Atlantic. Using gut content data for the Northeast Atlantic from DAPSTOM, an integrated database and portal for fish stomach records, key marine fish predators of the main forage fish species managed through catch limits within the region can be identified (see **Figure 2**).[b,35] So, cod is a significant predator, particularly for capelin, herring, and Norway pout. Whiting is a primary predator of sprat and anchovy, while hake preys on mackerel and horse mackerel. Interestingly, herring, a forage fish species, is the major predator of sandeel larvae. As for Greater silver smelt, there were only two associated samples, which were divided between cod and whiting.

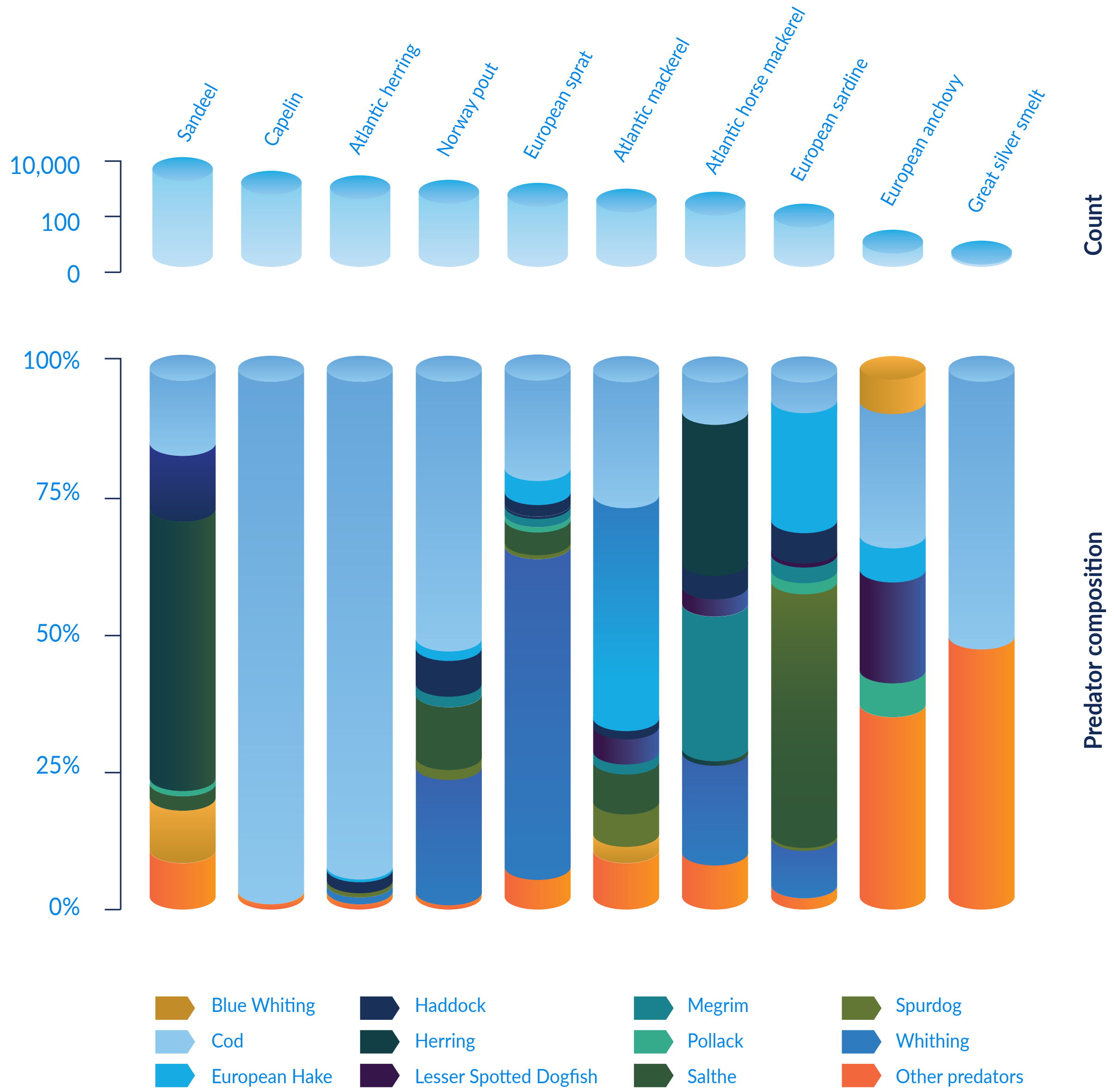


Figure 2 Key fish predators of forage fish within the Northeast Atlantic. Those constituting less than 5% of any forage fish predator compositions are labelled as 'Other Predators'. The top chart illustrates the amount of predator samples associated with each species. Data source: DAPSTOM

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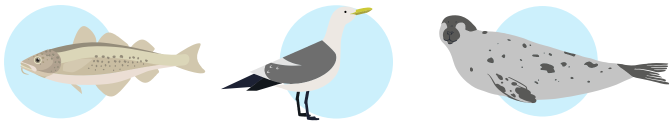
[b] For eight of the ten forage fish species highlighted in this report, this database contained a substantial number of predator samples associated with each species. However, for European anchovy and greater silver smelt, there were only a few associated samples. Therefore, the results for these species should be viewed with caution, as they are based on limited information.



Generally, forage fish frequently occurring in predators' diets constitute a larger proportion of those diets (see **Figure 3).** Sandeel, for example, occurred in over 60% of all observed predator diets and accounted for approximately 8% of the average predator diet. However, capelin represents an exception to this trend. While capelin occurs in only a few predators' diets (8.2%), it represents a large portion of the diet for those predators that do consume it— for instance, capelin made up 80% of the stomach contents for Greenland halibut. These results could be explained by the relative abundance of each of the forage fish species (i.e. the more abundant a species is, the more often it is found in predators diets), but also by the overlap in species distribution (e.g. halibut overlaps spatially much more with capelin than with any other forage fish species), underlining the ecological connectivity and dependence of these species.

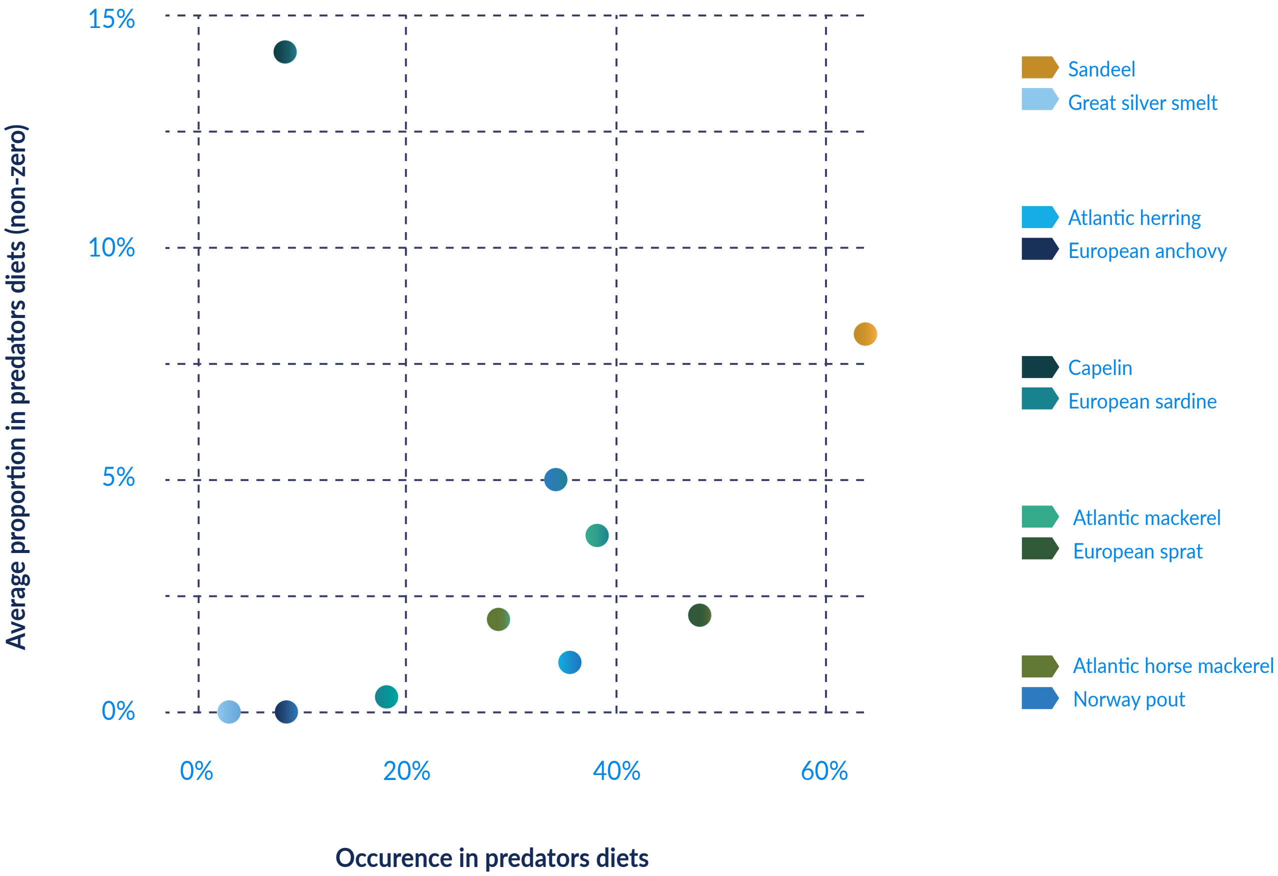


Figure 3 Relationship between the occurrence and average proportion of forage fish in predators' diets. Data source: DAPSTOM

“Forage fish… play a crucial role in the Northeast Atlantic concerning marine mammals”

Seabirds heavily rely on forage fish stocks, both globally and specifically in the Northeast Atlantic.[36] For instance, in the North Sea, sandeel plays a vital role in many seabird diets and years of poor sandeel abundance have been shown to impact the breeding success of regional seabird populations.[37] This connection is crucial as the success of breeding seabird populations is considered to be a good indicator of ecosystem health.[38] Specific examples of seabirds species in the NE Atlantic that rely on forage fish like sandeel, sprat and herring include Atlantic puffins (*Fratercula arctica*), Northern gannets (*Morus bassanus*), razorbills (*Alca torda*), black-legged kittiwakes (*Rissa tridactyla*) and European shags (*Phalacrocorax aristotelis*), among many others.

Forage fish also play a crucial role in the Northeast Atlantic concerning marine mammals. They serve as a primary food source for many marine mammal species, providing essential nutrients and energy that support their survival, reproduction, and behaviour. For example, harbor porpoises (*Phocoena phocoena*) predominantly feed on species like herring and sprat, significantly influencing their population dynamics and overall health.[39] Common dolphins (*Delphinus delphis*) are opportunistic feeders, often targeting schools of forage fish such as horse mackerel, Norway pout, sardines and mackerel[40,41]. The availability of forage fish strongly influences the distribution and behaviour of common dolphins in the region.[42] Minke whales (B*alaenoptera acutorostrata*) primarily feed on small schooling fish like herring and sandeel.[43] Grey seals (*Halichoerus grypus*), one of the most common seal species in the NE Atlantic, heavily rely on herring, sprat and sandeels as important prey items.[44,45] As in the case of the seabirds, changes in the availability of sandeels due to overfishing or other factors can have significant implications for grey seal populations. Harbour seals (*Phoca vitulina*) feed on a variety of forage fish species, including herring and sprat, which are vital for their growth and reproductive success.[46]

3. Management and status of the main forage fish

The management of fish species operates within a sound fisheries regulatory framework, domestic regulations, and international agreements[19,47,48] that, if well implemented, would ensure their sustainable exploitation. The primary and shared objective within the regulatory framework for forage fish stocks is to restore and maintain their stocks above biomass levels that can produce the MSY.[c,19,47,48,49,36] While this approach may be sustainable for the forage fish stocks themselves, it may not necessarily be sustainable for the species that depend on them and the overall ecosystem.

Considering the broad distribution of numerous forage fish species across waters extending beyond a single coastal state (see **figure 1**), the effective management of their fish stocks, including catch limits, requires international negotiations. While certain international negotiations are successful in reaching agreements for shared stocks, such as the EU-UK agreements on annual fishing opportunities, others have proven to be more challenging. The latter situation impacts some of the largest fish stocks in the European waters, including mackerel and blue whiting. In these two cases the absence of agreement on allocation key for respective quota shares has resulted in the adoption of unilateral quotas by different involved parties (i.e. EU, Faroe Islands, Greenland, Norway, Russia and since 2020 the UK). The sum of all unilateral quotas regularly exceeds the scientific advice on catch limits resulting in overfishing.

To ensure that fishing activities minimize their negative impacts on the marine ecosystem and avoid the degradation of the marine environment, the regulatory frameworks for European fish stocks also include the obligation to implement the ecosystem-based approach to fisheries management.[d] Additionally, fishing activity should contribute to achieving the Good Environmental Status of the marine environment as set out in the EU Marine Strategy Framework Directive.[50] However, despite this legal obligation and the important role of forage fish in the marine ecosystem, decision-makers have been slow to adopt measures to implement the EBFM approach for forage fish species.[18]

The setting of catch limits is the most important tool to control the exploitation rate of commercial fish stocks and make progress towards agreed management objectives. As a result, the most relevant forage fish stocks of commercial interest are managed through annual catch limits (Total Allowable Catches; TACs), expressed in weight (tonnes), with quotas assigned to the relevant parties. Decisions on TACs are adopted by different decision-makers depending on the stock and based on scientific advice provided by the International Council for the Exploration of the Sea (ICES). In instances of critical stock status, such as capelin, the

[c] For examples refer to Common Fisheries Policy Article 2.2, UK Fisheries Act 1.(3).(b), EU-UK TCA Fish.2.2, or Sustainable Development Goal target 14.4

[d] For examples, see Common Fisheries Policy Article 2.3, UK Fisheries Act 1.(4), EU-UK TCA Fish.3 (e), or Sustainable Development Goal target 14.2

established TACs are exclusively allocated for accidental catches (referred to as “by-catch TACs”) causing them to no longer be considered as target stocks. Conversely, in certain instances like for the Irish Sea, Celtic Sea, and southwest of Ireland herring stocks witness the exclusive allocation of TACs to vessels participating sentinel fishery.[e]

While scientific advice on setting catch limits for forage fish usually considers the high natural variability of these species[f], it does not fully incorporate the ecosystem considerations of these species. In a promising move to address this, this year the EU and UK agreed to submit a special request to ICES, asking to provide information on how ecosystem considerations, particularly predator-prey interactions and the rebuilding of sensitive higher trophic level species such as certain seabirds, and other ecosystems-based fisheries management aspects are factored in and applied in the provision of single stock advice for forage fish species.[51] This request represents a crucial step in identifying gaps and opportunities for including ecosystem considerations in the scientific advice on the management of forage fish in Europe.

Forage fish stocks, like other Northeast Atlantic stocks managed through TACs, are affected by the landing obligation, which is also known as the ‘discard ban’.[52] This means that during fishing activities, all catches of these stocks by the EU fleet must be retained on board, recorded, landed, and counted against the quotas. Despite efforts to implement the landing obligation, non-compliance is widespread across EU fishing fleets, unreported discarding continues, and the landing obligation is not effectively controlled posing significant risk to the sustainable exploitation of stocks covered by these provisions, such as forage fish.[53] However, it is worth noting that, exceptionally, discards for many forage fish in most of their fisheries are considered to be negligible.[54]

European countries also adopt technical measures to regulate the operation of fishing fleets, particularly the exploitation pattern of fishing activity (i.e. how fishing mortality is distributed across different fish species and their age compositions). This exploitation pattern is related to selectivity and determined by the characteristics of fishing gear (e.g. mesh size), area, and the seasonal distribution of fishing. With the aim of ensuring the protection of juveniles, countries set species-specific minimum conservation reference sizes or minimum landing sizes.

[e] A sentinel fishery refers to fishing operations that specifically targets certain fish stock(s), aiming to collect fisheries and environmental data, with the aim of monitoring the stock abundance.

[f] The ICES approach for MSY based management of numerous short-lived species, such as most of the forage fish, is the escapement strategy (i.e. to maintain spawning stock biomass above MSY $B_{trigger}$ and B_{lim} after the fishery has taken place). This can often be combined with an F_{cap}, or upper cap on fishing pressure, particularly when stocks are short-lived and/or unpredictable. For some short-lived species ICES recommends an escapement strategy with a cap on fishing pressure (F_{cap}).

Common Name	Stock		Fishing Pressure	Stock Size (tonnes)
Anchovy	ane.27.9a	Western component	Unknown	73 414
		Southern component	Unknown	4 402
Capelin	cap.27.2a514		Unknown	612 842
	cap.27.1-2		Unknown	1 437 960
Greater silver smelt	aru.27.123a4		Unknown	Unknown
	aru.27.5b6a		0.240	84 488
	aru.27.6b7-1012		Unknown	Unknown
Herring	her.27.6aN		Unknown	Unknown
	her.27.6aS7bc		Unknown	Unknown
	her.27.1-24a514a		0.192	3 531 608
	her.27.28		0.317	139 870
	her.27.20-24*		0.044	85 431
	her.27.irls*		0.048	22 149
	her.27.3a47d		0.238	1 480 607
	her.27.nirs		0.254	25 569
	her.27.25-2932*		Unknown	Unknown
	her.27.3031		0.250	410 006
Horse mackerel	hom.27.2a4a5b6a7a-ce-k8*		0.072	754 163
	hom.27.9a		0.020	1 214 200
	hom.27.3a4bc7d		Unknown	Unknown
Mackerel	mac.27.nea		0.360	3 769 326
Norway pout	nop.27.3a4		0.218	122 199
Sandeel	san.sa.1r		0.025	146 825
	san.sa.2r		0.680	73 350
	san.sa.3r		0.330	178 439
	san.sa.4		0.036	97 538
	san.sa.5r		Unknown	Unknown
	san.sa.6		Unknown	Unknown
	san.sa.7r		Unknown	Unknown
Sprat	spr.27.22-32		0.350	903 773
	spr.27.3a4		Unknown	206 581
	spr.27.7de		Unknown	Unknown

* Forage fish stock in critical status. The abundance level of the stocks is below safe biological limits (i.e. $SSB<B_{lim}$) or considered to be below any possible biomass reference point

Table 2 Stock size and exploitation rate of stocks of forage fish species included in this study and managed through catch limits in the Northeast Atlantic. The colours in the columns represent the following: **Fishing pressure**: Green: $F < F_{MSY}$; Red: $F > F_{MSY}$; Blue: F unknown or no reference points have been defined for this stock. **Stock size**: Green: $SSB > B_{MSY\ proxy}$; Red: $B_{MSY\ proxy} > SSB$; Blue: B unknown or no reference points have been defined for this stock. Cases for which ICES is not able to identify a value of F or B (i.e Unknown) but suggests that their values could be above or below sustainable values, the boxes have been coloured accordingly. Data source: 2021-2023 ICES stock assessment reports

The status of forage fish stocks, as outlined in **Table 2**, reveals a multifaceted scenario marked by distinct challenges. A key driver of their poor performance can be attributed to the consistent and substantial fishing mortality observed over preceding years. This sustained trend is underpinned by a recurring deviation from recommended sustainable catch limits based on scientific guidelines.[55,56]

Among the 32 forage fish stocks[g] analysed in the **Table 2**, only 31% (ten stocks) are identified as being sustainably exploited ($F<F_{MSY}$), while 25% (eight stocks) are classed as being subject to overfishing ($F>F_{MSY}$). Regarding abundance levels, 47% (15 stocks) are deemed to have a healthy size ($B>B_{MSY}$), whilst 22% (seven stocks) are considered to be in a bad condition ($B<B_{MSY}$) with four of them in critical status ($B<B_{lim}$), these are her.27.20-24, her.27.irls, her.27.25-2932, and hom.27.2a4a5b6a7a-ce-k8. Indicators for fishing mortality and stock abundance were unavailable or impossible to compare with corresponding reference points for 44% (14 stocks) and 31% (ten stocks), respectively (see **Figure 4**).

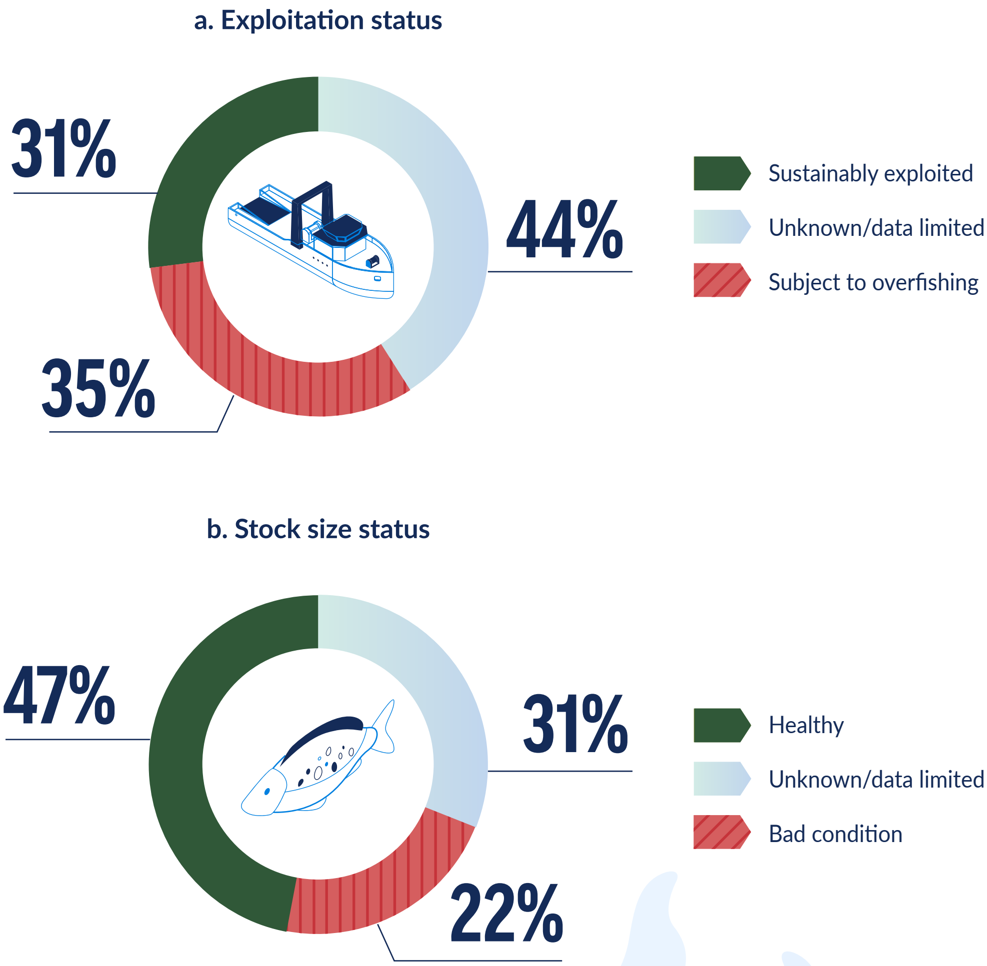


Figure 4 Exploitation status (a) and stock size (b) of stocks of forage fish species included in this study and managed through catch limits in the Northeast Atlantic. Data source: ICES stocks assessment

[g] For the purposes of this report the anchovy 27.9a stock is counted as two different stocks since the scientific assessment by ICES discriminates between two components, the western and the southern, which show differences in terms of conservation and exploitation status.

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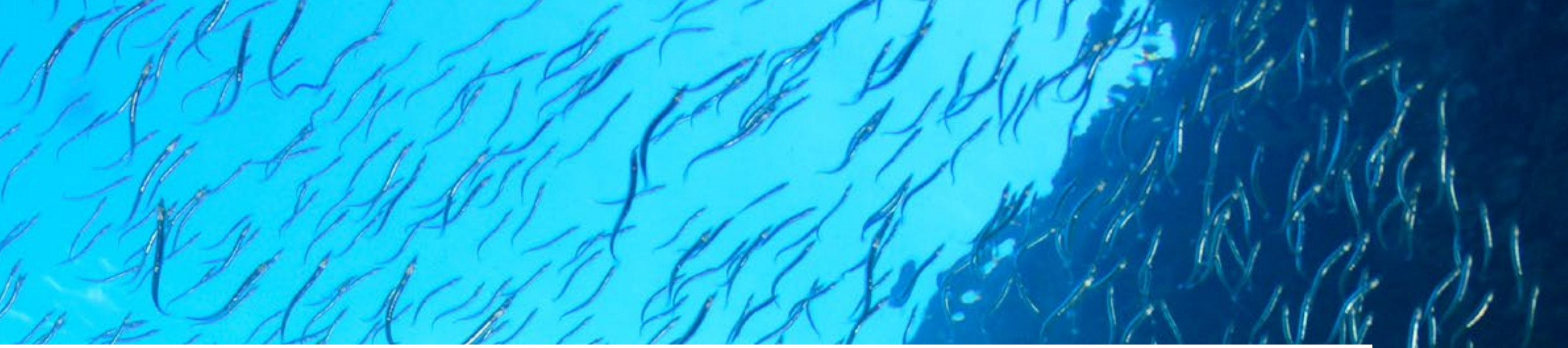


The lack of comprehensive information on stocks, ecological dynamics and biological traits of forage fish introduces an inherent uncertainty in stock estimations (as exemplified by the case of greater silver smelt 27.123a4). This uncertainty, in turn, can lead to an overestimation of stock status (as observed in the case of herring 27.i.rls) and subsequently compromises stock management effectiveness. This situation is further exacerbated by the misreporting of catches as other species (as shown with herring 27.25-2932)[57] and, in some cases, inadequate monitoring of spawning eggs (as noted with horse mackerel 27.2a4a2a4a5b6a7a-ce-k8). The complexity deepens as these stocks often span diverse jurisdictional boundaries, often with divergent management approaches and lacking a cohesive unified strategy in these countries. This disjointedness can lead to the establishment of unilateral TACs that collectively surpass scientific recommendations, resulting in the potential for overfishing at the beginning of this section for some shared fish stocks (e.g. mackerel 27.nea). The imposition of rigid management strategies limits the ability of fisheries to swiftly respond to unforeseen changes in stock status.

However, the state of forage fish species stocks extends beyond fishing pressure alone and it is shaped as well by a complex interplay of factors. Human activities such as sand and gravel extraction, dredge spoil dumping, and waste discharge from fish cages along with dam constructions, can imperil essential fish habitats, such as spawning and nursery habitats. This degradation or loss of critical fish habitats can impact stock health and recruitment, evident in cases such as herring 27.i.rls, herring 27.2 5-2932, and anchovy 27.9a.

Climate change is affecting the distribution and abundance of forage fish, aside from impacting the availability of plankton on which forage fish depend. This is causing challenges for managing fisheries. It is already anticipated to have repercussions on young forage fish being born, as expected in the case of Norwegian Spring Spawning herring. Changes in distribution and abundance of pelagic species crossing jurisdictional boundaries is also predicted to likely complicate negotiations on fishing rights allocations over shared stocks. This might lead to too much fishing, which could harm the fish stock.[58,59] Some types of forage fish, such as greater silver smelt and Norway pout, are especially sensitive to climate changes in the region. According to FishBase, they are among the species most at risk within the forage fish managed.[31,60] These findings underscore the pressing necessity for long-term management strategies aimed at fortifying the resilience of these pivotal forage fish stocks against the backdrop of evolving environmental conditions.

"Climate change is affecting the distribution and abundance of forage fish, aside from impacting the availability of plankton on which forage fish depend"

4. Exploitation of the main forage fish[h]

Forage fish catches hold significant relevance in both volume and value across Europe's fisheries sector. Despite their relatively smaller size compared to other commercial fish species, their widespread distribution and abundance make them a substantial component of fisheries landings. Within the Northeast Atlantic, the catch volumes of forage fish vary widely among them, with herring, sprat and mackerel emerging as the primary contributors in terms of volume, amounting to 632 100 tonnes, 363 000 tonnes and 301 400 tonnes, respectively. Mackerel and herring take the lead in value of landings, constituting €399 million and €264 million, respectively. Among the ten analysed species, capelin stands as the most valuable per tonne, while Norway pout, sprat and sandeel represent the species with the least average value per tonne (see **Table 3** for other reference).

Common Name	Value (in €) per (tonne of) landing	Total Landed Value (million €)	Total Landed Weight (thousand tonnes)
Anchovy	888	64.8	40.2
Capelin	**2 522**	< 0.1	< 0.1
Greater silver smelt	546	2.6	5.2
Herring	386	264.1	**632.1**
Horse mackerel	606	66.9	90.4
Mackerel	976	**399.2**	301.4
Norway pout	245	7.8	29.8
Sandeel	195	22.6	87.7
Sardine	884	60.0	52.4
Sprat	222	80.6	363.0

Table 3 Average value (in euros) per forage fish landing (in tonnes) for the period 2015-2019, total value and weight of forage fish landings (2019). Data corresponding to EU and UK fleets. The figures in bold in the three columns indicate the highest-ranking species per category. Data source: STECF Fisheries Dependent Information (2019)

The United Kingdom emerges as the predominant catcher of mackerel in the region, while herring displays a more diverse catchment, involving countries such as Denmark, Finland, Germany, the Netherlands, Sweden, and the United Kingdom. Denmark, with its significant catch volumes for species such as herring, sprat and sandeel, is identified as a key country with interests in these forage fisheries in the Northeast Atlantic (see **Figure 5.b**). Catches are used not only for direct human consumption, but also as crucial inputs for fishmeal and fish oil production, which find widespread applications in aquaculture, agriculture, and diverse industries. In fact, catches of capelin, some herring stocks, blue whiting, sprat, sandeel and Norway pout are almost exclusively used for fishmeal and fish oil.

[h] Due to the atypical developments in the fisheries sector over recent years, stemming from the COVID pandemic and the substantial surge in fuel costs triggered by the Russian invasion of Ukraine, the socio-economic information on fishing activity in this chapter refers to the year 2019.

Use of catches has implications on value, for example while both mackerel and sprat fisheries catch comparable landings, mackerel outshines sprat in terms of value, boasting landings that are roughly threefold more valuable (see **Figure 5.a**). This discrepancy primarily stems from divergent utilisation patterns: mackerel is primarily destined for human consumption, whereas sprat and other forage fish often find their way into fish oil, fishmeal, and other derived products. Uses of forage fish for non-human consumption has raised questions, given that the production of these feeds involve the capture of wild fish carrying implications in the status of forage fish and species dependent on them. It is expected that the world demand for fishmeal and fish oil could surpass the supply of forage fish as early as 2037,[61] representing a challenging for the conservation of forage fish.

a. Mean total landings value (€) 2015 - 2019

b. Mean total landings (tonnes) 2015 - 2019

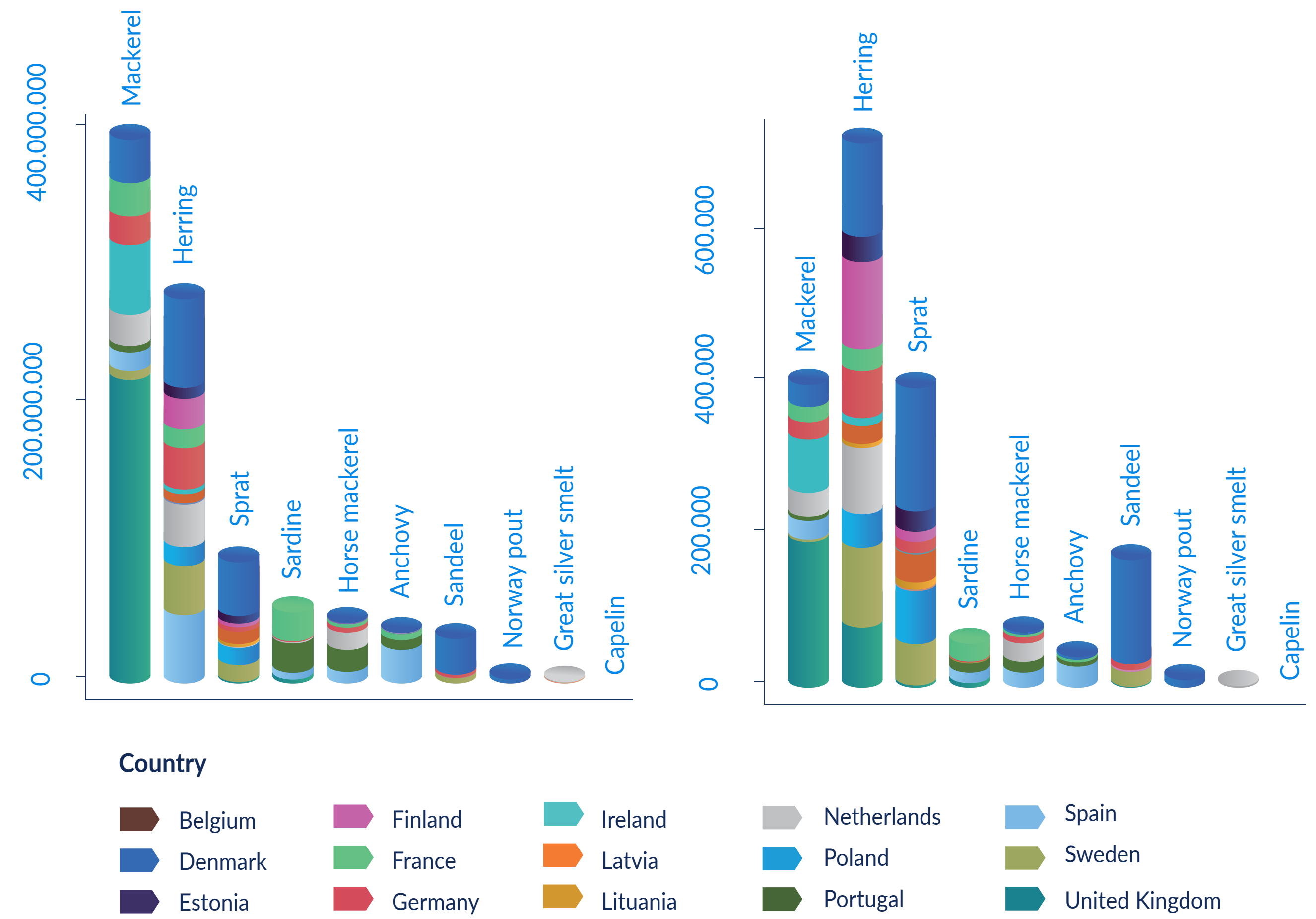


Figure 5 Summary of the fleets targeting forage fish species in the Northeast Atlantic. Mean yearly landings (value) per species (a). Mean yearly landings (tonnes) per species (b). Data source: STECF Fisheries Dependent Information (2019)

Forage fish are mainly caught using three main types of gear: pelagic trawlers (TM), demersal trawlers and seiners (DTS), and purse seiners (PS) (see **Figure 6a**). On average, over 400 demersal trawlers/seiners and 400 purse seiners operate in these fisheries annually, while over 200 pelagic trawlers are active in the Northeast Atlantic each year. Vessels measuring less than 12 m, employing passive gears or hooks represent less than 100 vessels each year (refer to **Figure 6b**). Most purse seiners vessels are of Spanish and Portuguese origin, primary method for anchovy and sardine harvesting. Denmark, France, and Spain encompass the majority of demersal trawl/seine vessels. Conversely, pelagic trawlers hail from various member states. Vessels under 12 m with passive gear are primarily Estonian, while all hook-based vessels are attributed to Spain. However, as demonstrated below, the catch volume does not necessarily correspond with the number of vessels.

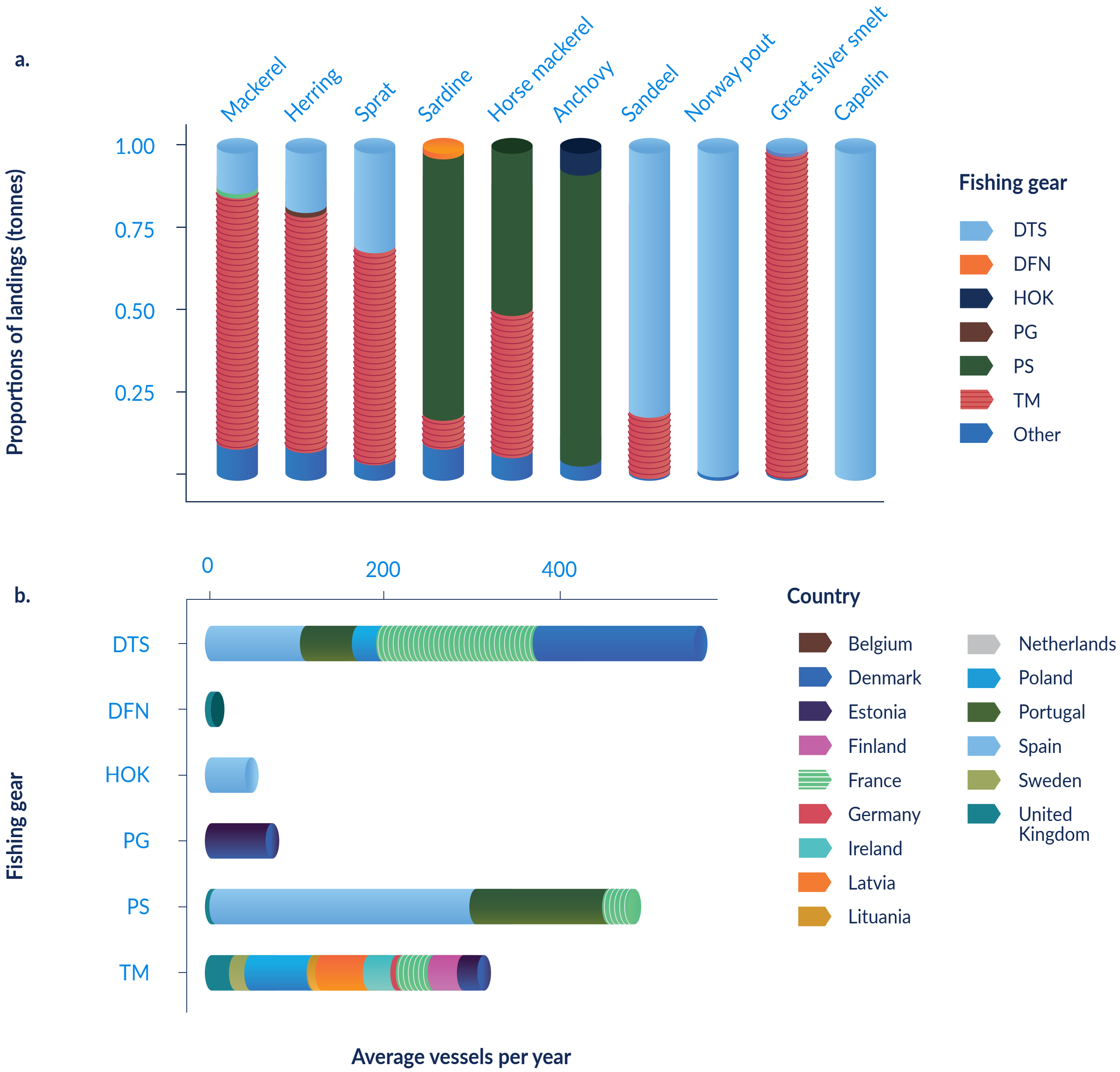


Figure 6 Proportion of landings (weight) by gear type. Fleets that account for less than 1% of total landings are labelled "Other" (a). Average number of vessels per gear type per country in the Northeast Atlantic (b). Gear type abbreviations: DTS (Demersal trawlers/seiners), DFN (Drift or fixed netters), HOK (Hooks), PG (Passive gear on vessels of < 12m), PS (Purse seiners), TM (Pelagic trawlers) Data source: STECF Fisheries Dependent Information (2019)

Crew engagement varies substantially across these fleet types. Purse seiner fleets typically have a larger crew (600-900) at any given time, in contrast to pelagic trawler fleets with fewer crew members (<300, see **Figure 7a**). However, a different pattern emerges concerning average crew earnings. Purse seiners yield lower individual crew earnings, whereas larger pelagic trawlers (vessels measuring 40m and above) and demersal trawlers/seiners boast the highest crew earnings (€100,000, see **Figure 7b**). This scenario brings the possibility that this trend of increased employment is primarily propelled by the considerably higher total landed value of mackerel and herring in contrast to other species.

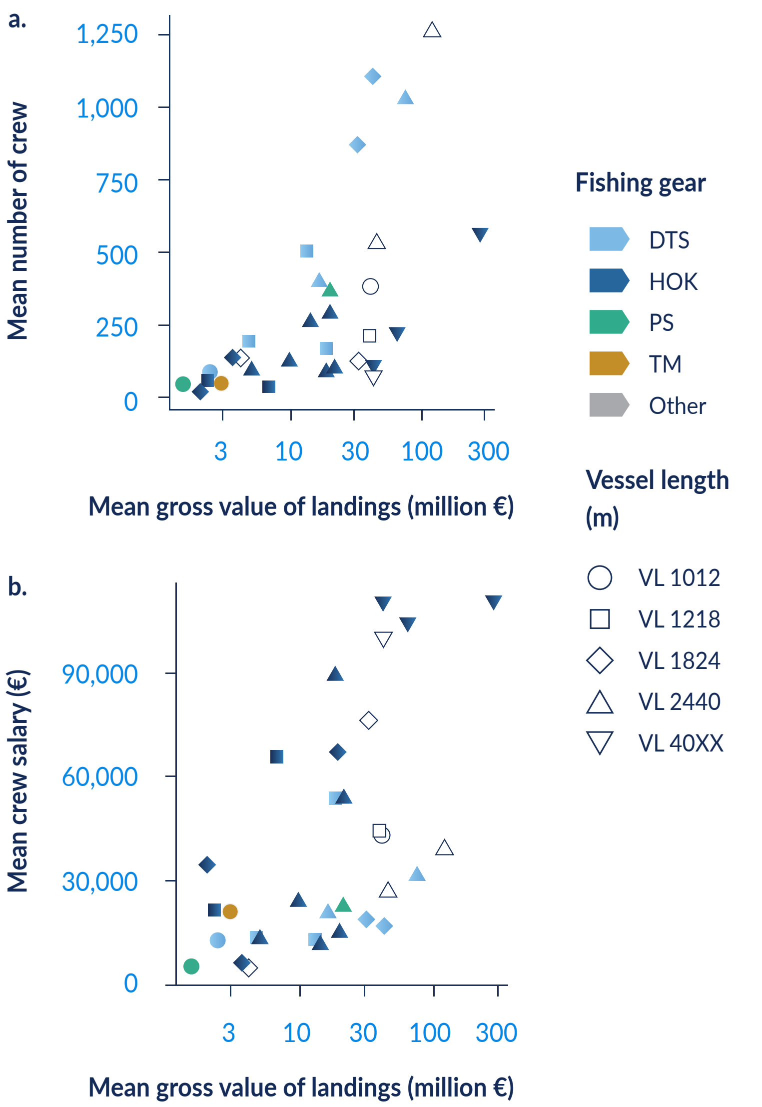


Figure 7 Mean gross landing value per fleet versus mean crew count per fleet (a). Mean gross landing value versus mean crew salary per fleet (b). In graphs a and b, colour represents the fishing gear (DTS - demersal trawlers/seiners in red, HOK – hooks in red, PS - purse seiners in purple, TM - pelagic trawlers in brown, other in grey) while shape represents vessel length. Vessel length abbreviations indicate a range of values, for example VL1012 indicates a vessel length range from 10 to 12m. VL40XX is all vessels 40m and larger. Data source: STECF FDI (2019)

5. Conclusions and recommendations

Northeast Atlantic forage fish, such as sandeel, sprat, and mackerel, play a critical role as fundamental links in marine ecosystems, serving as a primary food source for a variety of predators. Forage fish frequently occur in a range of predators' diets including seabirds, marine mammals, and economically important fish. In many instances, they constitute a substantial proportion of these predators´ dietary intake.

The prevailing fisheries management approach for European fish stocks, which centres around maximizing catches (MSY) through catch limits based on single-species advice, does not provide guarantees for adequately exploiting forage fish stocks. While the current approach may be sustainable for the forage fish stocks themselves, it is not necessarily sustainable for the species that depend on them, as the MSY strategy may not ensure an adequate food supply for them, and for the ecosystem at large.

Despite the commitment in the regulatory framework for fish stocks to be fished sustainably and maintained above healthy levels, the status of forage fish stocks varies widely. Among the 32 forage fish stocks analysed in this report, only 16% (five stocks) are known to be both sustainably exploited (F<FMSY) and at healthy abundance levels (B>BMSY proxy). The rest of the stocks are either subject to overfishing (F>FMSY) and/or are at worrying abundance levels (B<BMSY) and/or their exploitation and conservation status is unknown due to data limitations.

Scientific advice for forage fish management, including on catch limits, is limited and does not comprehensively integrate ecosystem considerations. The incomplete collection of data on fishing activities, lack of understanding of stock dynamics, migratory patterns, and interrelationships of forage fish species above and below their food web position, are among the factors limiting the quality of advice and hampering informed decision-making. Nevertheless, recent endeavours by the EU and UK to engage with ICES in integrating ecosystem considerations, particularly pertaining to predator-prey interactions, are noteworthy strides in improving management approaches.

In the Northeast Atlantic European fisheries sector, forage fish play a key role both in terms of volume and value of landings. However, there is notable variation among species as regards these volumes and values, with herring and mackerel being prime contributors, whereas other species like greater silver smelt and Norway pout make minimal contributions in both catch volume and economic value. The main methods employed for catching forage fish are demersal trawlers/seiners, purse seiners, and pelagic trawlers. Catches are intended for direct human consumption, as well as for industrial use including the production of fishmeal and fish oil for agricultural and aquaculture purposes.

Embracing an EBFM approach presents a promising path to integrate ecosystem considerations concerning forage fish. Nonetheless, challenges hinder the effective implementation of EBFM, such as existing gaps in fisheries data, limited understanding on interactions of forage fish species, and the intricate impacts of environmental shifts. To bolster the sustainable exploitation and conservation of forage fish and forage fish-dependent species, decision-makers in the Northeast Atlantic should consider implementing the following recommendations:

1. Set precautionary catch limits

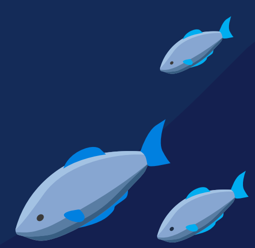
Given the current absence of comprehensive scientific advice that integrates ecosystem considerations, decision-makers should adopt a more precautionary approach to setting annual catch limits for forage fish stocks. Setting catch limits well below the advised maximum sustainable level (i.e. well below the F_{MSY} or F_{pa} point value) will help restore and maintain the abundance of forage fish species at more cautious levels regarding their ecological role. This would increase their resilience to environmental pressures and account for stock uncertainties. The adoption of any catch limit for a given forage fish stock must be contingent upon maintaining the stock's abundance above the B_{MSY} reference point. This approach should be maintained until more comprehensive scientific advice and management strategies become available (see points 2 and 4 on the right).

2. Integrate ecosystem considerations into scientific advice

Scientific advice for forage fish must comprehensively integrate ecosystem considerations, like species' interdependence and environmental influences, including climate change. To this end, resources should be allocated for research to improve knowledge about these species and to implement ecosystem models that define new reference points for stock assessments. A general cut-off biomass trigger reference point (e.g. 20-40% unexploited biomass)[62] could be considered to identify when the biomass of a forage fish stock nears levels risking harm to the ecosystem and requiring prompt action. Pending such new reference points, an interim goal of achieving 75% unexploited biomass could curb ecosystem impacts while enabling acceptable yields of low–trophic level species.

3. Enforce long-term management strategies

Northeast Atlantic decision-makers must adopt a robust approach to managing forage fish stocks. Long-term management strategies must be aligned with objectives aiming to maintain stock abundance within ecological limits, and balance socio-economic considerations and ecological risks. To be effective, these strategies, together with the related EBFM scientific advice, must be regularly tested and updated through management strategy evaluations. This will provide a structured and up-to-date framework to take informed decisions and sustainably manage these stocks.



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4. Safeguard essential forage fish habitats

Northeast Atlantic decision-makers must put in place spatial and temporal restrictions to human activities that harm habitats critical for the biological and ecological needs of forage fish. Protecting habitats integral to the life cycle of forage fish, including spawning, nursery, and feeding grounds, will significantly improve their reproductive success and overall stock growth. An example of this recommendation, which has been suggested by ICES for years for certain herring fish stocks, is to ban the dumping of dredge spoil and the extraction of marine aggregates from herring spawning grounds, unless the effects of these activities have been assessed and shown not to be detrimental.

5. Conduct comprehensive ecosystem impact assessments and implement a moratorium on new large-scale fisheries

The complex interactions within marine ecosystems and the role of forage fish in them makes it necessary to assess the full impact of forage fish fisheries. Northeast Atlantic countries should make mandatory comprehensive ecosystem impact assessments concerning existing forage fish fisheries. In the absence of such assessments, fishing for forage fish species that are crucial components of the marine ecosystem, such as sandeel, or that are not relevant either in terms of catch volume or economic value, such as greater silver smelt and Norway pout, should be banned. These impact assessments should prove that any activities taking place do not negatively impact the targeted forage fish species, their habitats, dependent species reliant on them, or the overall functioning of the marine ecosystem. A moratorium on new large-scale fisheries targeting forage fish is recommended due to uncertainties regarding the impact and potential disruption caused by these fisheries on the resilience and equilibrium of marine ecosystems.

6. Adopt collaborative and adaptative cross-boundary management strategies

It is imperative for parties exploiting shared stocks to jointly agree on management objectives and measures to ensure their sustainable exploitation, which is difficult to achieve through unilateral action alone. The current situation, with the mackerel dispute on quota shares that has led to overfishing, is untenable. Northeast Atlantic decision-makers must improve coordination, harmonize objectives, and streamline assessments of shared stocks. Shared strategies should be adaptative and responsive to evolving conditions and address multifaceted challenges, like stock abundance changes, distribution shifts, and potential neighbouring country conflicts.

7. Improve data collection

Northeast Atlantic countries should increase scientific surveys and monitoring of fishing activity for all types of catch (i.e. landings, discards, and recreational fisheries), to bolster the reliability of data, reduce misreporting and decrease mislabelling (e.g. of sprat and herring). This will help to address stock information gaps, improve stock assessments, and help make well-informed decisions to better manage stocks.

8. Promote an ethical use of forage fish

Europe must prioritise a sustainable but also ethical use of living marine biological resources. The use of a significant proportion of the catches of forage fish for industrial purposes (i.e. not for direct human consumption) has raised questions stemming from the potential conflict between human needs and the ecological importance of forage fish. Given their pivotal role in marine ecosystems and the potential consequences of disrupting predator-prey dynamics, ethical concerns arise about prioritising catch use for industrial purposes over prioritising the health of the ecosystem and preserving biodiversity. This dilemma highlights the need to balance human interests with broader ecological considerations.

6. References

[1] Santos, M. B., German, I., Correia, D., Read, F. L., Martinez Cedeira, J., Caldas, M., López, A., Velasco, F., & Pierce, G. J. (2013). Long-term variation in common dolphin diet in relation to prey abundance. Marine Ecology Progress Series, 481, 249–268. https://doi.org/10.3354/meps10233

[2] Smout, S., Rindorf, A., Hammond, P.S., Harwood, J., & Matthiopoulos, J. (2014). Modelling prey consumption and switching by UK grey seals, ICES Journal of Marine Science, 71(1), 81–89, https://doi.org/10.1093/icesjms/fst109

[3] Certain, G., Masse, J., Van Canneyt, O., Petitgas, P., Doremus, G., Santos, M. B., & Ridoux, V. (2011). Investigating the coupling between small pelagic fish and marine top predators using data collected from ecosystem-based surveys. Marine Ecology Progress Series, 422, 23–39. https://doi.org/10.3354/meps08932

[4] Saraux, C., Sydeman, W., Piatt, J., Anker-Nilssen, T., Hentati-Sundberg, J., Bertrand, S., & Crawford, R. J. M. (2021). Seabird-induced natural mortality of forage fish varies with fish abundance: evidence from 5 ecosystems. Fish and Fisheries, 22, 262–279. https://doi.org/10.1111/faf.12517.

[5] Rochet, M.-J., Collie, J. S., & Trenkel, V. M. (2013). How Do Fishing and Environmental Effects Propagate Among and Within Functional Groups? Bulletin of Marine Science, 89(1). https://doi.org/10.5343/bms.2011.1138

[6] Pikitch, E., Boersma, P.D., Boyd, I.L., Conover, D.O., Cury, P., Essington, T., Heppell, S.S., Houde, E.D., Mangel, M., Pauly, D., Plagányi, É., Sainsbury, K., & Steneck, R.S. (2012). Little Fish, Big Impact: Managing a Crucial Link in Ocean Food Webs. Lenfest Ocean Program. Washington, DC. 108 pp. https://www.lenfestocean.org/~/media/legacy/Lenfest/PDFs/littlefishbigimpact_revised_12june12.pdf?la=en

[7] Chassot E, Bonhommeau S, Dulvy NK, Mélin F, Watson R, Gascuel D, & Le Pape O. Global marine primary production constrains fisheries catches. Ecology Letters. 2010;13:495–505. https://doi.org/10.1111/j.1461-0248.2010.01443.x

[8] Saba, G. K., Burd, A. B., Dunne, J. P., Hernández-León, S., Martin, A. H., Rose, K. A., Salisbury, J., Steinberg, D. K., & Hatje, V. (2021). Toward a better understanding of fish-based contribution to ocean carbon flux. Limnology and Oceanography, Advance online publication. https://doi.org/10.1002/lno.11709

[9] Shelton, A. O., Samhouri, J. F., Stier, A. C., & Levin, P. S. (2014). Assessing trade-offs to inform ecosystem-based fisheries management of forage fish. Scientific Reports, 4, 7110. https://doi.org/10.1038/srep07110

[10] Essington, T. E., Moriarty, P. E., Froehlich, H. E., Stawitz, C. C., & Kareiva, P. (2015). Fishing amplifies forage fish population collapses. Proceedings of the National Academy of Sciences, 112(21), 6648-6652. https://doi.org/10.1073/pnas.1422020112

[11] Schwartzlose, R. A., Alheit, J., Bakun, A., Baumgartner, T. R., Cloete, R., Crawford, R. J. M., ... Zuzunaga, J. Z. (2010). Worldwide large-scale fluctuations of sardine and anchovy populations. South African Journal of Marine Science, 21(1), 289-347. https://doi.org/10.2989/025776199784125962

[12] Giron-Nava, A., Ezcurra, E., Brias, A., Velarde, E., Deyle, E., Cisneros-Montemayor, A. M., Munch, S. B., Sugihara, G., & Aburto-Oropeza, O. (2021). Environmental variability and fishing effects on the Pacific sardine fisheries in the Gulf of California. Canadian Journal of Fisheries and Aquatic Sciences. Advance online publication. https://doi.org/10.1139/cjfas-2020-0010

[13] Anderson, C. N. K., Hsieh, C., Sandin, S. A., Hewitt, R., Hollowed, A., Beddington, J. R., May, R. M., & Sugihara, G. (2008). Why fishing magnifies fluctuations in fish abundance. Nature, 12(4), 381–389. https://doi.org/10.1038/nature06851 https://doi.org/10.1038/nature06851

[14] Hsieh, C., Reiss, C. S., Hunter, J. R., Beddington, J. R., May, R. M., & Sugihara, G. (2006). Fishing elevates variability in the abundance of exploited species. Nature, 443(7113), 859–862. https://doi.org/10.1038/nature05232

[15] Lindegren, M., Van Deurs, M., MacKenzie, B. R., Clausen, L. W., Christensen, A., & Rindorf, A. (2017). Productivity and recovery of forage fish under climate change and fishing: North Sea sandeel as a case study. Fisheries Oceanography, Advance online publication. https://doi.org/10.1111/fog.12246

[16] Murray, C. S., Wiley, D., & Baumann, H. (2019). High sensitivity of a keystone forage fish to elevated CO2 and temperature. Conservation Physiology, 7(1), coz084. https://doi.org/10.1093/conphys/coz084

[17] Karnauskas, M., Walter III, J. F., Kelble, C. R., McPherson, M., Sagarese, S. R., Craig, J. K., Rios, A., Harford, W. J., Regan, S., Giordano, S. D., & Kilgour, M. (2021). To EBFM or not to EBFM? that is not the question. Fish and Fisheries, Advance online publication. https://doi.org/10.1111/faf.12538

[18] European Climate, Infrastructure and Environment Executive Agency. (2022). The implementation of ecosystem-based approaches applied to fisheries management under the CFP (EASME/EMFF/2018/011 Specific Contract Lot 1 No.1, EASME/EMFF/2018/011 Specific Contract Lot 2 No.3, Final Report). Luxembourg: Publications Office of the European Union. https://doi.org/10.2926/57956

[19] European Union. (2013). Regulation (EU) No 1380/2013 of the European Parliament and of the Council of 11 December 2013 on the Common Fisheries Policy, amending Council Regulations (EC) No 1954/2003 and (EC) No 1224/2009 and repealing Council Regulations (EC) No 2371/2002 and (EC) No 639/2004 and Council Decision 2004/585/EC. http://data.europa.eu/eli/reg/2013/1380/oj

[20] Zimmermann, F., & Werner, K. M. (2019). Improved management is the main driver behind recovery of Northeast Atlantic fish stocks. Fish and Fisheries, Advance online publication. https://doi.org/10.1002/fee.2002

[21] European Commission. (2023). Communication from the Commission to the European Parliament and the Council on Sustainable fishing in the EU: state of play and orientations for 2024. COM/2023/303 final. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52023DC0303

[22] Möllmann, C., Lindegren, M., Blenckner, T., Bergström, L., Casini, M., Diekmann, R., Flinkman, J., Müller-Karulis, B., Neuenfeldt, S., Schmidt, J.O., Tomczak, M., Voss, R., & Gårdmark, A. Implementing ecosystem-based fisheries management: from single-species to integrated ecosystem assessment and advice for Baltic Sea fish stocks, ICES Journal of Marine Science, Volume 71, Issue 5, July/August 2014, Pages 1187–1197, https://doi.org/10.1093/icesjms/fst123

[23] Koehn, L. E. (2019). Advances in Models for Assessing Interactions of Forage Fish and Their Predators and Application to Ecosystem-Based Fisheries Management (EBFM) (Doctoral dissertation, University of Washington).

[24] Hilborn, R., Amoroso, R. O., Bogazzi, E., Jensen, O. P., Parma, A. M., Szuwalski, C., & Walters, C. J. (2017). When does fishing forage species affect their predators? Fisheries Research, 191, 211-221. https://doi.org/10.1016/j.fishres.2017.01.008

[25] Engelhard, G. H., Peck, M. A., Rindorf, A., Smout, S. C., van Deurs, M., Raab, K., Andersen, K. H., Garthe, S., Lauerburg, R. A. M., Scott, F., Brunel, T., Aarts, G., van Kooten, T., & Dickey-Collas, M. (2014). Forage fish, their fisheries, and their predators: who drives whom? ICES Journal of Marine Science, 71(1), 90–104. https://doi.org/10.1093/icesjms/fst087

[26] Campbell, K. J., Steinfurth, A., Underhill, L. G., Coetzee, J. C., Dyer, B. M., Ludynia, K., Makhado, A. B., Merkle, D., Rademan, J., Upfold, L., Sherley, R. B., & other authors. (2019). Local forage fish abundance influences foraging effort and offspring condition in an endangered marine predator. Journal of Applied Ecology, 56(7), 1751-1760. https://doi.org/10.1111/1365-2664.13409

[27] van der Lingen, C.D., Bertrand, A., Bode, A., Brodeur, R.,Cubillos, L., Espinoza, J., Friedland, K., Garrido, S., Irigoien, X., Miller, T., Möllmann, C., Rordríguez-Sánchez, R., Tanaka, H. & Temming, A. (2009). Trophic dynamics. In Checkley, D.M., Alheit, J., Oozeki, Y. & Roy, C (Eds), Climate Change and Small Pelagic Fish (pp. 333-451). Cambridge University Press. https://doi.org/10.1017/CBO9780511596681

[28] Peck, M.A., Alheit, J., Bertrand, A., Catalán, I.A., Garrido, S., Moyano, M., Rykaczewski, R.R., Takasuka, A., & van der Lingen, C.D. (2021). Small pelagic fish in the new millennium: A bottom-up view of global research effort. Progress in Oceanography, 191 – 102494. https://doi.org/10.1016/j.pocean.2020.102494

[29] Shelton, A. O., Samhouri, J. F., Stier, A. C., & Levin, P. S. (2014). Assessing trade-offs to inform ecosystem-based fisheries management of forage fish. Scientific Reports 2014 4:1, 4(1), 1–9. https://doi.org/10.1038/srep07110

[30] Karnauskas, M., Walter, J. F., Kelble, C. R., McPherson, M., Sagarese, S. R., Craig, J. K., Rios, A., Harford, W. J., Regan, S., Giordano, S. D., & Kilgour, M. (2021). To EBFM or not to EBFM? that is not the question. Fish and Fisheries, 22(3), 646–651. https://doi.org/10.1111/FAF.12538

[31] Froese, R., & Pauly, D. (Eds.). (2023). FishBase. World Wide Web electronic publication. Retrieved from https://www.fishbase.se/ version (06/2023).

[32] Jansen, T., & Gislason, H. (2011). Temperature affects the timing of spawning and migration of North Sea mackerel. Continental Shelf Research, 31(1), 64-72. https://doi.org/10.1016/j.csr.2010.11.003

[33] Nilsson, L. A. F., Thygesen, U. H., Lundgren, B., Nielsen, B. F., Nielsen, J. R., & Beyer, J. E. (2003). Vertical migration and dispersion of sprat (Sprattus sprattus) and herring (Clupea harengus) schools at dusk in the Baltic Sea. Aquatic Living Resources, 16(3), 317-324. https://doi.org/10.1016/S0990-7440(03)00048-9

[34] Kaschner, K., Kesner-Reyes, K., Garilao, C., Segschneider, J., Rius-Barile, J. Rees, T., & Froese, R. (2019, October). AquaMaps: Predicted range maps for aquatic species. Retrieved from https://www.aquamaps.org

[35] Pinnegar, J.K. (2014). DAPSTOM - An Integrated Database & Portal for Fish Stomach Records. Version 4.7. Centre for Environment, Fisheries & Aquaculture Science, Lowestoft, UK. February 2014, 39pp.

[36] Piatt, J. F., & Kitaysky, A. S. (2011). Global Seabird Response to Forage Fish Depletion--One-Third for the Birds. Science, 334(6063), 1703-1706. https://doi.org/10.1126/science.1212928

[37] Furness, R. W., & Tasker, M. L. (2000). Seabird-fishery interactions: Quantifying the sensitivity of seabirds to reductions in sandeel abundance, and identification of key areas for sensitive seabirds in the North Sea. Marine Ecology Progress Series, 202. https://doi.org/10.3354/meps202253

[38] Piatt, I., & Sydeman, W. (2007). Seabirds as indicators of marine ecosystems. Marine Ecology Progress Series, 352. https://doi.org/10.3354/meps07070

[39] Taupp, T. (2021). Against all odds: Harbor porpoises intensively use an anthropogenically modified estuary. Marine Mammal Science, Advance online publication. https://doi.org/10.1111/mms.12858

[40] Brophy, J.T., Murphy, S. & Rogan, E. (2009). The diet and feeding ecology of the short-beaked common dolphin (Delphinus delphis) in the Northeast Atlantic. Report to the International Whaling Commission. SC/61/SM 14

[41] Murphy, S., Pinn, E.H. & Jepson, P.D. (2013). The short beaked common dolphin (Delphinus delphis) in the north east Atlantic distribution, ecology, management and conservation status. Oceanography and Marine Biology, 51, 193-280.

[42] Fariñas-Bermejo, A., Berrow, S., Gras, M., O'Donnell, C., Valavanis, V., Wall, D., & Pierce, G. J. (2023). Response of cetaceans to fluctuations of pelagic fish stocks and environmental conditions within the Celtic Sea ecosystem. Frontiers in Marine Science, 10. https://doi.org/10.3389/fmars.2023.1033758

[43] Eerkes-Medrano, D., Aldridge, D. C., & Blix, A. S. (2021). North Atlantic minke whale (Balaenoptera acutorostrata) feeding habits and migrations evaluated by stable isotope analysis of baleen. Ecology and Evolution, Advance online publication. https://doi.org/10.1002/ece3.8224

[44] Wilson, L. J., & Hammond, P. S. (2019). The diet of harbour and grey seals around Britain: Examining the role of prey as a potential cause of harbour seal declines. Aquatic Conservation: Marine and Freshwater Ecosystems, Advance online publication. https://doi.org/10.1002/aqc.3131

[45] Lundström, K., Hjerne, O., Alexandersson, K., & Karlsson, O. (2007). Estimation of grey seal (Halichoerus grypus) diet composition in the Baltic Sea. NAMMCO Scientific Publications, 6, 177–196. https://doi.org/10.7557/3.2733

[46] Wilson, L. J., & Hammond, P. S. (2016). Comparing the Diet of Harbour and Grey Seals in Scotland and Eastern England. Scottish Marine and Freshwater Science Report, 7(19). Marine Scotland Science. ISSN: 2043-7722. DOI: 10.7489/1798-1. https://doi.org/10.7489/1798-1

[47] United Nations. (2023). Take Action for the Sustainable Development Goals. https://www.un.org/sustainabledevelopment/sustainable-development-goals/

[48] European Union. (2021). Trade and Cooperation Agreement between the European Union and the European Atomic Energy Community, of the one part, and the United Kingdom of Great Britain and Northern Ireland, of the other part. Publications Office of the European Union. http://data.europa.eu/eli/agree_internation/2021/689(1)/oj

[49] UK Government. (2020). Fisheries Act 2020. https://www.legislation.gov.uk/ukpga/2020/22/contents/enacted

[50] European Union. (2008). Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008 establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive) https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32008L0056

[51] United Kingdom and European Union. (2023). Written Record of Fisheries Consultations from 9 to 13 March 2023 about Sandeels. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1143911/Written_Record_of_fisheries_consultations_from_9_to_13_March_2023_between_the_United_Kingdom_and_the_European_Union_about_sandeels_in_2023.pdf

[52] European Commission, European Climate, Infrastructure and Environment Executive Agency. (2021). Synthesis of the landing obligation measures and discard rates, Publications Office, 2021. Final report. https://data.europa.eu/doi/10.2826/176808

[53] STECF. (2020). Evaluation of Member States' Annual Reports on the Landing Obligation for 2019. STECF-Adhoc 20-02. Publications Office of the European Union. https://doi.org/10.2760/304431

[54] ICES. (2018). Report of the Herring Assessment Working Group for the Area South of 62°N (HAWG). 29-31 January 2018 and 12-20 March 2018. ICES HQ, Copenhagen, Denmark. ICES CM 2018/ACOM:07. 960 pp. https://archimer.ifremer.fr/doc/00472/58380/

[55] Grossman, J. (2022). Taking stock 2022 are TACs set to achieve MSY?. ClientEarth. https://www.clientearth.org/media/rine44zc/taking-stock-2022-are-tacs-set-to-achieve-msy.pdf

[56] Bell, E., Nash, R., Garnacho, E., De Oliveira, J., & O'Brien, C. (2022). Assessing the sustainability of fisheries catch limits negotiated by the UK for 2020 to 2022. Centre for Environment, Fisheries & Aquaculture Science (CEFAS).https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1061261/Assessing_negotiated_catch_limits_2020_to_2022.pdf

[57] ICES. (2023). Herring (Clupea harengus) in subdivisions 25–29 and 32, excluding the Gulf of Riga (central Baltic Sea). Replacing advice provided in May 2023. ICES Advice: Recurrent Advice. Report. https://doi.org/10.17895/ices.advice.23310368.v1

[58] Peck, M.A., Catalán, I.A., Damalas, D., Elliott, M., Ferreira, J.G., Hamon, K.G., Kamermans, P., Kay, S., Kreiß, C.M., Pinnegar, J.K., Sailley, S.F. & Taylor, N.G.H. (2020). Climate Change and European Fisheries and Aquaculture: 'CERES' Project Synthesis Report. Hamburg. https://doi.org/10.25592/uhhfdm.804

[59] ClimeFish. (2019). Case study facts: Northeast Atlantic Fisheries. https://climefish.eu/2019/04/10/north-east-atlantic-fisheries/

[60] Jones, M.C. & Cheung, W.W.L. (2017). Using fuzzy logic to determine the vulnerability of marine species to climate change. Global Change Biology, 24, 719-731. https://doi.org/10.1111/gcb.13869

[61] Froehlich, H. E., Jacobsen, N. S., Essington, T. E., Clavelle, T., & Halpern, B. S. (2018). Avoiding the ecological limits of forage fish for fed aquaculture. Nature Sustainability, 1, 298–303. https://doi.org/10.1038/s41893-018-0093-x

[62] Trenkel, V. M. (2017). GHOTI: How to provide scientific advice for ecosystem-based management now. Fish and Fisheries, 19(1), 1-14. https://doi.org/10.1111/faf.12263

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