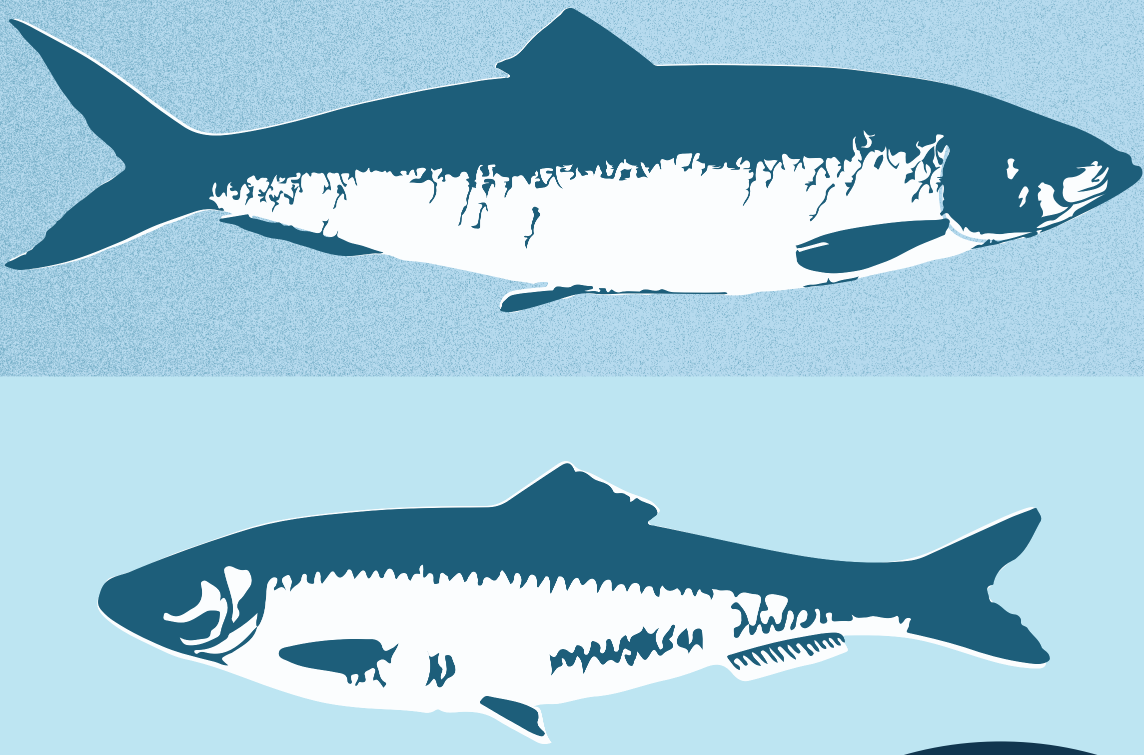
Small fish with a big impact

– a review of forage fish importance for a healthy Baltic sea



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SVENSKA POSTKODLOTTERIETS STIFTELSE

Small fish with a big impact

The Fisheries Secretariat (FishSec) is an independent non-profit organisation dedicated to the protection and restoration of marine ecosystem services, with a focus on fisheries.

Our goal is well managed seas with rich biodiversity and thriving fish stocks to secure healthy and local sea-food to consumers and a sustainable fishing sector.

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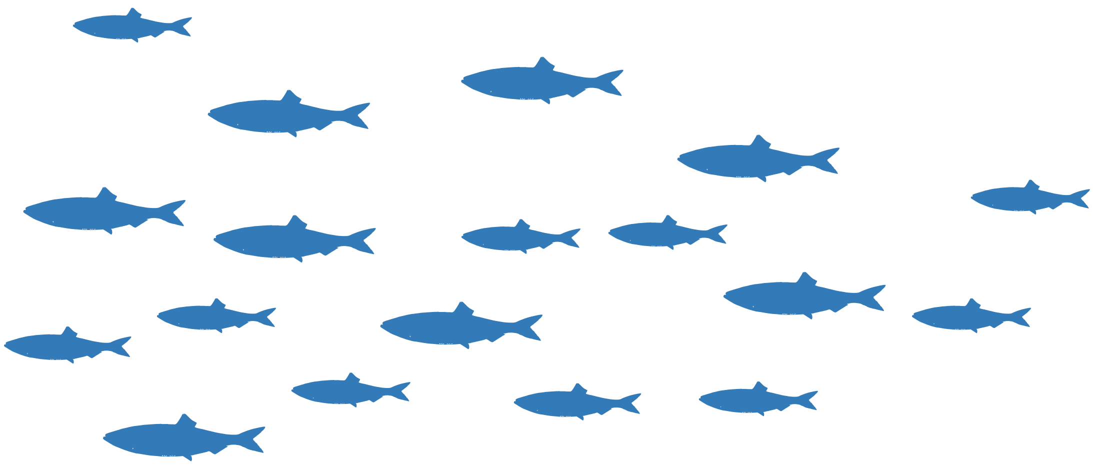

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Executive summary

The Baltic Sea is home to two main species of forage fish: European sprat and Atlantic herring. These small, pelagic fish are crucial to the region; they play a key role in the marine ecosystem while also representing significant economic value for the fishing and processing sector. However, three of the four herring stocks have been in decline, with western Baltic herring in particularly poor condition. More recently, the Baltic sprat population has had several years of very low recruitment.

A new scientific report published by FishSec emphasises the key role that small pelagic fish - forage fish - play in the Baltic Sea, showing that changes in their stock status have not been sudden but rather the result of ongoing longer processes, driven by high fishing pressure in combination with other factors such as increasing water temperatures, lower salinity and changes in food availability. This decline is affecting both the Baltic ecosystem and the fishing sector in the region. Most of the sprat catch is destined for industrial processing rather than direct human consumption, while herring is used both for human consumption and for fishmeal and oil production, particularly as feed in aquaculture.

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The report summarises current knowledge on forage fish in the Baltic Sea. Based on an extensive review of scientific literature and reports, it provides an overview of population health and the significance of sprat and herring stocks. The report includes:

- An examination of stock status and the vital role of forage fish in the Baltic sea ecosystem.
- An overview of pressures affecting their populations.
- A brief review of the EU fisheries management and implementation of key existing EU fisheries rules.
- Suggested policy measures for improved forage fish management.

Herring and sprat are two of the main fish species in the relatively species poor Baltic Sea. These populations are distinct and uniquely adapted to the brackish waters of the Baltic. As prey for top predators such as cod, salmon, seabirds and marine mammals, and as predators of zooplankton, sprat (*Sprattus sprattus*) and herring (*Clupea harengus*) occupy a pivotal position in the Baltic Sea food web. Of the four herring stocks, only the small Gulf of Riga stock appears healthy and more stable, whereas Gulf of Bothnia and Central Baltic stocks have experienced steep declines. The western Baltic spring-spawning herring is at a critically low level and the International Council for the Exploration of the Sea (ICES) has advised zero catch for this stock since 2019; while this was largely followed in the Baltic management area, catches remained far too high in the Kattegat and Skagerrak, preventing a recovery of the stock.

Sprat, managed as a single stock, increased during the 1990s and remained relatively stable until recently. However, due to very low recruitment from 2021 to 2023, the stock has recently declined.

Pivotal role in the ecosystem

Much of the scientific literature focuses on the relationship between forage fish and their predators, as well as on their role in transferring energy and nutrients from lower to higher trophic levels. In addition to their key role as prey, sprat and herring are planktivores that act as a link for energy and nutrients between tiny plants and animals and large predators. This underscores their central role in the marine ecosystem. The health of forage fish populations is critical, not only for their own sustainability but also for the broader marine ecosystem. Larger herring may also act as piscivores, potentially helping to regulate the increasing stickleback population. This is important as stickleback numbers have surged largely because of a lower predation pressure and favorable environmental changes.

Stressors

Beyond periods of intense fishing pressure, several other factors have affected forage fish in the Baltic Sea. These include climate-driven changes in water temperature, salinity and stratification, eutrophication, habitat degradation and pollution - all of which affects the health of forage fish populations. The availability, size and species composition of plankton also have direct effects. Moreover, competition among planktivores, egg predation and interactions with the growing stickleback population and invasive species can all simultaneously impact the health and condition of sprat and herring populations.

Climate change, as described above, is a stressor to all marine life and reduces overall ecosystem resilience. In the shallow, enclosed Baltic Sea, these effects are especially pronounced, particularly for cold-water species sensitive to warming and reduced salinity. This makes efforts to reduce human pressures and restore weakened fish populations even more urgent.

Forage fish management

All Baltic Sea fish populations targeted by commercial fisheries are managed under EU laws, governed by the EU's Common Fisheries Policy (CFP). Despite legal obligations to restore stocks to biomass levels above Maximum Sustainable Yield, political decisions have resulted in stocks remaining near or below the limit biological reference point for spawning stock biomass (B_{lim}), increasing the risk of collapse and failing to meet legal obligations under both the Baltic Multiannual Plan (MAP) and the CFP. For example, the agreement on quotas for 2024 for Central Baltic and Bothnian herring did not comply with the safeguard set out in the multiannual plan, which aims to keep the probability of stocks falling below critical spawning stock biomass limits to less than 5%.[1] Scientific advice indicated that even zero catch of the CBH and GoBH stocks would not meet this threshold, yet fishing limits were set above precautionary levels. Prematurely increasing fishing quotas before fish populations have fully recovered to healthy levels is short-sighted and jeopardises these vulnerable stocks.

Considering the current state of the Baltic Sea ecosystem, the overall decline that can be seen in many species and the continued issues related to climate change and other stressors in the region, key species such as the unique forage fish populations adapted to the particular brackish waters of the Baltic Sea need to be managed in a much more precautionary way that ensures resilience. Improved management of Baltic sprat and herring stocks offers clear benefits, not only for the health of the Baltic Sea ecosystem and the recovery of its predators, but also for the viability of fisheries in the long term.

▶ **For key recommendations, see p 72-73.**

1 Article 4.6 of the Baltic Multiannual Plan

Abbreviations, terminology & acronyms

AGRIFISH	Agriculture and Fisheries Council configuration
B_{lim}	Biomass limit reference point
B_{MSY}	Biomass at Maximum Sustainable Yield
B_{pa}	Precautionary approach biomass reference point
$B_{trigger}$	Biomass trigger reference point in ICES advice
CBH	Central Baltic Herring
CFP	EU Common Fisheries Policy
DE	Germany
DK	Denmark
EBC	Eastern Baltic cod
EBFM	Ecosystem-based fisheries management
EBM	Ecosystem-based management
EC	European Commission
EE	Estonia
EFCA	European Fisheries Control Agency
EMFAF	European Maritime, Fisheries and Aquaculture Fund
EU	European Union
F	Fishing mortality
FAO	UN Food and Agriculture Organisation
FI	Finland
F_{lim}	Limit reference point for fishing mortality
F_{MSY}	Fishing mortality consistent with achieving Maximum Sustainable Yield
F_{pa}	Precautionary reference point for fishing mortality
GES	Good Environmental Status
GoBH	Gulf of Bothnia Herring
GoRH	Gulf of Riga Herring
HELCOM	Helsinki Commission
ICES	International Council for the Exploration of the Sea
ITQ	Internal Transferable Quota
LO	Landing Obligation
LSF	Large-Scale Fisheries
LT	Lithuania
LV	Latvia
MAP	Multiannual plan
MSFD	Marine Strategy Framework Directive
MSY	Maximum Sustainable Yield
PL	Poland
REM	Remote Electronic Monitoring
SD	Subdivision
SE	Sweden
SSB	Spawning Stock Biomass
SSCF	Small-Scale Coastal Fleet
STECF	Scientific, Technical and Economic Committee for Fisheries
TAC	Total Allowable Catch
WBC	Western Baltic cod
WBSSH	Western Baltic Spring Spawning Herring
WGBFAS	ICES Baltic Fisheries Assessment Working Group

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Structure of the report

The current report consists of seven main chapters with the following structure:

Chapter 1 — **Introduction.** Describes the aim, background and methodology used for the literature review of the report.

Literature review:

Chapter 2 — **Baltic forage fish: biology, stocks, and current status.** The first part of the literature review, summarizing the current situation of Baltic Sea forage fish. It includes background information on herring and sprat, changes in stock status, biological characteristics, growth, and development.

Chapter 3 — **Importance for the ecosystem.** The second part of the literature review, which examines interactions between forage fish, their predators, and prey based on scientific literature. It highlights the crucial role of forage fish in maintaining ecosystem health.

Chapter 4 — **Key pressures on Baltic forage fish.** The third part of the literature review, identifying key pressures affecting Baltic Sea forage fish, based on recent scientific literature.

Chapter 5 — **Management of forage fish stocks in the Baltic Sea.** Discusses the strategies and policies for managing forage fish stocks in the region.

Chapter 6 — **Fishery for sprat and herring in EU Member States around the Baltic Sea.** Provides an overview of forage fish consumption and the fishery for sprat and herring stocks in each of the Baltic Sea countries.

Chapter 7 — **Conclusions and recommendations.** Connects biological features, ecosystem importance, environmental conditions, fisheries, and management with policy and political commitments. It also presents practical recommendations.

Chapter 1
Introduction

Aim & scope of the report

This report aims to provide an overview of the current scientific knowledge on forage fish in the Baltic Sea and to offer recommendations for improved management of these fish. The report is a key output of *Small Fish –Big Impact*, a project set up to explore the state of forage fish in the Baltic Sea. The project started in 2023 and is funded by Svenska Postkodlotteriets Stiftelse (the Swedish Postcode Lottery Foundation) as part of the *Small Fish – Big Impact* project grant.

In the long-term, the aim of the *Small fish – Big Impact* project is better management of forage fish stocks in line with ecosystem boundaries. The ultimate goal is the restoration of ecosystem dynamics in the Baltic Sea, allowing fish and other wildlife populations to rebuild, as well as allowing traditional fisheries to flourish.

Context and rationale

Forage fish are small to medium-sized pelagic fish that play a vital role in marine ecosystems. Globally, this group includes species such as sprat, herring, sandeel, mackerel, anchovies, and sardines. These small, schooling fish serve as a primary food source for larger predators, including marine mammals, seabirds, and commercially valuable larger fish like salmon and cod (e.g. Casini et al., 2016; Certain et al., 2011; Lai et al., 2021; Saraux et al., 2021). Forage fish are normally found gathered in large groups, where they consume plankton and smaller aquatic organisms. These fish play a key role in the food web and help maintain the health and productivity of marine ecosystems.

Forage fish within the Baltic Sea, as well as globally, are currently facing significant challenges, including overfishing, pollution, habitat degradation, eutrophication, and climate change. Recognizing and addressing these challenges is essential for protecting the forage fish themselves, but also for the broader biodiversity and ecological integrity of the Baltic Sea.

Atlantic herring (*Clupea harengus*, referred to as "herring" throughout this report) and European sprat (*Sprattus sprattus*, referred to as "sprat" throughout this report) are important forage fish species in the Baltic Sea and are therefore the focus of this report. They are among the most commercially important fish species in the region, ranking as the top landed species by EU Member States operating in the Baltic Sea, both in terms of weight and economic value. Together, sprat and herring accounted for the majority (>90%) of Baltic landings in 2022 (STECF, 2024).[2] Sprat and herring have also been the subject of numerous scientific studies and publications.

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2 In 2022, the weight of (Baltic Sea) landings was 249 700 tonnes (54% of the total landed weight) for European sprat and 178 100 tonnes (38% of the total landed weight) for Atlantic herring. Sprat generated a value of EUR 63.7 million (39% of the total landed value) and herring a value of EUR 48.0 million (29% of the total landed value) (STECF 2024).

From a management perspective, sprat in the Baltic Sea is considered a single stock, managed as one single unit with a single Total Allowable Catch (TAC) quota set annually for the entire Baltic (ICES, 2025e). In contrast, there are four management units for the herring, each having their own, separate annual TACs. The four herring TACs set for the Baltic Sea are: Bothnian herring (GoBH), Central Baltic herring(CBH), Gulf of Riga herring (GoRH) and the Western Baltic spring spawning herring (WBSSH, which extends beyond the Baltic Sea management area) (ICES, 2025a, 2025b, 2025c, 2025d).

Three of the four herring stocks are currently in poor or severely weakened condition and Baltic sprat had a unusually low recruitment over three consecutive years (year classes 2021–2023). The Baltic cod, along with sprat and herring have made up the majority of the commercial fishery, is also on the brink of collapse, with a lack of food identified as one of the drivers behind the decline (e.g. Eero, 2012; Neuenfeldt et al., 2019).

Method

Note that we did not generate new data for this report and that the order and length of each subsection do not necessarily reflect their relative importance.

Based on an examination of academic studies and reports, this report provides a review of the current scientific literature on the status of forage fish in the Baltic Sea, summarized in Chapters 2-4. A systematic search of peer-reviewed literature was conducted using predefined search criteria. Three separate searches were carried out in October 2023, using the Scopus literature database. These searches yielded results including research papers, scientific reviews, short communications, and books (including some non-peer-reviewed grey literature). Additional but less extensive searches for newly published papers and reports were also conducted in spring 2024 and 2025. The main focus of the final report is on literature published between 2013 and 2025. The material underwent a three-step process: i) initial identification through the Scopus database search, ii) duplicate removal and abstract screening for relevance (relevant materials were categorised with a stoplight system), iii) extraction of detailed information from relevant sources for the final review.

Recent reports and advice sheets from the International Council for the Exploration of the Sea (ICES)[3] (published in 2024 or earlier), reports from the Scientific, Technical and Economic Committee for Fisheries (STECF), as well as other grey literature reports and papers referenced in the items found from the literature search, were also examined for relevance and inclusion in the review where appropriate.

Papers were excluded if they, for example, focused on other species than those targeted in this review, if they were beyond the geographic scope of our review, or if the full paper was inaccessible. Additionally, the review was limited to materials written in English or Swedish.

3 **Note:** At the time of writing the major parts of this report, ICES advice for fishing opportunities for 2026 was not yet published. Unless otherwise specified, the text references advice and information published prior to the advice from May 2025.

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Reference points

Modern fisheries management relies on the use of reference points to assess fish stock abundance and fishing pressure, which then guides decisions about how much can be harvested from the stocks (Trijoulet et al., 2022). Biological reference points have been used by scientists for decades to assess fish stock status and today, they are one of the most widely used and more effective foundations for modern fisheries management. Maximum sustainable yield (MSY) is, for instance, often used as a "conceptual reference point" when the objective is to maximise yield (FAO).

International Council for the Exploration of the Sea (ICES) separates stocks into one of six different categories[4], depending on the type and amount of information available for each stock that can be used to assess its state and its level of exploitation. Category 1 stocks, including Baltic Sea herring and sprat stocks, are analytically assessed stocks with reference points that are "absolute". Below is a list of some of the most commonly used reference points with relevance for Baltic forage fish:

B_{lim} Spawning stock biomass limit reference point which defines a limit "*below which the stock is considered to have reduced reproductive capacity*".[a]

MSY $B_{trigger}$ Spawning stock biomass reference point below which "*specific and appropriate management action is to be taken to ensure that exploitation rates in combination with natural variations rebuild stocks above levels capable of producing MSY in the long term*".[b]

B_{pa} *"A stock status reference point above which the stock is considered to have full reproductive capacity, having accounted for estimation uncertainty"*.[a] As long as the biomass remains above B_{pa}, the risk of impaired recruitment is considered low.

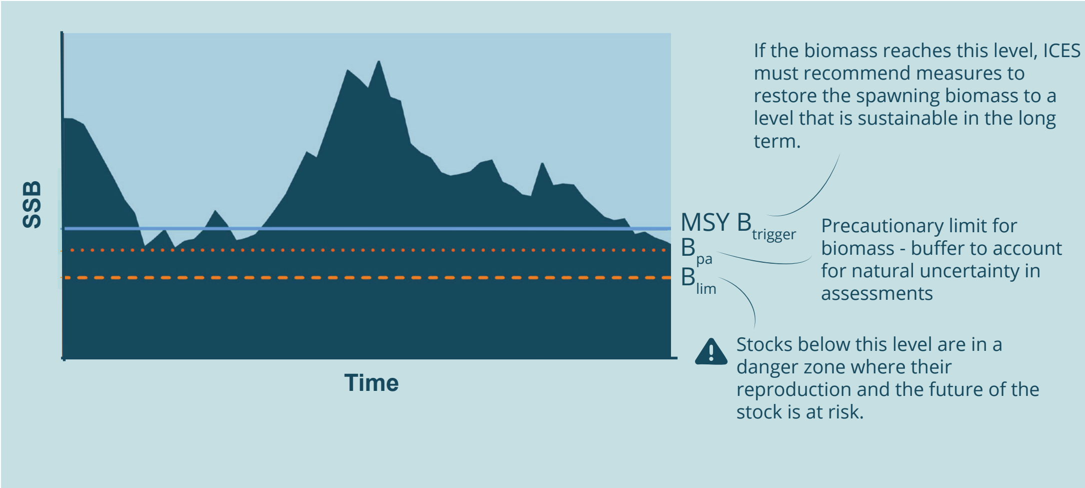
F_{pa} A precautionary exploitation rate reference point. If fishing pressure approaches this point, management measures must be taken to protect the stock.

F_{lim} Limit reference point for fishing mortality. If fishing exceeds this level, the stock's biomass will be heavily reduced and can fall below B_{lim}.

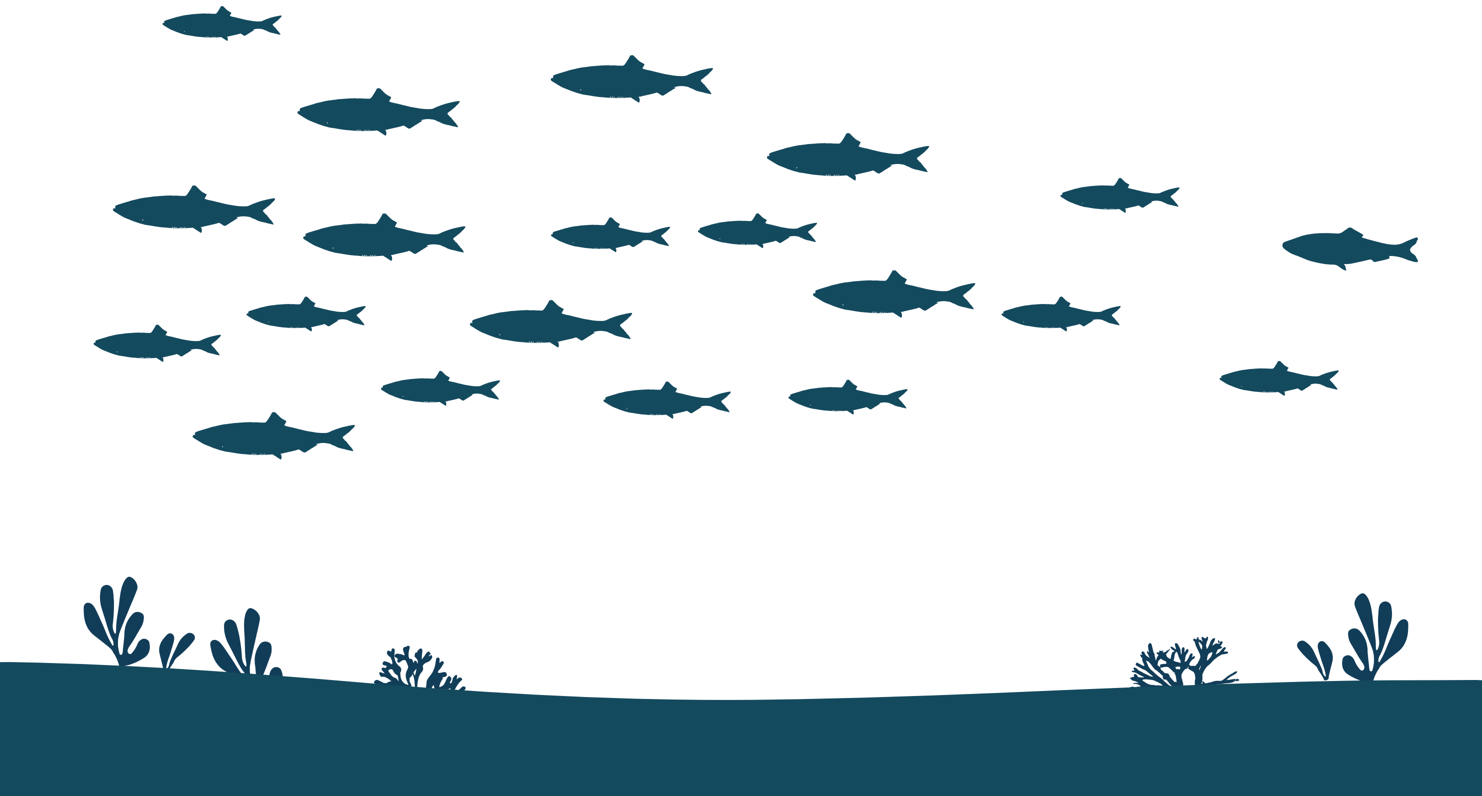
F_{MSY} The Fishing mortality which is expected to give maximum sustainable yield in the long term (the maximum amount of fish that can be harvested from a stock while still leaving enough for the population to sustain itself over time).

Based on [a]ICES (ICES, 2017b) and [b]Article 2 of EU Regulation 2019/472

4 Category 1 (stocks with quantitative assessments) is the highest category, for which full analytical assessments are made. Category 2 and 3 are considered data limited, Category 5 is stocks with only landings or short data series available and Category 6 is negligible landings and bycatches (ICES, 2019). For stocks from categories 3, 4, 5 and 6, the ICES precautionary approach is always applied, while stocks from Category 1 and 2 can be set for either the MSY approach or PA approach depending on the stock. At the time of writing the majority of this report, ICES advice for fishing opportunities for 2026 was not yet published.



The figure above illustrates how a graph showing the development of a spawning stock's size over time can look, using on GoBH data as an example (ICES, 2024f). To ensure that the stock spawning stock biomass is large enough, minimum levels are used. These are defined by two reference points: the biomass limit (B_{lim}) and the precautionary biomass limit (B_{pa}), shown here together with MSY $B_{trigger}$.



Chapter 2
Baltic Sea forage fish: biology, development and stock status

Our literature review showed that a wide range of topics is covered in the scientific literature on the Baltic Sea forage fish. Chapters two, three and four focus mainly on their importance for the ecosystem and the external factors that affect them (based on our literature review), while policy, management, and fisheries are primarily addressed in Chapters five and six.

Background

In addition to environmental challenges, the main commercial fish stocks in the Baltic Sea (cod, herring and sprat) have faced substantial, targeted fishing pressure, in combination with environmental stressors (HELCOM, 2023). Considering the Baltic Sea's variation in salinity levels, temperature fluctuations and oxygen variations, it poses a challenging environment for the fish living there.

The Baltic Sea is divided into management subdivisions (SDs) by ICES. These subdivisions are used for fisheries management (Figure 1). As previously mentioned, sprat in the Baltic Sea is managed as one unit (SD 22–32) while there are four separate management units for Baltic Sea herring: the Bothnian herring in the north (SD 30–31), the Central Baltic herring in the central Baltic Sea (SD 25–29 and 32), the Gulf of Riga herring in the east (SD 28.1) and the Western spring spawning herring in the southwest (SD 20–24), which extends outside the Baltic Sea (ICES 2024c, 2024d, 2024e, 2024f).

During the past century, the Baltic Sea has undergone ecological regime shifts where the food web has changed. In the late 80s, one of these regime shifts led to a decline of the Baltic cod, which was replaced by sprat and herring as the new dominant species in the ecosystem (Pachur and Horbowy 2013; Margonski et al., 2010).

Definition and role of "forage fish"

Forage fish are small to medium-sized pelagic fish species that play a crucial role in transferring energy within aquatic food webs. They are normally found in large groups and serve as a primary food source for larger predatory species, making them of great importance to the food web. They generally have an abundance which shifts faster than the abundance of predators (Smith et al., 2011; Link et al., 2009; Engelhard et al., 2014). Forage fish also bridge the gap between lower trophic levels,[6] i.e. plankton and marine life at higher trophic levels, such as large-sized fishes. Understanding the dynamics of forage fish populations is essential for sustaining the balance and biodiversity of marine ecosystems and thereby also securing healthy fish populations. For instance, the decrease in predatory fish in the Baltic Sea, together with the effects of climate change and eutrophication, has also led to an increase of other planktivores in some areas, such as the three-spined stickleback (*Gasterosteus aculeatus*), resulting in planktivore competition which could affect the access to food for sprat and herring (Novotny et al., 2022; Olsson et al., 2019).

This report mainly focuses on two species of forage fish: European sprat and Atlantic herring, as these two species are the main pelagic fish in the Baltic Sea (Svedäng, Almqvist, and Axenrot 2023) which will be reviewed below.

5 The trophic levels represent different stages in a food chain, categorising organisms based on their energy source, from primary producers (low trophic level) to top predators (high trophic level).

Baltic Sea herring- introduction

The Baltic Sea herring is a subspecies to the Atlantic herring, a small, schooling clupeid. The Atlantic herring is also found throughout the Northern Atlantic and the North Sea (Bekkevold et al., 2011). Atlantic herring has adapted to a range of environments, with salinities from 34–35 PSU in the Atlantic Ocean and 2–3 PSU, along with large seasonal temperature variations in the Baltic Sea (Han et al., 2020).

Herring are pelagic fish, meaning that they inhabit the water column (also known as the pelagic zone) where they group up in large schools that stay near the bottom during the day while rising closer to the surface at night. Light plays a crucial role in regulating the herring's vertical distribution. Sprat and herring commonly form schools at dawn and disperse at dusk, and often migrate vertically in the water column (Nilsson et al., 2003).

Herring can be found throughout the entire Baltic Sea and it is estimated that there are around ten separate herring populations present in the Baltic Sea (Ojaveer, 1988; Raid et al., 2022). Baltic herrings can be broadly separated into two types of populations, gulf herrings that spend the majority of their time in the gulfs (Gulf of Bothnia or Gulf of Riga) and open sea herrings which migrate between the gulfs where they usually spawn and the open

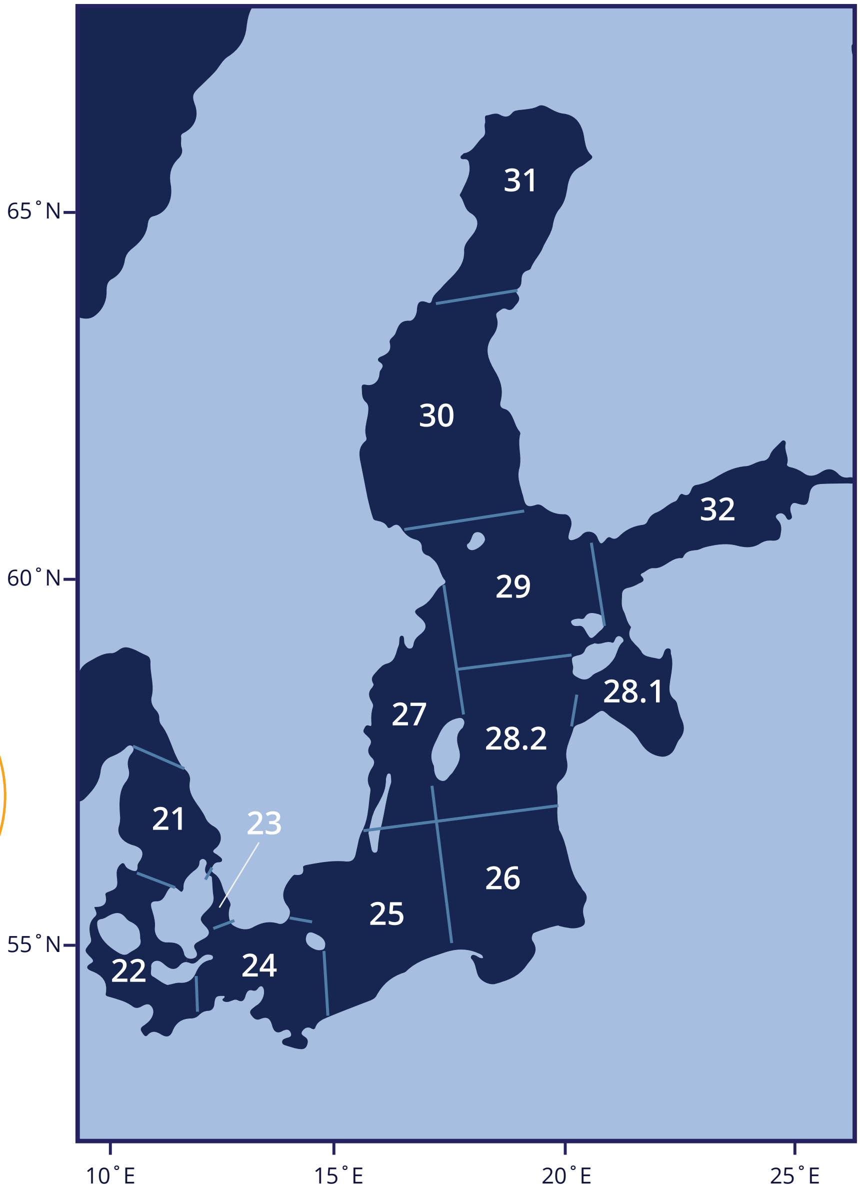


Figure 1. *ICES Subdivisions (SDs) in the Baltic Sea ecoregion.*

water where they feed and spend the winters (Raid et al. 2022; Ojaveer 1988). Although herring is a pelagic species, it is the only clupeoid that lays demersal eggs (Maravelias et al., 2000). Herring may prefer specific vegetation/species of macroalgae for egg deposition after spawning, and Casabona et al did not find positive effects of reef restoration on herring, the authors state that restoration of herring spawning habitats needs to be explored further (Casabona et al., 2024).

The herring plays a pivotal role in both the fisheries and the marine ecosystems of the Northern Hemisphere. In fact, the herring is an extremely popular target species for fisheries, according to the Food and Agriculture Organization of the United Nations (FAO), herring is the target species for one of the world's most important commercial fisheries and among the top 10 most landed fish species in the world, (fourth on the list in 2020 (FAO, 2020). FAO has also stated that the Atlantic herring, together with the European pilchard and Atlantic cod, "*had higher than average proportions of overfished stocks*" (FAO, 2020, 2022).

Historically, the herring was also of high cultural and economic importance around the Baltic Sea. For instance, the Hanseatic League partially originated in the 12th century due to trade involving herrings along the southern Baltic coast (Hunt, 2017).

The most recent annual economic report by the Scientific, Technical and Economic Committee for Fisheries (STECF, 2024) shows that in 2022, herring was the second-highest landed species in terms of weight and value after sprat (see also Figure 2). It is also one of the main fisheries in the North East Atlantic Fisheries Commission convention area, together with mackerel, blue whiting, redfish, haddock, and deep-sea species (STECF, 2023). The Baltic herring fishing pressure increased from the 1920s onwards, and the highest landings were around 460 000 tonnes in the 1980s.

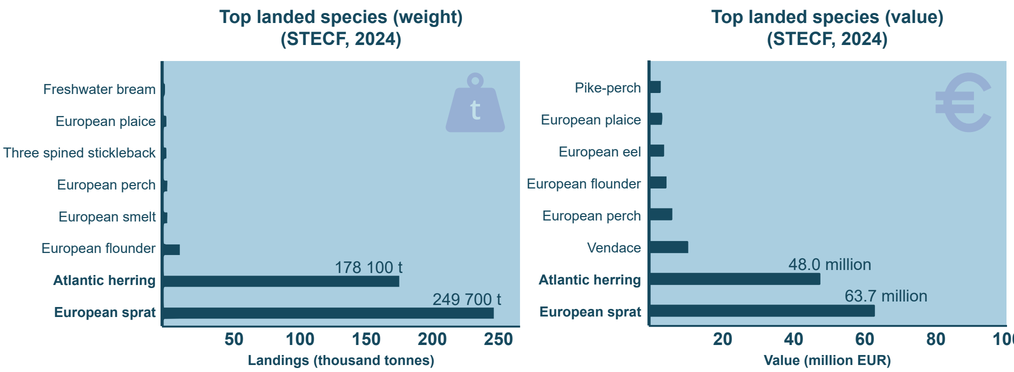


Figure 2. *The top landed fish species in the Baltic Sea in 2021, in terms of weight and value. Based on the latest STECF report (STECF, 2024)*

Because of the herring's popularity for fisheries, numerous scientific papers have studied its larval development and reproductive biology (Fischbach et al., 2022, 2023). However, despite the fact that the herring is one of the most studied fish species in the world, there are still some knowledge gaps concerning the factors affecting its reproductive success (Kotterba et al., 2017; Polte et al., 2013). Herring can either be split into autumn or spring spawners. Baltic Sea autumn spawners were once dominant but have now declined (ICES, 2025f).

Baltic Sea sprat - introduction

European sprat (*Sprattus sprattus*) is another small-bodied, schooling fish from the Clupeidae family. Sprat in the Baltic Sea (*S. sprattus balticus*) is one of three subspecies of sprat that have been defined. European sprat is also found in the North-East Atlantic, the North Sea, the Mediterranean and the Black Sea (Whitehead 1985). Sprat is distributed throughout most parts of the Baltic Sea, including areas of lower salinity. However, reproduction is mainly possible in the areas where salinity in the brackish water is high enough. As mentioned above, both sprat and herring are pelagic fish that migrate vertically through the water column depending on the time of day (Nilsson et al. 2003).

Baltic Sea sprat (single stock)

The abundance of sprat started increasing around the time that the Baltic cod began to decline in the 1980s (until the late 2010s) and both the biomass and catch for Baltic sprat reached a peak at around 1 730 000 tonnes and 540 000 tonnes, respectively, in the mid 1990s (ICES 2024g; ICES, 2023a). This represents about a tenfold increase in sprat landings over that period. Sprat in the Baltic Sea (subdivisions 22–32) are managed as one single stock. The stock was benchmarked in 2023 (ICES 2023a), which led to an update of the fishing mortality and biomass reference points. The Fmsy reference point is now a bit higher but "the catch advice decreased slightly mainly due to a large decline in the stock size" (ICES 2023e). The SSB and catch of sprat was at its highest in the 1990s (as shown in Figure 4) and the SSB has stayed relatively even over the last two decades.

The majority of the Baltic sprat catch is taken by pelagic trawlers (ICES 2023e) and is mostly used for industrial processing, as the market for human consumption around the Baltic Sea is considerably smaller than that for herring (see examples in Chapter 6). Of the Baltic Sea EU Member States, Poland and Sweden catch the largest shares of Baltic sprat.

It is important to note that according to the 2024 ICES advice and WGBFAS report, the recruitment for the Baltic Sea sprat has been very low for three years (2021-2023) in a row (ICES 2024a), among the lowest in the entire time series since the 1970s. Sprat recruitment has varied year to year before which can be explained by the recruitment being spasmodic for this stock, but it is usually not this low for several consecutive years. The low recruitment is concerning since if the sprat recruitment does not recover, there is a risk for a severe decline in the Baltic Sprat population, leading to further issues for the Baltic ecosystem as a whole (lower quotas for fishing would also be expected).

As mentioned above, the recruitment values for the Baltic sprat stock's during 2021- 2023 were some of the lowest in the time series and it is unusual to have consecutive years with such low recruitment. ICES advice noted that "*Forecasts for 2026 assume a much higher recruitment than has been observed in these three years, resulting in an expected increase in biomass in 2026. If this assumption were too optimistic, biomass could decrease below biomass reference points*" (ICES 2024g).

The sprat stock was benchmarked in 2023 (ICES 2023e) which led to an update of the fishing mortality and biomass reference points. Due to the three years with poor recruitment, ICES advice for fishing opportunities for 2025 (ICES 2024g) was considerably lower than for the previous year (ICES 2023e). Currently, the size of the spawning-stock remains above MSY $B_{trigger}$, B_{pa} and B_{lim} (ICES 2025e).

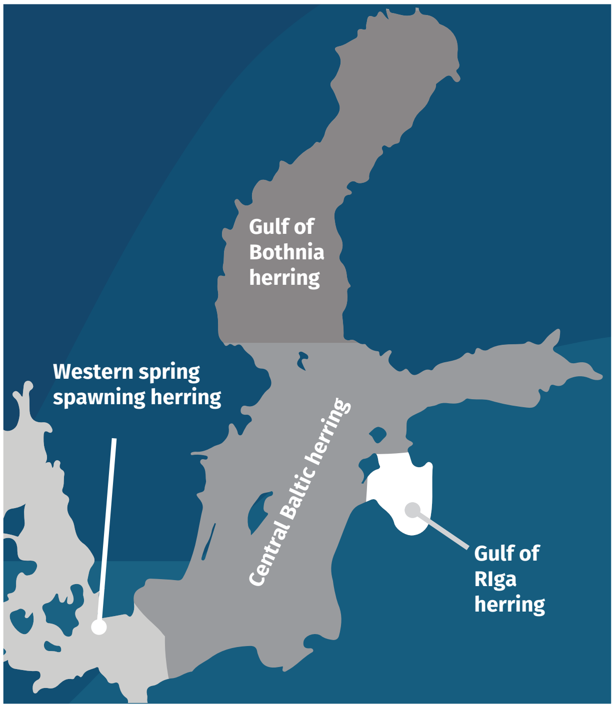


Figure 3. *Distribution of the four herring stocks in the Baltic Sea.*

Overview of stock status

As mentioned previously, Baltic Sea herring is split into four separate management units/ stocks (CBH, WBSSH, GoBH and GoRH, see Figure 3). The state of each stock is described further in the sections below (based on the latest ICES assessments unless otherwise specified).[6] See also Figure 4 for SSB and catch levels for these stocks and Supplementary Figure 1-5 for historical catches.

Gulf of Bothnia Herring (GoBH)

The Gulf of Bothnia herring is located in the northern part of the Baltic Sea and is fished by Finland and Sweden. The GoBH stock assessment has been marked by uncertainty as ICES notes that the assessment quality for this herring stock could be affected by "*a high level of uncertainty in recent years' young age-class estimates, and the uncertainty is in turn propagated into the assessment and forecast*". Prey availability (such as *Mysidae* and/or *Pseudocalanus* spp) is also suggested to affect the variability seen in the estimated weight at age values for this stock (ICES, 2025d).

The proportion of older individuals has declined during the last ten years compared to the mean previously in the time-series for the stock (ICES, 2024). Additionally, the stock is made up of genetically distinct spawning components (Han et al., 2020, Goodall et al. 2024) and could be "*vulnerable to loss in genetic diversity*" (ICES, 2024).

A maximum catch of 62 684 tonnes is advised for 2026 for GoBH, a decrease from the maximum of 74 515 tonnes advised for 2025 (ICES, 2025d).

Central Baltic Herring (CBH)

Central Baltic herring is the largest of the Baltic herring stocks and is composed of a number of local populations. The SSB for this stock (shown as relative SSB in the latest ICES assessments) has declined significantly since the 1970s (see Figure 4).

Small fish with a big impact

6 As noted in the Methods section, ICES advice for fishing opportunities for 2026 was not yet published while the bulk of this report was written. the overview of stock status is updated with the lates stock advice from 2025, nut unless otherwise specified, the text references advice and information published prior to the advice from May 2025.

The catch of CBH in the central Baltic Sea is also estimated to be mixed with catch of GoR herring in the same management area. ICES advises a maximum quota of 154 542 tonnes for CBH in 2026 (taking into account the mixing between the Central Baltic herring and Gulf of Riga herring), compared to a maximum of 125 344 tonnes for 2025 (ICES, 2025c). This increase is explained by a large year class from 2022 contributing to the estimations for the spawning stock biomass (the number of mature fish) together with the increasing trend of weight-at-age over the last years. However, the stock still has a relative spawning-stock size below MSY $B_{trigger}$ (considered a sustainable level of stock spawning biomass) and below the precautionary reference point B_{pa}.

The ICES assessment for CBH in 2021 showed that the stock had been overfished during the 2005–2020 period, because biomass and recruitment had been highly overestimated during that period while fishing mortality was underestimated (Svedäng & Berkow, 2021).

Gulf of Riga Herring (GoRH)

Herring in the comparatively small Gulf of Riga area stands out from the other Baltic herring stocks in a positive way as it is in comparatively good shape in terms of a stable or increasing SSB and good health condition. The GoR herring also has a distinct body shape, with larger heads and slim bodies in comparison to herring from the southern parts of the Baltic Sea (Raid et al., 2022). This stock is caught both inside the Gulf of Riga (Subdivision 28.1) and outside of it. Stock mixing could be an issue for this stock where it overlaps with CBH (ICES, 2025a).

The Riga herring is estimated to have a large SSB and to be the most stable out of the four Baltic Sea herring stocks. There is some decrease in spawning stock biomass according to the latest assessment (ICES, 2025a) and ICES advises a maximum quota of 34,367 tonnes for 2026 (accounting for stock mixing), a decrease from the advice of 45 235 tonnes for 2025. However, this stock size remains above the reference points MSY $B_{trigger}$, B_{pa}, and B_{lim} (ICES, 2025a).

The fishery of herring in the GoR is only performed by Latvia and Estonia and the human consumption of herring in these countries is relatively high in comparison to other countries around the Baltic Sea (Pihlajamäki et al., 2019; Tuomisto et al., 2020).

Western Baltic Spring spawning herring (WBSSH)

The WBSSH herring migrates between the North Sea and the Western Baltic Sea for feeding and overwintering, and uses areas along the southern and western Baltic coasts for spawning, with the Greifswald Bay being a particularly important spawning ground (Nielsen et al., 2001; Bekkevold et al., 2007). After spending early life stages in the shallow nursery areas and metamorphosis to the juvenile stage, the herring moves on to offshore areas (Polte et al., 2017). Three to four distinct local stock components have been identified in the SD 20–24 area (Skagerrak, Kattegat, and the western Baltic) as well as the eastern North Sea, and these are managed collectively as a single WBSSH stock (Nielsen et al., 2024).

Over the past decades, this stock has declined due to low recruitment over a period of around two decades and high fishing mortality (ICES, 2024j). The stock is in such poor condition that ICES has recommended a complete ban on exploitation since 2019, which was largely followed and resulted in significantly decreased catches (from around 26 500 tonnes in SD 22, 23 and 24 in 2017 to 660 tonnes in 2024) (ICES, 2025b)[7]. However, catches remained too high for a longer time in the Kattegat and Skagerrak areas, which affected

7 Currently bycatch quota of 788 tonnes for WBSSH

the recovery of the stock. As the WBSSH stock spatially overlaps with the North Sea autumn-spawning herring, it is caught alongside it to some extent (ICES, 2024j). To ensure that catches are avoided, measures such as area and/or time restrictions on the fishery for herring in the eastern parts of the overlapping areas may be needed.

The western Baltic spring spawning herring population remains in very poor condition with no clear signs of recovery. Even if SSB has increased slightly the last few years, it is still below B_{lim}, and both recruitment and catches (which are exclusively bycatch as no directed fisheries are permitted) are very low. ICES advises zero catch for the stock for 2026 – the same advice given for the past eight years.

Baltic sprat

Baltic sprat is composed of a single large population and managed as one unit. The Baltic sprat stock has been a relatively stable stock in terms of SSB over the last decades. ICES advised a maximum quota of 230 518 tonnes for 2026, compared to 164 947 tonnes for 2025. Following three consecutive years of very low recruitment (2021 to 2023), the 2024 year class is estimated to be strong, contributing to improved recruitment estimates, and, consequently a higher SSB and catch advice. However, some uncertainty remains regarding this improvement. ICES notes that "*the 2024 year class (recruitment at age 1 in 2025) is estimated to be strong. However, in the autumn acoustic survey this year class was distributed mainly in north-eastern areas and this increases the uncertainty of its future contribution to the sprat biomass. The estimate of this year class is based on only this survey and its strength is uncertain until confirmed by the next survey (conducted in May 2025)*". The result of this survey has not yet been published at the time of writing this report.

Despite previous declines in recruitment and SSB, the sprat stock size has stayed above the reference points (B_{lim}, B_{pa} and $MSYB_{trigger}$) throughout the last decades.

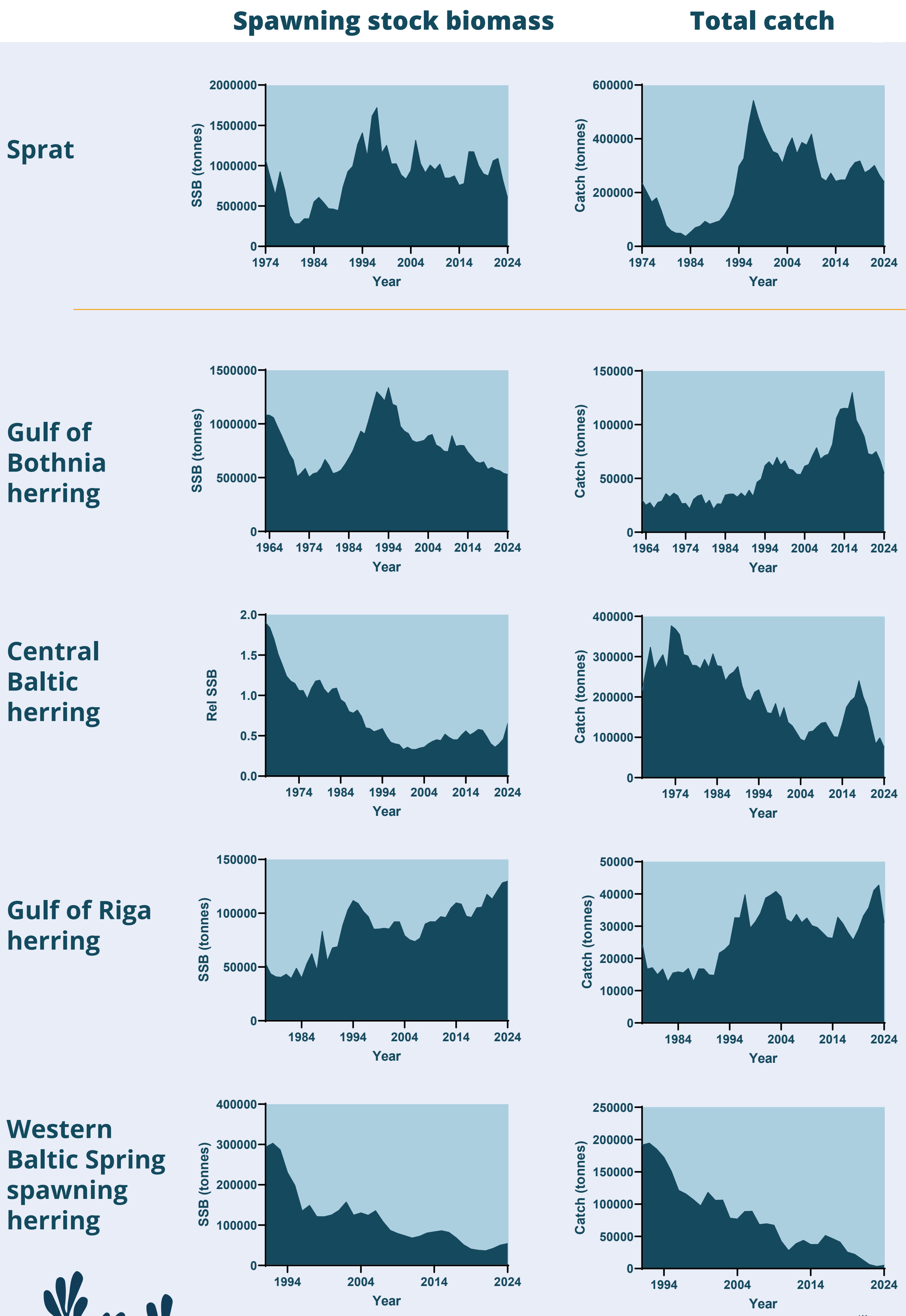


Figure 4. *SSB (left column) and total catches (right column) for sprat and herring stocks in the Baltic Sea based on ICES stock assessment data. (ICES, 2025)*

Chapter 3
The importance of forage fish for the ecosystem

The Baltic Sea has undergone so-called regime shifts or major ecosystem shifts, particularly over the 20th century due to the cumulative effects of external pressures. Productivity, climate, and hydrography have been identified as important factors affecting the Baltic food web over the last century, whereas fishing as a factor became important more recently (Tomczak et al., 2022). Over the last decades, the Baltic Sea ecosystem has undergone a regime shift, from being dominated by cod to being dominated by forage fish, primarily due to overfishing and rising hypoxia levels (Möllmann et al., 2009; Karlson et al 2024).

Ecological Importance and food web roles

In marine ecosystems, including the Baltic, forage fish act as prey for predator species from the upper levels of the ecosystem, such as larger (piscivorous) fish, marine mammals and seabirds. Forage fish also bridge the gap between lower trophic levels, i.e. plankton and larger marine life at higher trophic levels (as shown in Figure 5). This makes forage fish essential for maintaining the balance of marine ecosystems.

Larger fish are typically the main predator, and eat the largest proportion of the consumed forage fish biomass. Seabirds, however, can have a very big effect on a local level, for example around seabird breeding colonies which can reduce or deplete the prey availability in the surrounding area (Saraux et al., 2021, and references therein). Forage fish abundance, and consequently their availability as prey, generally varies at a faster rate than the number of predators which have longer life spans (Engelhard et al., 2014). Factors like fishing, food availability, climate change, and local predation pressure can all contribute to these fluctuations.

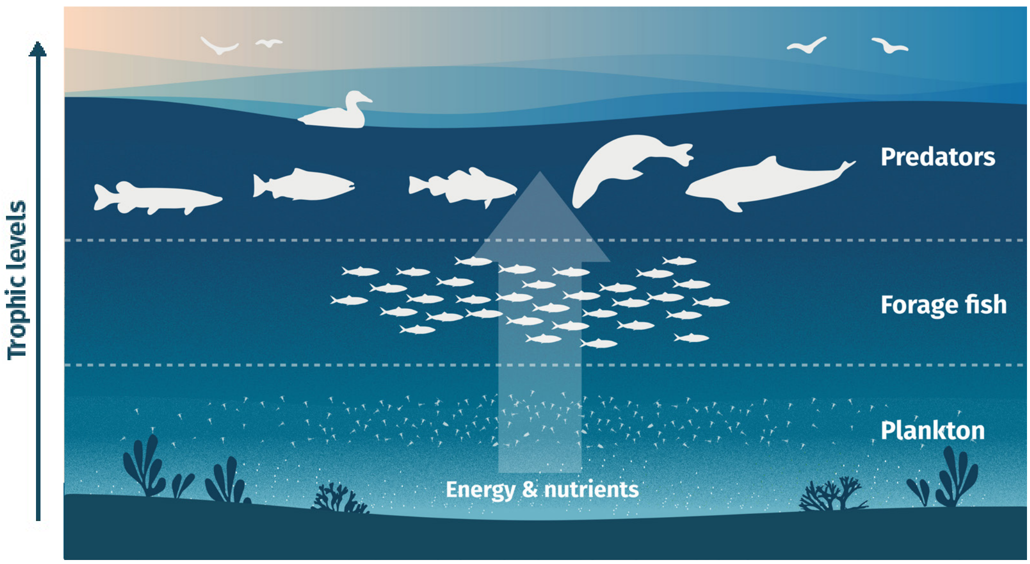


Figure 5 *Simplified (general) illustration of the central position of forage fish in the Baltic Sea ecosystem as prey for a range of predators as well as their importance in energy and nutrient transfer from lower to higher trophic levels.*

The Baltic Sea, with its relatively low species diversity compared to nearby regions like the North Sea, consequently has a simpler food web and less complex predator-prey relationships. In the eastern Baltic, this is especially evident, as it has traditionally been seen as having three main species with importance in its upper-trophic food web – sprat, herring and the eastern Baltic cod. However, forage fish also play a crucial role in the more complex food web of the North Sea. Species like herring, Norway pout (Trisopterus esmarkii), sprat, sardine and anchovy, sardine and anchovy and sandeels (Ammodytes marinus) are prominent forage fish in this region. North Sea herring is important for human consumption while sprat, sandeel and Norway pout are fished for industrial processing (Engelhard et al., 2014).

Sandeels (*Ammodytes* spp.) in the North Sea are a prime example of a heavily exploited and ecologically important forage fish species. Sandeels belong to the sand lance family (Ammodytidae) and spend the majority of their lives partially buried in sandy or gravelly areas on the seafloor. Similarly to sprat and herring in the Baltic Sea, sandeels are a key prey item for larger fish as well as marine mammals and seabirds while also being a target fishery species (e.g. Kerr et al 2017). Sandeel are a sedentary species (Wright et al., 2000), remaining in one location, with limited interaction with other areas, causing them to form separate, reproductively isolated subpopulations in different locations. Due to the sedentary traits of sandeel, local depletion can adversely affect predators in areas where many predators rely on local sandeel as prey, such as near seabird colonies (ICES, 2024b). Their population fluctuations can thereby have widespread effects on predators, including piscivorous fish (for instance cod, haddock and whiting), but particularly for puffins and other seabirds (Régnier et al., 2024; Saraux et al., 2021).

Sandeels in the North Sea were earlier managed as four stocks, but are now separated into seven stock areas. Out of these stock areas, three are evaluated using analytical assessments, one is considered data-limited and managed using an index of abundance, while the other three rely solely on catch statistics (Kerr et al 2017; ICES, 2015).

Baltic cod

The Atlantic cod (*Gadus morhua*) is one of the Baltic Sea's top predators. Cod in the Baltic Sea is separated into two populations, Eastern Baltic Cod (EBC) and Western Baltic Cod (WBC) with distribution areas in SD 24–32 and SD 22–24, respectively. The Eastern Baltic cod resides further northeast, near the threshold of salinity and oxygen conditions suitable for the habitation and successful reproduction of cod, as the Atlantic cod is inherently a saltwater species (e.g. Hinrichsen et al., 2011). The conditions in the Baltic Sea have become less favourable for cod reproduction over time, and EBC biomass has declined sharply since the late 1980s due to lower reproduction and high fishing pressure.

Another factor suggested as a driver for the poor condition of Baltic cod is the lack of food, both at younger life stages as well as for the older and larger, piscivorous cod and particularly for the EBC (Bryhn et al., 2022). Low oxygen levels or oxygen depletion in the Baltic Sea could affect cod physiology directly but can also indirectly be adverse by reducing the availability of benthic prey (Casini et al., 2016). For larger and older cod, fish prey is also an important source of food. The distribution of the main prey species – sprat and herring – have shifted further north in the Baltic Sea over the last decades while cod have remained to the south and now have a reduced spatial overlap with the forage fish prey. The factors driving this distribution shift are still not fully understood (Eero et al., 2012). Others have also noted that the reduced spatial overlap with sprat has likely led to a decrease of sprat in the (EBC) cod diet (Bryhn et al. 2022; Neuenfeldt et al. 2019).

See our report *The Decline of Cod in the Baltic Sea* for more information on the situation for Baltic Sea cod (Birgersson et al., 2022).

Baltic Salmon

Baltic Sea Atlantic salmon (*Salmo salar*) is another popular species which has been valuable for humans around the Baltic Sea since prehistoric times and primarily comes from rivers in the northern Baltic area. It is a top predator in the Baltic Sea and eats both sprat and herring, feeding mainly in the Baltic proper but also in the Bothnian Sea. Together with the grey and ringed seal, salmon are among the top herring predators (Kiljunen et al., 2020). The Baltic Salmon are also known to suffer from the reproduction disorder M74 syndrome, which has affected both farmed salmon and wild salmon feeding in the Baltic Sea. This syndrome is related to fat and thiamine (vitamin B1) content in their prey (e.g. Balk et al., 2016; Keinänen et al., 2022, 2024; Majaneva et al., 2020; Vuorinen et al., 2021). If the salmon diet mainly consists of young sprat this will cause the salmon to consume less thiamine "per unit energy" and thereby be deficient in thiamine (Keinanen et al., 2012; Keinänen et al., 2022). As a consequence of this syndrome, both reproduction and survival in the salmon are negatively affected. Other species can also be adversely affected by this syndrome but herring for example, was not shown to be in itself suffering from thiamine deficiency (Balk et al., 2016).

Keinänen et al (2022) studied thiamine in salmon feeding on different diets (located in three Baltic Sea areas). The study showed that thiamine deficiency was less linked to lipid content and more to concentrations of polyunsaturated fatty acids (n-3 PUFAs) (Keinänen et al., 2022). Furthermore, Lai et al examined food web interactions in the Baltic Sea using multispecies bio-economic models and showed that a combination of increasing seal populations with lower herring availability can severely affect salmon harvests (Lai et al., 2021). Keinänen et al (2025) also found that consuming high-lipid prey reduces post-smolt survivability and leads to thiamine deficiency in salmon. Availability of prey and quality of the available prey, especially the abundance of younger sprat versus herring in the Baltic Proper, can thereby affect the number of salmon surviving long enough to return to their spawning rivers (2025).

Northern pike

The Northern pike (*Esox lucius*, hereafter pike) is another piscivorous fish that can be found in the Baltic Sea. It is of lower commercial interest but has high value for recreational fisheries and as a top predator in the coastal areas (e.g. Bergström et al., 2022; Hansson et al., 2017). Due to its freshwater origin, the pike is limited to areas with lower salinity such as coastal areas in the central and northern Baltic Sea, as well as estuaries and lagoons in the southern and western Baltic Sea. In the lagoons one of the favoured prey species for pike is herring (Arlinghaus et al., 2023). Local decline of pike in the Baltic Sea has been observed in several studies (Bergström et al., 2022) and a recent study assessing regional population trends across the entire Baltic Sea showed some uncertainty in data but an overall declining trend for pike in the Baltic Sea, and particularly in the central and southern areas while there was a positive trend for pike abundance in Finland and Estonia (Olsson et al., 2023).

A literature synthesis by Arlinghaus et al regarding pike fishery in the Baltic Sea showed that numerous drivers have contributed to the decline of the pike in the southern Baltic Sea, including access to prey due to the decline in WBSS herring (Arlinghaus et al., 2023). Studies have also suggested that an ecosystem based management would be beneficial for Baltic Sea pike (Olsson et al., 2023).

Seabirds

Varying species of seabirds including the common murre/guillemot (*Uria aalge*, *Alcidae*), the razorbill (*Alca torda*), lesser black-backed gull (*Larus fuscus*), herring gull (*Larus argentatus*), and great cormorant (*Phalacrocorax carbo*) are top predators in the Baltic Sea. One of the best known examples of seabirds in the Baltic Sea feeding on forage fish comes from studies with common murre and razorbill around Stora Karlsö, an island located between Sweden's two largest islands, Gotland and Öland (SD 27). This area hosts the largest seabird colony in the Baltic Sea, where sprat and herring are among the preferred prey for breeding seabirds, particularly that breed there, particularly the common murre and razorbill (Engvall et al., 2023; Evans et al., 2013; Hentati-Sundberg et al., 2018; Kadin et al., 2012, 2016; Saraux et al., 2021).

Saraux et al (Saraux et al., 2021) showed that at low prey biomass, "*predation by seabirds became a source of important additional pressure*" on the stocks, using the link between Baltic Sea sprat and common murre as one of five case studies. The authors suggest that management of forage fish must take seabirds into account and that a threshold level for forage fish at low abundance should be taken into account by managers (Saraux et al., 2021). Previous studies have also advised that a certain minimal biomass of forage fish must be left (e.g. "one third for the birds") in order to allow for successful seabird breeding (Cury et al., 2011).

Beyond the Baltic Sea, seabirds are (of course) also affected by low forage fish availability. For example, one of the most vital forage fish species for seabirds in the North Sea is the sandeel (N.B. sandeels can also be found inside the Baltic Sea but are outranked by herring and sprat as the dominant Baltic forage fish). Big fluctuations in the abundance of forage fish can be a problem for seabird breeding (Saraux et al., 2021). A recent positive development for the forage fish in the North Sea was the closure of sandeel fishing in the English North Sea and in Scottish waters (UK Government Response, 2024), which is helpful for vulnerable seabirds like the puffin and kittiwake which rely on sandeel for feeding their chicks and which have been adversely affected by the sandeel depletion in the area (Dunn, 2021; Furness, 2007).

Marine mammals

The grey seal (*Halichoerus grypus*) is the largest seal found in the Baltic Sea and one of the area's top predators (Ohlberger et al., 2019). It feeds primarily on fish, for example herring, cod, flounder, sprat and perch, but the prey species varies somewhat with life stage, geographic location, season, and between years (Hansson et al., 2017; Lundström et al., 2010). Other marine mammals in the Baltic Sea that have forage fish as a part of their diet include the smaller ringed seal (*Pusa hispida*) (Kiljunen et al., 2020) and the harbour porpoise (*Phocoena phocoena*). Cod and herring are the main prey for adult porpoises (Andreasen et al., 2017).

The grey seal abundance has increased in the Baltic Sea over the last four decades. As top predators of the marine ecosystem, grey seals have historically been heavily affected by a range of environmental pollutants, most notably organochlorine pollutants like DDTs which led to declines in reproduction and low population numbers in the 1980s (Bergman, 1999). Levels of these pollutants have declined following regulatory bans, but seals are also affected by the availability of prey, including the declining fish stocks in the Baltic Sea, and may move to seek out new foraging areas when prey availability declines.

Herring was the second most important prey for grey seal (in terms of weight proportion) in a study from the Stockholm archipelago, while the most important prey species was perch and the third most important was pike (Svensson, 2021). A study by Hansson et al (2017) noted that compared to fishing pressure, the impact of predation by seals and birds was small on herring and even smaller for sprat in SD 24-32, but that "*since these fish populations are impacted by fisheries, increased mortalities caused by seals and birds, without reductions in the fishery, may contribute to a total mortality rate that exceeds the capacity of compensatory responses*" (Hansson et al., 2017). Costalago et al. (2019) also concluded that predation by grey seals likely affects the biomass of cod, herring, and sprat significantly less than climate change and fishing pressure. It is worth noting that both seal abundance and fishing pressure have changed since these studies were conducted. Furthermore, the effects of seal predation likely vary depending on location across the Baltic Sea, and updated data are needed to evaluate the overall impact of seals on forage fish beyond local predation pressure.

Forage fish diet and role as predators

With their place in the middle of the trophic levels, forage fish also act as predators themselves, with various copepod species and water fleas (*Cladocerans*) being some of the main prey (Livdāne et al., 2016; Ojaveer et al., 2017). The diet of sprat and herring varies depending on prey availability, season, location, time of day and the age of the individual. Larger and older forage fish are able to feed on larger prey and have better hunting abilities, and herring can, for instance, influence stickleback in overlapping areas through both predation and competition (Donadi et al., 2024).

Bernreuther et al. (2018) showed that sprat and herring in the Central Baltic Sea are mainly zooplanktivorous, with copepods (*Temora longicornis*, *Pseudocalanus acuspes* and *Acartia* spp.) and cladocerans (*Bosmina* spp. and *Podon* spp) being popular prey in spring and summer, respectively but that they had relatively low trophic coupling and predation pressure on zooplankton throughout the year (Bernreuther et al., 2018). There is an overlap in diet causing some competition between sprat and herring but there is also some specialisation or differences in selectivity between the species. Plankton availability also varies with water temperature and is sensitive to climate change (Engelhard et al., 2014). WKHERBAL notes that availability and distribution of zooplankton, impacts the condition of Baltic herring and should therefore be investigated further. Availability of large zooplankton such as *Mysidae* and *Pseudocalanus* is assumed to have a particularly big impact on condition and size of CBH and GoBH herring (ICES, 2024i). Additionally, prey of the right size needs to be available at the right life stage for forage fish, and "mismatch" in the timing of prey availability after herring larvae hatching could, for example, lead to starvation in herring larvae (see e.g. Polte et al., 2021 for climate-induced changes in herring reproductive success in the western Baltic).

A unique population of large, piscivorous herring ("Slåttersill") was recently identified along the Swedish coast through whole-genome sequencing. Stomach content analyses showed that the main prey for this herring was stickleback (Donadi et al., 2024). It is possible that this large piscivorous (i.e. fish-eating) herring could help counteract the stickleback expansion and help restore the food web to some extent, as long as it is managed favorably. Goodall et al. stress that a "*comprehensive understanding of the population structure is particularly important in species that are heavily exploited by industrial fishing, both for avoiding unsustainable overfishing and for protecting ecosystem function*" (Goodall et al., 2024). Stocks like GoBH and CBH, which are comprised of many distinct spawning components and can be at risk of losing genetic diversity if the stocks decline (Han et al., 2020; ICES, 2025d, ICES 2024i). Precautionary management and additional studies of population structure are important in order to preserve this genetic diversity.

Competition between planktivores

Aside from competition between sprat and herring over zooplankton such as the copepod *Pseudocalanus* spp., there is also an increase in competition with the three spined stickleback, an opportunistic species which has increased due to lower predation pressures from cod, pike and perch, combined with eutrophication and climate change (Olsson et al., 2019). Sticklebacks are small mesopredators which are tolerant to a range of temperatures and respond fast to changing conditions in the sea. Stickleback now makes up a larger proportion of the Baltic Sea biomass than previously (Svedäng et al., 2023). It is unclear exactly when the increase started but a sharp increase was seen in some parts of the Baltic around the 2011–2014 period (Olsson et al., 2019). A new study by Olin et al, based on thousands of samplings along the Baltic Sea coast, shows that the increase in stickleback has negative effects on pike and perch populations as well as cascading effects at levels further down in the food web (Olin et al., 2024).

The stickleback feeds on zooplankton, benthic fauna and fish eggs, including eggs of their predators, which allows them to suppress predators and expand further which creates a feedback loop as these predators would normally feed on stickleback and help regulate their abundance (Olin et al., 2024). Together with perch, stickleback is also a threat to forage fish (mainly herring) through egg predation and could possibly even affect herring recruitment locally (Kotterba et al., 2014; Kotterba et al., 2017). WKHERBAL recommends that modelling is used to assess the overlap between stickleback, sprat and herring to further investigate the competition between these species (ICES, 2024i) and that the interaction with stickleback should be examined further, both for stickleback as potential prey for large herring (see previous section) and as predators of herring eggs (ICES, 2024i).

This chapter emphasizes the crucial ecological role of forage fish in marine ecosystems. Species such as Baltic sprat and herring serve as key prey for a variety of predators, helping to maintain ecosystem balance by linking lower and higher trophic levels. In environments with low biodiversity, like the Baltic Sea, this can become even more critical as there are not many other species available to fill the same role. Declines in forage fish populations driven by human activities and environmental changes have significant implications for predator species, as seen in the collapsed Baltic cod population and the declining Baltic salmon condition. Contributing factors likely include reduced availability and quality of prey, along with shifts in prey distribution due to climate change. The health of forage fish populations is therefore fundamental to sustaining marine food webs. Efforts are needed to counteract pressures on these species and support the resilience and ecological stability of marine ecosystems.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Growth and development

Development of forage fish is affected by a number of factors. For example, studies have shown that the physio-chemical environment affects the growth and mortality in herring larvae. Temperature is also known to affect timing of developmental events. A study by Polte et al (Polte et al., 2021) showed that reproduction in spring spawning herring was affected by the annual timing of the spawning period. One limiting factor of reproduction is salinity as both sprat and herring are species of marine origin. Furthermore, herring growth has been assumed to be affected by both food availability/competition for food as well as abiotic factors (e.g. Smoliński 2019; Lindegren, Ostman, and Gårdmark 2011; Margonski et al. 2010).

Further analysis of herring diet including stomach content studies are recommended by WKHERBAL (ICES 2024h). This report also lists a number of factors which impact the condition, size and age structure of Central Baltic herring and Bothnian herring (ICES 2024h):

Factors affecting Bothnian herring and Central Baltic herring

GoBH

Altered age structure
- *"increased F in the early 2010s "*

Reduced size
- *"regime shift at the end of the 1980s (ages 1-3)*
- *decreasing size of phytoplankton and zooplank-ton species*
- *changes in zooplankton community due to lower salinity*
- *density dependence (ages 1-4)"*

Condition
- *"food availability, specifically the large bodied Limnocalanus macrurus, Mysidae and Pseudo-calanus. Missing mysids likely explain the drop observed in 2021, on ages 3 and older*
- *density dependence (ages 1-5 in the 2010s, ages 6 and older in the 1990s)"*

CBH

Altered age structure
- *"effects of fishing pressure*
- *changes in the proportions of populations in the stock"*

Reduced size
- *"changes in the proportions of populations in the stock and/or changes in the proportions of fast and slow-growing individuals within the same population (Rosa Lee effect)*
- *competition with sprat*
- *food availability (including Mysidae and Pseudo-calanus)*
- *abiotic factors"*

Variations in condition
- *"competition with sprat*
- *food availability (including Mysidae and Pseudo-calanus)*
- *abiotic factors"*

(ICES 2024i, p19)

Chapter 4
Pressures on Baltic Sea Forage Fish

The impacts of climate change and human-induced pressures are progressively affecting ecosystems worldwide. The Baltic Sea is a relatively shallow, semi-enclosed inland sea, ranking among the largest brackish areas globally and is also the youngest sea in the world. The average depth is only 54 metres, making the Baltic Sea very shallow compared to many other seas and oceans. Its water temperature is influenced by depth, location, and seasonal changes. Oxygen concentration also varies throughout the sea. The weather also fluctuates greatly, as it is influenced by both a temperate marine zone and a subarctic continental zone (Reusch et al., 2018). Its hydrological features make the Baltic Sea unique and has also led to biodiversity patterns with a mixture of marine and freshwater species (Voipio, 1981). The Baltic Sea contains relatively few species in total, which have been able to adapt to the challenging environment (Johannesson et al., 2011). Due to the brackish water gradient, marine species are predominantly found in the southwest, while freshwater species inhabit the northern and eastern parts of the Baltic Sea (e.g Ojaveer et al. 2010).

Freshwater is introduced to the brackish sea from rain and numerous rivers while marine water from the North Sea enters from the south, contributing to the characteristic salinity gradient in the brackish Baltic Sea. A salinity gradient from the south to the north is formed (salinity in the Danish straits in the south is ten times higher than the Bothnian Bay in the north (20‰, and 2‰ respectively, while the average salinity is 7‰.) and stratification with higher salinity in the deeper water layers and lower salinity at the surface can also be found in many areas (Meier et al., 2022). As the salinity levels change along the gradient of the Baltic Sea, fewer marine species are found in the north, and freshwater species gradually become more common (Ojaveer et al., 2010).

Reusch et al has suggested that the Baltic Sea is a suitable case study or "time machine" which can be used to study the "*consequences and mitigation of future coastal perturbations*" (Reusch et al., 2018). The authors state that the Baltic Sea is currently "*affected by levels of*

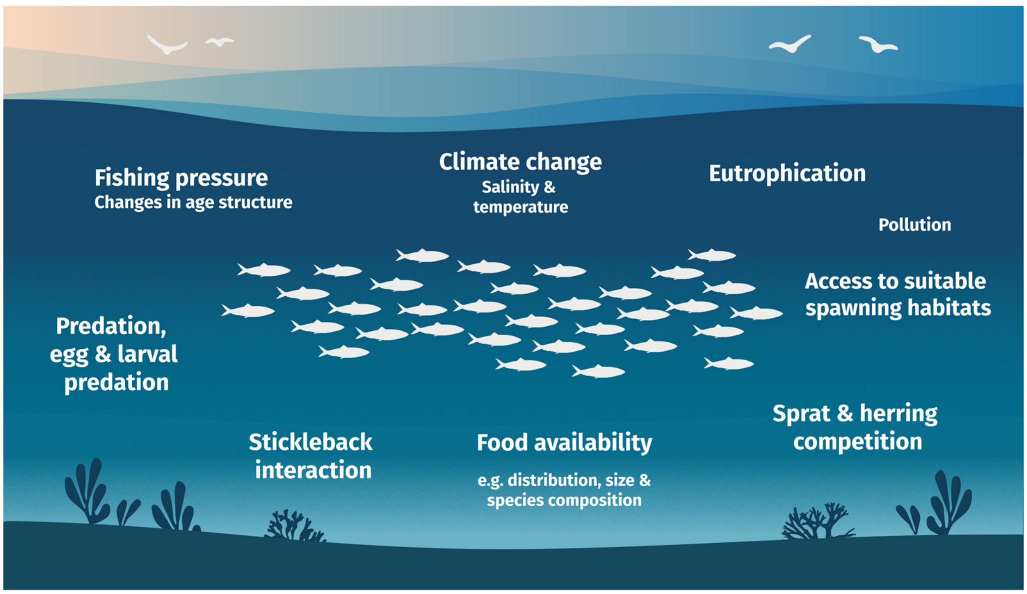

Figure 6. *Simplified overview of factors that have an impact on Baltic Sea forage fish based on our literature study. NB there are geographical variations and adult fish are affected differently than young life stages (eggs and larvae). Additionally, factors such as temperature can, for instance, have a positive effect on growth to a certain level and is also not affecting sprat and herring in the same way. Some factors are directly or indirectly linked together, further complicating the situation.*

warming, acidification, nutrient pollution, and deoxygenation that most coastal areas will experience only in the future", making it suitable for studies of what could happen in other systems in the future. In addition, the Baltic Sea area is also well studied, with a long tradition of scientific studies and "*the region is an ideal illustration of a complex governance setting in which environmental management has to operate*" (Reusch et al., 2018).

In summary, fish living in the Baltic Sea face a combination of various stressors. Beyond fishing pressures and predation by other fish, mammals and seabirds, several external factors can affect the status of forage fish in the Baltic Sea, and may need to be taken into consideration for forage fish stocks. Below follows more extensive sections about the factors that are most frequently discussed in recent scientific literature on Baltic Sea forage fish. Note that the order and length of these sections as well as their placement in Figure 6 do not indicate their relative importance. See also Chapter 3 for factors such as interactions with stickleback, food availability, competition and predation.

Climate change

The effects of climate change are more easily noticeable on land while shifts within marine environments are more challenging to detect. On land, the timing of seasonal processes is recognized as a "*present-day threat to species' reproductive success*", while in aquatic environments the changes are not as visible and more focus is on the direct physiological impact of the increased temperatures and acidification of the oceans (Polte et al., 2021). Water temperature is one factor that affects forage fish reproduction, including the location and seasonal timing of, for instance, spawning in herring (Cardinale et al., 2009). Rising temperatures can accelerate development or shift the timing of life history events in an organism (Weigel et al. 2021).

The Baltic Sea, being both shallow and semi-enclosed, can undergo relatively fast environmental changes. It is gradually becoming warmer and less saline due to climate-driven habitat changes (Illing et al., 2016), which favours some species and is a disadvantage for others (Peltonen & Weigel, 2022). The Baltic Sea ranks among the marine ecosystems experiencing the swiftest warming worldwide, alongside other inland or partially enclosed seas in Europe and Asia (Belkin 2009).

Forage fish are generally responsive to changes in climate (Engelhard et al., 2014) and altered distribution patterns for herring have been assumed to be driven by climate-induced shifts in the geographical location of their food (Toresen & Østvedt, 2000). Additionally, altered plankton populations have been linked to climate change (Beaugrand et al., 2002; Richardson & Schoeman, 2004).

Coastal areas are particularly affected by environmental change, which can subsequently affect both fish and fisheries in the area. A recent study by Peltonen & Weigel (Peltonen & Weigel, 2022) examined 16 fish species, including sprat and herring, in areas along the Finnish coast and found that environmental change (including temperature, salinity and near-bottom oxygen concentrations) could be responsible for a number of variations in fishery yields. The yield of cold affinity species from marine origins (including cod and herring) decreased while freshwater species and species adapted to warmer temperatures were more likely to benefit from the changes. For herring, the results showed a decreasing yield, which might indicate that environmental change over the last decade or so has been disadvantageous (Peltonen & Weigel, 2022). Eutrophication and decreasing salinity can also contribute to a less favourable situation for herring recruitment (Rahikainen et al., 2017).

In contrast, Sprat stood out as this species has increased even though it is originally a marine species with cold-affinity (Peltonen & Weigel, 2022). Previous studies have also shown that sprat reproduction benefits from warming water temperatures (e.g. Voss et al., 2011), although the decreased predation pressure from Baltic cod is also a likely contributor (Peltonen & Weigel, 2022). However, there is still likely a limit to how far north the sprat can reproduce as salinity needs to be high enough (5–8 ppt) for eggs to develop successfully (e.g. Petereit et al., 2009).

The western Baltic herring stock has been below the biomass limit reference point (B_{lim}) for nearly two decades and is in urgent need of rebuilding (ICES, 2024g). The spawning stock size is so small that even at very low fishing pressure, rebuilding can be difficult (ICES, 2024j). The advice for this stock emphasizes that, in addition to lower fishing pressure, there is a need for conservation measures in order to protect areas used for spawning and as nursery areas (ICES, 2024d).

Research on this stock, the effect of warmer winter temperatures has been conducted over more than 15 years, after the decline in the early 2000s. The timing of the herring's spawning period are also assumed to affect this stock's survival due to the need for access to suitable food during larval stages. Polte et al (2021) investigated climate effects in the form of warming winters on spring spawning herring recruitment to determine a temperature threshold for the onset of spawning. The study found that warming winters are a stressor for the reproductive capacity of (spring spawning) herring. Cold periods late in the season affected larval hatching and herring reduced production as well as the number of surviving juveniles (Polte et al., 2021).

Some studies suggest that fisheries management frameworks should include assessments of climate vulnerability (e.g. Froese et al., 2022; Spencer et al., 2019). A study by Froese et al (2022) was, for example, aimed at differentiating between mismanagement (such as unsuitable gear selectivity or excessive catch levels) and climate change as factors contributing to the decline in reproduction and spawning stock size for herring and cod in the western Baltic Sea. The study found that for both cod and herring in the Western Baltic Sea, mismanagement rather than climate change is likely the primary explanation for their current poor status (Froese et al., 2022). Froese et al also point out that it is important to distinguish between mismanagement and climate change since "*if climate change is the main cause of decline, then there may be little that managers can do other than adjusting fishing to reduced productivity*" (Froese et al., 2022).

Climate change is clearly influencing the Baltic Sea ecosystem and its species, and will likely continue to do so in the future. Mitigating climate change requires sustained global efforts on a long term scale, and both biodiversity and ecosystem health will remain vulnerable to its impacts. Continued research is also needed to distinguish the effects of climate change from other environmental and human-induced pressures.

Eutrophication

Eutrophication, a pressing environmental concern in the Baltic Sea, is a process that results from an excessive influx of nutrients, primarily nitrogen and phosphorus, leading to an overabundance of algae and subsequent oxygen depletion. The Baltic Sea was initially a nutrient-poor area but underwent rapid nutrient enrichment in the 1900s due to increased nutrient influx from anthropogenic activities, including runoff from agriculture and surrounding urban areas, which peaked between the 1950s and 1980s (Gustafsson et al., 2012).

Eutrophication first affects the primary producers; and leads to a chain reaction where primary production increases through elevated growth of phytoplankton, which in turn reduces the water quality and makes the water less favourable for fish and other organisms to live in. The water quality changes can alter the species composition or spatial overlap and interactions between species, depending on which animals are favoured by the new conditions (Carstensen et al., 2014).

Eutrophication in the Baltic Sea (as well as elsewhere) has also led to harmful algal blooms, reduces light levels and visibility in the water and leads to oxygen deficiency in deeper waters, with complete oxygen depletion in some areas, leading to what are known as dead zones.This is particularly harmful for species which use these areas for spawning and reproduction (Carstensen et al., 2014; Casini et al., 2016; Tomczak et al., 2022).

A study by Eero et al (Eero et al., 2016) assessed the effects of eutrophication on forage fish production and found that for sprat in the Baltic Sea, the trends seen in sprat biomass over recent decades "have occurred independently of nutrient dynamics, largely driven by climate and top-down control (predation, fishing)", suggesting that the fish biomass may not match the trends in nutrient dynamics but will instead likely be more affected by "other prevailing ecosystem and climate conditions". The authors reason that the effects of nutrient dynamics on pelagic fish abundance could vary by species (Eero et al., 2016).

On a positive note, the latest HELCOM HOLAS report states that nutrient inputs into the Baltic Sea have decreased, showing a clear downward trend for the total input of both phosphorus and nitrogen in the Baltic Sea over the last decades. However, eutrophication and its effects still remains a major issue for the Baltic Sea (HELCOM, 2023) and improvement is expected to take a considerable amount of time, especially in combination with climate change. A modelling study by Murray et al (Murray et al., 2019) suggests that adhering to the Baltic Sea Action Plan would lead to a good eutrophication status in the long term in most areas of the Baltic Sea.

Pollution

Pollution from hazardous substances is another issue impacting the status of the Baltic Sea and the degradation of its biodiversity, which was highlighted in HELCOM's holistic assessment where pollution was listed as one of the key pressures (HELCOM, 2023). Agricultural runoff, industrial discharge, shipping activities, and inadequate waste management practices have all contributed to the pollution. The Baltic Sea has a relatively long history of chemical contamination in the form of traditional persistent pollutants (e.g. dioxins, PCBs, DDTs) and heavy metals, but there are also newer contaminants of emerging concern, including perfluorinated compounds (PFASs) (Reusch et al., 2018).

Fish with a high fat content are able to biomagnify certain types of pollutants, such as dioxins and PCBs, in the Baltic Sea food web, as these contaminants are fat-soluble. Species like herring and salmon in the Baltic Sea often have levels of PCBs and dioxins that exceed the EU regulation limits (Tuomisto et al., 2020). The presence of dioxins still somewhat limits market opportunities for Baltic herring (Hornborg, 2023). Somewhat surprisingly, dioxin levels can vary between herring populations, with the "Slåttersill" exhibiting low levels despite its large size and high fat content. This could plausibly be explained by its diet, which consists largely of fish and thus results in lower exposure to sediment-bound contaminants compared to a diet of bottom-dwelling prey such as Mysids (Goodall et al., 2024; Karlsson, 2025).

Chemical warfare agents dumped in the Baltic Sea after World War II can still be found in some of the deeper parts of the sea, and the canisters holding these compounds can leak as they deteriorate. Approximately 50,000 tons of chemical weapons were disposed of in the Baltic following the war (Vanninen et al., 2020). As these compounds were designed to harm humans through chemical or biological means, they also have the potential to negatively impact the environment and marine life near the affected containers (Szarejko & Namieśnik, 2009; Vanninen et al., 2020). A study of arsenic compounds in herring, sprat, and other species in the southern Baltic, linked to dumped chemical munitions, found the highest levels in sprat, while cod had the lowest among the tested species. The concentrations were below international safety limits and are considered unlikely to pose a risk to human consumers ((Polak-Juszczak & Szlinder Richert, 2021). However, the quantities of leaked compounds are relatively large and may still pose a threat to fish in these areas (Polak-Juszczak & Szlinder Richert, 2021).

While persistent legacy contaminants such as PCBs and DDT have been decreasing after their peak in the 1970s and 80s, pollution of the Baltic Sea remains a significant problem. It is important that international biomonitoring of Baltic Sea pollution, including newer contaminants like PFASs, continues in the Baltic Sea at the international level.

Habitat degradation

Enclosed areas like the Baltic Sea are particularly susceptible to ecological degradation because of the slow water turnover rate and the continuous input, cycling, and accumulation of various contaminants, such as persistent organic pollutants (Rebryk & Haglund, 2022). Kraufvelin et al (Kraufvelin et al., 2018) characterised habitats that are essential for fish in the Baltic Sea as well as the pressures these habitats are under. The paper lists climate change, eutrophication, coastal construction and development of invasive species and fisheries as important cumulative pressures affecting fish in coastal areas, and also states that conservation coverage for essential fish habitats in those areas is still lacking (Kraufvelin et al., 2018).

Out of the advice for Baltic Sea forage fish stocks, the Western Baltic herring advice has the biggest focus on conservation considerations, with ICES stating that "*measures to protect and restore known spawning habitats and nursery areas are needed*" for this stock (ICES, 2025b). They state that the non-fishing factors have a considerable impact on WBSS herring, particularly affecting early life stage survival.

Parasites

Seal parasites have presented an issue for seals as the final host but also for e.g. Baltic cod as an intermediary host (e.g Ryberg et al., 2020) and have increased with the increasing number of grey seals in the Baltic. However, forage fish are less explored as intermediary hosts for seal parasites. Nadolna-Ałtyn et al., (2018) found that in their most recent sampling (but not their earlier one), sprat from the southern Baltic Sea contained larvae of the seal liver worm Contracaecum osculatum (Nadolna-Ałtyn et al., 2018) which could indicate that sprat act as "*a transmitter of this parasite to piscivorous organisms in several areas of the Baltic Sea*". Zuo et al also found C. osculatum occurrence in about 11.6% of sampled sprat individuals (2016).

Sahlstén et al found the intestinal parasites Corynosoma spp, which is normally found in seals, in both Great cormorants and in around 14% of herrings sampled from the northern Baltic Sea (Sahlstén et al., 2023). The authors saw a big variation in prevalence between year and site where herrings were sampled (Sahlstén et al., 2023). Parasites like liver worms and intestinal parasites may occur to a larger extent in fish that are already in poor condition, as this can make them more susceptible to infections (Lafferty & Kuris, 1999). Further investigation of parasite-host relationships for forage fish are needed even though this is not likely to be the dominant factor affecting the state of the forage fish stocks.

Invasive species and forage fish egg predation

The changing conditions of the Baltic Sea, e.g. climate change has led to more favourable conditions for certain species, including invasive species like the round goby (Neogobius melanostomus), which have low commercial value and which take over areas of the coastal Baltic Sea (Ojaveer et al., 2018). Wiegleb et al (2018) assessed the impact of round goby on herring egg predation, and showed that smaller round gobies did eat herring eggs in the field but but the overall effect on survival was minor in comparison to egg predation from three-spined stickleback or European perch (e.g. (Wiegleb et al., 2018)). In large numbers, juvenile round goby could potentially be a problem for herring eggs in locations such as the Greifswald bay, where spawning beds for spring-spawning herring are found (Henseler et al., 2021). However, a recent modelling study by Naddafi & Florin found that increasing numbers of round goby would be unlikely to affect sprat or herring abundance (2025).

Another possible predator during early life stages is the comb jelly (Mnemiopsis leidyi), an invasive species in the Baltic Sea known to feed on ichthyoplankton. It could therefore potentially affect the larval survival of herring. A laboratory study by Stoltenberg et al (2024) demonstrated that M. leidyi was capable of consuming herring yolk-sac larvae. The authors suggest that jellyfish should be considered as a factor affecting fish recruitment but also note that further studies are needed to better understand the interaction. Earlier studies have similarly shown effects of jellyfish predation on herring larvae, with Aurelia aurita having a large impact on herring recruitment in the Kiel Fjord predation of (Möller, 1984).

Fishing as a pressure on forage fish condition, age structure and size structure

Apart from the aforementioned environmental pressures, fishing and fisheries management have an impact on the status of commercially valuable fish stocks. In fact, the HELCOM HOLAS assessment lists overfishing as a key pressure on the Baltic Sea ecosystem (HELCOM, 2023).

Commercial fishing has been shown to adversely affect marine fish populations on a number of levels, from the direct/indirect mortality during fishing, to changes in body size, sex ratios, a reduction of age of maturation as well as changes in the habitats and ecosystems that are needed for fish populations (Griffiths et al. 2024, and references therein). Furthermore, truncated size and age structure of commercially targeted species can be a result of gear selectivity and fisher's behaviour (Barnett et al., 2017; Pauly et al., 1998).

Changes in age and size structure as well as the condition of CBH and GoB herring and the drivers behind these changes have been discussed in the WKHERBAL workshop which aimed to establish "*a roadmap for possible conservation measures*" for Baltic Sea Herring (ICES 2024h). Drivers causing the changes in herring condition, as well as herring age- and size structure were discussed.

During the WKD3C3SCOPE workshop held in 2023, it was agreed that "overall, healthy fish stocks are characterized by high productivity, wide age and size structuring in the population, and the ability to quickly recover from disturbances" (ICES, 2023f). It was also agreed that factors influencing a stock's productivity and health include stock biomass, fishing pressure and environmental pressures, the latter being especially important for short-lived stocks. "It was suggested that the age structure of a stock might be more relevant for evaluating the health of long-lived stocks.". Long-lived stocks are also more likely to contain some very large and old individuals that act as "megaspawners", contributing a lot to reproduction (ICES, 2023f).

Chapter 5 further discusses fishing limits, management decisions, quota-setting and misreporting linked to Baltic Sea forage fish.

Aside from the impact of fishing pressure, forage fish in the Baltic Sea face a range of environmental stressors that affect their health, condition and productivity which is summarized in this chapter based on the literature review. Climate-driven changes in temperature, salinity, and stratification, along with eutrophication, habitat degradation, and pollution, have all impacted key species like sprat and herring to varying extents. Shifts in zooplankton communities, competition among planktivores, rising stickleback numbers, and invasive species are also contributing to the state and condition. In the shallow, enclosed Baltic Sea, such cumulative pressures must be considered in efforts to protect and restore fish populations.

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Ecosystem Based Management

What is Ecosystem Based Management?

Ecosystem-based management is one expression of a set of principles aiming at the management of natural resources within the boundaries of nature. It can be expressed in several different ways, where multiple similar expressions exist which to a large extent cover the same basics and are used exchangeably (Wang, 2004). One distinction though is relatively often drawn between "ecosystem management" and "ecosystem approach", where ecosystem management, or ecosystem-based management, often entails a more concrete management tool for specific areas, while the ecosystem approach is used as a vision for a sustainable future of different issue areas (Maltby, 2000).

EBM in scientific literature

In essence, ecosystem-based management includes some core elements which are given more or less attention depending on context. These elements include 1. The view of humans as part of the ecosystem, instead of separated from it, i.e. human activities and natural resource management is part of and shapes the ecosystem, but it needs to keep within the ecological boundaries of the system. There also lies the need to consider ecosystem connections. 2. An effective management requires both scale- and sector integration, meaning the management must follow the ecological borders instead of administrative or sectorial boundaries. 3. It is important that the management always follows the best scientific knowledge available. 4. In management decisions, stakeholder participation is essential, and 5. The management system needs to be adaptive in a changing environment, i.e. be flexible for the changing nature of the ecosystem and its ecosystem services (Long et al., 2015; Söderström & Kern, 2017).

Following the logic of EBM there are several strains of literature covering more specific fields, such as fishing through the development of ecosystem-based fisheries management (EBFM) which has been increasing in scope over the last 20 years (Lidström & Johnson, 2020; Pikitch et al., 2004) synthesise a large literature overview of the essence of EBFM:

1. *"avoid degradation of ecosystems, as measured by indicators of environmental quality and system status."*
2. *"minimize the risk of irreversible change to natural assemblages of species and ecosystem processes."*
3. *"obtain and maintain long-term socioeconomic benefits without compromising the ecosystem."*
4. *"generate knowledge of ecosystem processes sufficient to understand the likely consequences of human actions. Where knowledge is insufficient, robust and precautionary fishery management measures that favor the ecosystem should be adopted."*

Pikitch et al. 2004, p 346

Several authors also stress the importance of a holistic view of the management, especially in the light of interactions between species and the environment which requires a shift away from single-species management to multi-species management. The precautionary principle is stressed, including the reverse burden of proof where fishing operations should be allowed if they can prove not to harm the environment and the need for flexible management that adapts to local conditions is stressed to facilitate implementation (Lidström & Johnson, 2020; Pikitch et al., 2004; Trochta et al., 2018). In a recent paper from Scotti et al (Scotti et al., 2022), several scenarios of fisheries management in the western Baltic Sea are analysed, including fishing at the current management level (business as usual), maximum or half of sustainable fishing or fishing with ecosystem-based fisheries management with reduced fishing on forage fish. The results clearly show that EBFM fishing increased the populations of both cod and herring, hence resulting in larger catches of these species, and it also proved to be beneficial to the harbour porpoise population. Fishing at its current state continues the low catches of depleted stocks and also poses a threat to harbour porpoises (Scotti et al., 2022).

Human consumption of forage fish - direct and indirect

Forage fish are a key resource for both direct human consumption and for global fishmeal and fish oil production, which are important for aquaculture and livestock feeds (Hornborg and Langeland 2024). Denmark, in particular, is among the leading producers of fish meal and fish oil. Compared to species such as salmon, forage fish species are "underutilised" for human consumption. For instance, Finland uses only around 3% of its herring catch as domestic food, reflecting the lower demand for small pelagics compared to the preference for eating, for instance, farmed salmonids (Pihlajamäki et al., 2019) *and references therein)*. When comparing Sweden, Finland, Denmark and Estonia, Estonia is the only country where herring is primarily caught for human consumption. 62% of Estonians ate Baltic herring "*at least sometimes*," compared to only 25% in Denmark while Finland and Sweden were at 54 and 42%, respectively (Pihlajamäki et al., 2019). The authors also suggest that the availability of herring on the market needs to improve. The consumption of herring varies both between Baltic MS, and within countries depending on age. A study by Tuomisto et al (Tuomisto et al., 2020) also included case studies comparing herring consumption, finding that Estonia has the highest consumption of Baltic herring out of the four countries, and that 30% of the Estonians over 45 years of age ate more than 3.6 kg of Baltic herring per year, while the average for the countries studied was around 1 kg/year (Tuomisto et al., 2020).

Pihlajamäki et al. compared the drivers and barriers of Baltic herring consumption with those of salmon and found that consumer information needs improvement, along with consideration of the complexities surrounding the consumption of forage fish, including differing perspectives between countries (Pihlajamäki et al., 2019). The authors also stated that the availability of herring on the food market needs to increase. A recent case study by Hornborg (Hornborg, 2023) assessing sustainability and looking into environmental, social and economic values linked to Swedish herring fisheries in the Baltic Sea. Hornborg states that some benefits of direct human consumption include decreased greenhouse gas emissions, an increase in nutritional value, more affordable seafood for consumers, on top of the increased economic value for fishermen, although there are also challenges (Hornborg, 2023). In Sweden, there is some reluctance to consume Baltic herring due to concerns over dioxin contamination (Pihlajamäki et al., 2019). Sweden has an exemption allowing large herring to be sold on the Swedish market regardless of their contaminant levels, but the Swedish Food Agency is responsible for informing the public about dietary advice and risks with eating fatty fish from the Baltic Sea (Livsmedelsverket, 2023).

Fish meal and fish oil

A substantial amount of the landings from fisheries around the world end up processed into fish meal or fish oil instead of being directly used for human consumption. Fishmeal and fish oil are mainly used by aquaculture, followed by the pig and poultry industries (EUMOFA, 2023). Fishmeal and fish oil can be

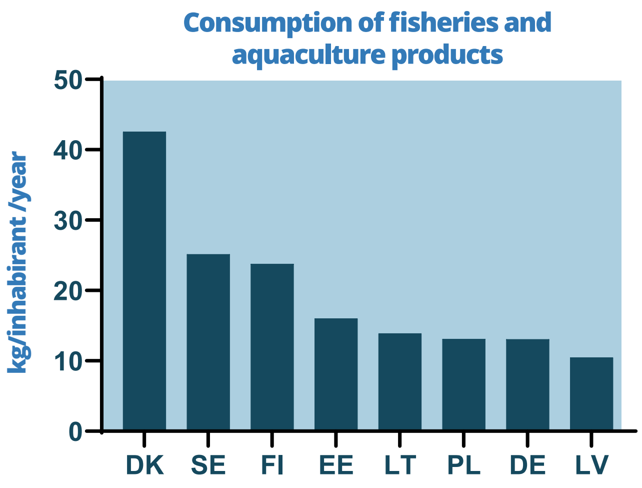


Figure 7. *Overview of fish and seefod consumption in Baltic Sea member states showing that Denmark by far consumes the most fish and otehr seafood productswhile Latvia, Poland, Germany and Latvia consume the least.Based on EC (2022).*

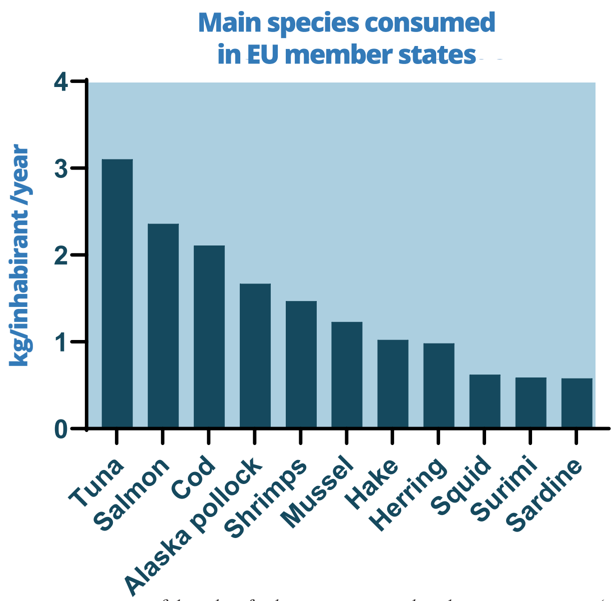


Figure 8. *Main fish and seafood species consumed in the European Union (Based on EC 2022, with data for 2019).*

produced from whole fish or from by-products from processing larger fish. Small pelagic species like Peruvian anchoveta, sardine, mackerel, and herring are used as whole fish (FAO, 2022). The EU produces about 10–15% of the global total of fishmeal and fish oil (EUMOFA, 2023) with Denmark as the main producer among Baltic Sea countries, accounting for 40% to 50% of the total EU production, and this production is mainly based on forage fish like sandeel, blue whiting and herring (EUMOFA, 2023).

The Research Institutes of Sweden (RISE) were commissioned to map where fishmeal and oil from Baltic Sea herring ends up, and results were published in a report (Hornborg & Langeland, 2024). The report showed that out of 167 678 tonnes live weight herring landed in the Gulf of Bothnia, Central and Western Baltic in 2023, 38 027 tonnes of Baltic herring was received by Danish processing factories and made into fishmeal and fish oil. Most of the fish meal and fish oil (69.3 and 99.8%, respectively) were destined for aquaculture (Hornborg & Langeland, 2024). This is in line with the global use of fishmeal and fish oil which is primarily consumed by aquacultured species (Majluf et al. 2024). Globally, 12 of the 20 most landed marine fish species are forage fish caught by reduction fisheries and processed into fishmeal and oil. Atlantic herring is number four on this list with 19.4 million tonnes landed globally during 2010–2020 while sprat is number 17 on the list (5.8 million tonnes landed globally). The most landed fish species, by far, is another forage fish, the Peruvian anchovy (*Engraulis ringens*) with 53.6 million tonnes landed globally, and which is the world's largest single-species fishery (Majluf et al. 2024).

The RISE report authors note that Baltic Sea landings often contain a mixture of sprat and herring which are not separated by species before processing as this is not physically possible at present (Hornborg 2023; Hornborg and Langeland 2024). The authors called for more transparency and detailed reporting from feed producers, along with more efficient data management strategies (Hornborg & Langeland, 2024).

Development of aquaculture feed alternatives that do not rely on wild fish stocks is ongoing, and could be a more sustainable option, especially with the decline of some forage fish stocks. These feeds could for example be plant/algae based or contain alternative protein sources from insects or waste from other industries (EC COM(2021) 236). Majluf et al. suggest that *"Reducing or eliminating the use of forage fish in aquaculture will only make aquaculture more resilient to climate change*" (Majluf et al. 2024).

Chapter 5
Management of forage fish stocks in the Baltic Sea

Introduction & importance of precautionary management

Precautionary management of forage fish stocks helps ensure sustainable harvests while preserving their crucial ecological role in the marine food web. In principle, the EU Common Fisheries Policy (CFP) requires an ecosystem-based approach to fisheries management to safeguard ecosystems, address multi-species interactions, and ensure that resources remain viable for future generations. However, much of the existing management still focuses on single-species Total Allowable Catches (TACs) and has not fully embraced ecosystem considerations. This section reviews the current EU management framework, identifies critical gaps, and proposes avenues for a precautionary, ecosystem-based regime.

Policy Framework

The Common Fisheries Policy and Ecosystem-Based Fisheries Management

Under the Treaty on the Functioning of the European Union (TFEU), fisheries is an exclusive competence of the EU, meaning only the EU can adopt legislation regulating EU fisheries. The CFP (Regulation (EU) No 1380/2013) was established in 1983 and was meant to be an overarching EU fisheries policy instrument, which includes agreements and guidelines regarding commercial fishing for the EU fleet. The first iteration of the CFP mainly focused on setting catch limits for commercial fish species and the division of these fishing opportunities between member states. Since then, it has been reformed in 2002 and 2013, with new conservation elements added, such as aiming to ensure stocks are fished at levels consistent with the maximum sustainable yield (MSY) by 2020, the latest.

> *"The CFP shall apply the precautionary approach to fisheries management, and shall aim to ensure that exploitation of living marine biological resources restores and maintains populations of harvested species above levels which can produce the maximum sustainable yield."*
>
> **Regulation (EU) No 1380/2013**

The CFP introduces a clear commitment to ecosystem-based fisheries management, although implementation in practice has been challenging. It is highlighted in the following sections in the CFP:

"13) An ecosystem-based approach to fisheries management needs to be implemented, environmental impacts of fishing activities should be limited and unwanted catches should be avoided and reduced as far as possible."

CFP, 2013, p2

"(3) The CFP shall implement the ecosystem-based approach to fisheries management so as to ensure that negative impacts of fishing activities on the marine ecosystem are minimised, and shall endeavour to ensure that aquaculture and fisheries activities avoid the degradation of the marine environment."

CFP, 2013, p 8, Part 1 Article 2 Objective 3

"(9) 'ecosystem-based approach to fisheries management' means an integrated approach to managing fisheries within ecologically meaningful boundaries which seeks to manage the use of natural resources, taking account of fishing and other human activities, while preserving both the biological wealth and the biological processes necessary to safeguard the composition, structure and functioning of the habitats of the ecosystem affected, by taking into account the knowledge and uncertainties regarding biotic, abiotic and human components of ecosystems"

CFP, 2013, p 9, Part 1, Article 4 Definitions

"(5) Multiannual plans may contain specific conservation objectives and measures based on the ecosystem approach in order to address the specific problems of mixed fisheries in relation to the achievement of the objectives set out in Article 2(2) for the mixture of stocks covered by the plan in cases where scientific advice indicates that increases in selectivity cannot be achieved. Where necessary, the multiannual plan shall include specific alternative conservation measures, based on the ecosystem approach, for some of the stocks that it covers."

CFP, 2013, p 13, Part III, Article 9

Annual fishing opportunities & the scientific advice process

The International Council for the Exploration of the Sea (ICES) is a scientific organisation that produces and delivers science-based fisheries advice to the European Union and other governments on an annual basis, following what is often called the "fisheries management year."

This process begins when the European Commission requests advice from ICES regarding fishing opportunities for the coming year. Scientists from various ICES working groups then meet to analyse the latest data of fish stocks and provide guidance and advise on fishing levels considered sustainable under the management framework of the CFP and or EU multiannual plans.

Based on ICES's advice, and input from different stakeholders, the European Commission publishes a proposal for fishing opportunities[8] (usually in late August). EU Member States then discuss and negotiate this proposal, ultimately agreeing on Total Allowable Catches (TACs) during the October AGRIFISH Council for the Baltic Sea. In December, the Council similarly decides on fishing opportunities for the North Sea and North-East Atlantic; every two years in November, it does so for certain deep-sea stocks.

Commercial fisheries in the Baltic Sea thus operate under these TACs – catch limits set in tonnes or numbers of fish (for example for salmon). Each Baltic Member State receives a portion of the overall catch limit, which is fixed according to historical agreements, also referred to as "relative stability". Member States distribute these quotas domestically according to their national system and are responsible for ensuring that their quotas are not overfished.

8 e.g https://ec.europa.eu/commission/presscorner/detail/en/ip_24_4401

Catch limits and national quotas concern fish stocks located in EU waters or fished by EU fishing vessels in certain non-EU waters. Catch limits for fish stocks shared with other countries are subject to international agreements with those countries.

Figure 9 provides an overview of each phase in the **Baltic Sea fisheries management year**, illustrating how ICES advice, Commission proposals, and Council decisions fit together.

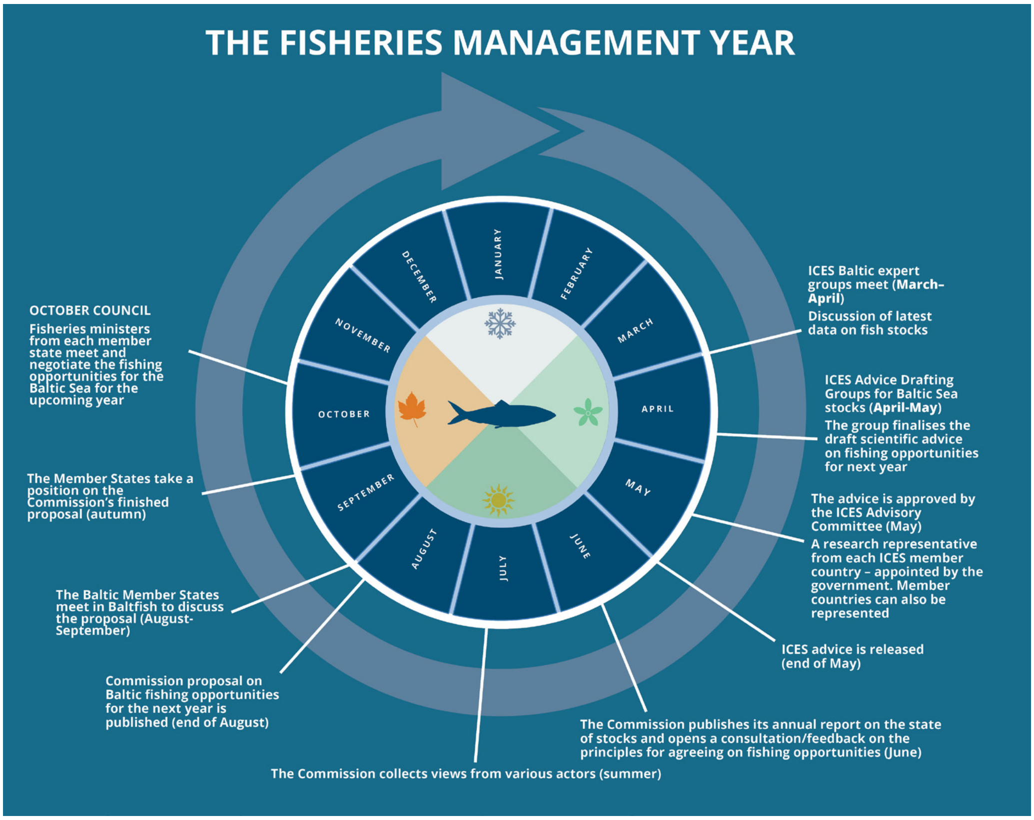
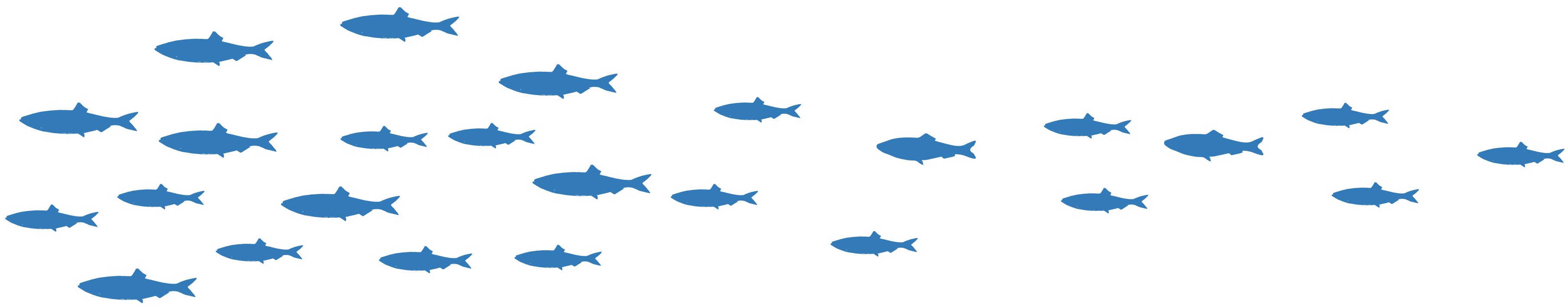


Figure 9. *Overview of annual events during the Baltic Sea "fisheries management year".*

The overarching goal, as mandated by the Common Fisheries Policy Art 2 (Objectives), is to "*ensure that fishing and aquaculture activities are environmentally sustainable in the long-term and are managed in a way that is consistent with the objectives of achieving economic, social and employment benefits, and of contributing to the availability of food supplies.*" **In order to do so, the precautionary approach to fisheries management shall be applied, and managers shall aim to ensure that exploitation of living marine biological resources restores and maintains populations of harvested species above levels which can produce the maximum sustainable yield.** Essentially, the Maximum Sustainable Yield (MSY) is used to estimate the maximum catch that can be taken from a fish stock while leaving enough fish to increase or maintain the stock at the maximum sustainable stock level. Reference points like F_{MSY} (fishing mortality (F) that yields MSY) and B_{MSY} (biomass at MSY) help evaluations as well. A healthy/sustainable stock should be below the reference point FMSY and above B_{MSY} (Griffiths et al. 2024). Although the CFP (EU 2013) aimed for all European fish stocks to be fished at MSY levels by 2020, this goal was not reached, as described in the next section.

Table 1. *Overview the advice given by ICES and TACs set through council agreements for Baltic Sea forage fishing opportunities (in tonnes) over recent years. (Based on: ICES advice sheets 2024 and 2025 and (Council of the EU, 2024).*

	ICES stock catch advice for 2021	Council Agreement TAC set for 2021	ICES stock catch advice for 2022	Council Agreement TAC set for 2022	ICES stock catch advice for 2023	Council Agreement, TAC set for 2023	ICES stock catch advice for 2024	Council Agreement, TAC set for 2024	ICES stock catch advice for 2025	Council Agreement, TAC set for 2025	ICES stock catch advice for 2026	C Council Agreement, TAC set for 2026
WESTERN HERRING	0 t	1 575 t	0 t	788 t	0 t	788 t	0 t	788 t	0 t	788 t	0 t	To be set in October
BOTHNIAN HERRING	65 018 t	117 485 t	111 345 t	111 345 t	102 719 t	80 074 t	63 049 t	55 000 t	74 515 t	66 466 t	Up to 62 684 t	
RIGA HERRING	39 446 t	39 446 t	44 945 t	47 697 t	43 226 t	45 643 t	35 902 t	37 959 t	39 233 t	41 635 t	Up to 34 367 t	
CENTRAL BALTIC HERRING	97 551 t	97 551 t	71 939 t	53 653 t	95 643 t	61 051 t	52 459 t	40 368 t	125 344 t	83 881 t	Up to 154 542 t	
SPRAT	22 958 t	222 958 t	291 745 t	251 943 t	249 237 t	201 554 t	241 604 t	201 000 t	169 131 t	139 500 t	Up to 230 518 t	



Stock status and management decisions on annual catch limits

The CFP's fundamental MSY Objective in Article 2(2) of the CFP Basic Regulation explicitly applies to both fishing pressure and biomass, requiring not only that by 2020 all stocks are fished in line with (i.e. at or below) the MSY exploitation rate (FMSY), but, crucially, that all stocks are maintained or restored above levels capable of producing the MSY (B_{MSY}). The same objective underpins the Baltic multiannual plan (MAP) for herring, sprat and cod, where required actions for stocks under both B_{lim} and MSY $B_{trigger}$ are noted specifically. Yet, the current fisheries management approach in the Baltic is not geared towards delivering such stock recovery above B_{MSY} but instead keeps stocks around the lowest available biological reference point, B_{lim}, which is far below the actual target of B_{MSY} and entails a higher risk of stock collapse, perpetuating the precarious state of the ecosystem.

An overview of ICES advice and TACs set for the Baltic forage fish fishing opportunities over the last few years are shown in Table 1. The advice for WBSSH has remained at zero throughout this period, GoBH and sprat have been decreasing, while GoRH has remained relatively stable with a small increase for 2025. The sharp increase in the latest advice for CBH (from tonnes to 125 344 tonnes – a 139% increase) is in contrast to the previous year, and this change is also reflected in the proposal[9] by the Commission (increased from 40 368 tonnes to 83 881 tonnes – a 108% increase) as well as in the quota set for 2025 by EU fisheries ministers in October 2024.

The poor status of the stocks clearly shows that is not enough to set TACs not exceeding the FMSY point value, but instead there is a need for far more precaution in decisions on Baltic fishing opportunities in order to ensure rapid population recovery. Importantly, the current approach has also failed to deliver on the requirement of the Marine Strategy Framework Directive to attain Good Environmental Status (GES) by 2020, including, for example, in terms of fishing pressure and biomass recovery in line with MSY (see Descriptor 3 of the EU Marine Strategy Framework Directive (MSFD)), but also regarding the need to safeguard food webs (see MSFD Descriptor 4).

Failures to implement ecosystem-based management within the Baltic MAP and the controversy surrounding Article 4.6

Multiannual plans for managing fisheries in different sea basins are a central part of the EU's Common Fisheries Policy. The Baltic MAP for cod, herring, and sprat in the Baltic Sea (Regulation (EU) 2016/1139) entered into force on January 1, 2017. It displays a clear objective of sustainable fishing through EBM and the precautionary approach (STECF, 2023), as highlighted by the following paragraphs showing the legal obligation of ecosystem-based fisheries management:

> *"The objectives of the CFP are, inter alia, to ensure that fishing and aquaculture are environmentally sustainable in the long term, to apply the precautionary approach to fisheries management, and to implement the ecosystem-based approach to fisheries management."*
>
> **(Baltic MAP, Article 4, p 1)**
>
> and
>
> *"The plan shall implement the ecosystem-based approach to fisheries management in order to ensure that negative impacts of fishing activities on the marine ecosystem are minimised. It shall be coherent with Union environmental legislation, in particular with the objective of achieving good environmental status by 2020 as set out in Article 1(1) of Directive 2008/56/EC."*
>
> **(Baltic MAP, Article 3 Objectives (3), p 5)**

9 https://ec.europa.eu/commission/presscorner/detail/en/ip_24_4401

However, the effectiveness has been widely debated. The European Commission's first evaluation credited the MAP with reducing fishing pressure, noting that the decline of key species such as cod predates the plan and that poor overall Baltic Sea conditions play a role in the decline of fish stocks (EC, 2020). Critics argue that introducing MSY ranges undermines sustainability and stock recovery (PEW, 2019).

In 2023, the MAP became central to a legal conflict over Article 4.6 in the MAP, known as the "5% rule", which mandates fixing fishing opportunities such that the probability of the spawning stock biomass falling below B_{lim} remains under 5% (EU 2016) and the ICES fishing level advice. ICES advice in 2023 highlighted that even a zero catch for Bothnian and Central Baltic herring could not ensure compliance with this rule (ICES 2023c, 2023d). In its advice sheet for the Central Baltic herring, ICES stated that "*Even a zero catch in 2024 will not bring the stock above* B_{lim} *in 2025 with 95% probability*" (ICES, 2023c), and for the Bothnian herring: "*Even a zero catch in 2024 will not ensure that the probability of SSB falling below* B_{lim} *in 2025 will be reduced to less than 5%.*" (ICES, 2023d). Despite this, ICES did advise on fishing opportunities for both stocks with the F ranges 48 824 – 63 049 tonnes for the Bothnian herring and 41 706 – 52 549 tonnes for the Central Baltic herring. Thereby ignoring the 5 % rule of the Baltic MAP.

In contrast, the Commission's annual fishing proposal (COM/2023/492) advised halting targeted herring fishery, allowing only bycatch in the sprat fishery. The Commission reasons that:

> (14) *"As regards herring in the Gulf of Bothnia, ICES downsized the stock's biomass which is now below the reference point below which specific and appropriate management action is to be taken* ($B_{trigger}$)*. Furthermore, ICES states that, even with no catches, the probability for the stock to fall below* B_{lim} *in 2025 is 9 %. In those circumstances, it is appropriate to close the targeted fisheries pursuant to Article 4(6) of Regulation (EU) 2016/1139 and to set the fishing opportunities for unavoidable by-catches at a low level while avoiding the phenomenon of 'choke species'."*
>
> and
>
> (16) *"As regards central Baltic herring, ICES now estimates that the stock has been below* B_{lim} *most of the last 30 years, including in recent years. Furthermore, even with no catches, the probability for the stock to stay below* B_{lim} *in 2025 is 22 %. In those circumstances, it is appropriate to close the targeted fisheries pursuant to Article 4(6) of Regulation (EU) 2016/1139 and to set the fishing opportunities for unavoidable by-catches at a low level while avoiding the phenomenon of 'choke species'."*
>
> **(COM/2023/492, p 11-12)**

Yet the AGRIFISH Council rejected the Commission's precautionary proposal and instead set total allowable catches (TACs) following ICES's F ranges. According to David Langlet, professor in environmental law at Uppsala University, this decision is illegal as it breaches the MAP as well as the MSY target in the CFP. Also, it is not in alignment with ecosystem-based fisheries management or the targets of Good Environmental Status (GES) in the MSFD (Langlet, 2024).

After the decision in the AGRIFISH October council, the Commission released a proposal to remove the Article 4.6 from the Baltic MAP and the corresponding article in other MAPs as well with the motivation that it had a large socio-economic impact and that it "contradicted" other articles in the MAP (COM(2023)771). This proposal was heavily criticised by NGOs as well as by Stockholm University Baltic Sea Centre (Berkow &

Svedäng, 2024) and, as pointed out by Langlet (Langlet, 2024) the timing of the proposal indicates that both the Council and the Commission believes the article 4.6 to hinder the business as usual fishing as was proposed in the October council. However, a deletion of the article at a later stage does not work in retrospect - the agreement made in the council in October 2023 is still illegal.

Moreover, the Commission tried to push the voting of the removal of article 4.6 in a so-called "fast track procedure" in the European Parliament to avoid the regular voting procedures. However, the Parliament did not accept this and voted down the proposal for a fast track procedure. The Commission also launched a feedback opportunity[10] for everyone to express their view of the proposal to delete article 4.6. However, this feedback had a closing time (31 January 2024) which was after the vote in the Parliament on the fast track procedure. Of the 23 entries of the feedback, 20 were negative towards the omission of article 4.6. The three entries in favour of the change were business associations.

On 23 September 2024, the European Parliament's Fisheries Committee (PECH) declined to reopen the proposal of the European Commission (COM(2023)771) to amend the Multi-Annual Plans (MAPs) for the Baltic Sea, North Sea, and Western Waters. The proposal, first tabled in December 2023 and endorsed by the Fisheries Council that month, would have deleted the MAP provisions requiring fishing opportunities to be set so that the risk of any stock falling below its limit reference point remains under 5%.

The committee vote was tied (13 – 13); because a positive majority was needed to proceed, the proposal is considered rejected. The decision prevents the Commission and Council from weakening the MAP safeguards without Parliament's consent. Nonetheless, concerns remain that the Council may continue to set total allowable catches that disregard the safeguards, as occurred in October 2023 when ministers set the 2024 quota for central Baltic herring above the level implied by the Baltic MAP and again in October 2024, when the sprat TAC was set too high with regard to Art 4.6. The October 2023 decision is being challenged before the General Court of the European Union by environmental organisation Coalition Clean Baltic (CCB) to invalidate the 2024 fishing quotas for Baltic herring. The case highlights the ongoing challenges in ensuring that EU fishing limits align with scientific advice and legal frameworks designed to protect vulnerable fish stocks, and the reluctance to implement EBFM.

Management decisions, sub populations and lack of risk assessments

The Landing Obligation, uncertainties and misreporting

The landing obligation (LO) (EU 2013) is an EU policy – first implemented in 2013, in place since 2015, and as of 2019 fully implemented for a number of targeted fisheries in the EU (with some exceptions) – which makes it illegal to discard unwanted catches. For small pelagic fisheries, including fisheries for sprat and herring, the LO was to be in place from "1 January 2015 at the latest" (EU No 1380/2013). As a result of the landing obligation, further catches must cease once the quota for a stock is fully fished. The goal is to enhance catch selectivity and minimise unwanted catches by ensuring that all catches are landed. The LO states that:

10 https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/14057-Fisheries-correction-to-multiannual-plans_en

> *"All catches of species which are subject to catch limits and, in the Mediterranean, also catches of species which are subject to minimum sizes as defined in Annex III to Regulation (EC) No 1967/2006, caught during fishing activities in Union waters or by Union fishing vessels outside Union waters in waters not subject to third countries' sovereignty or jurisdiction, in the fisheries and geographical areas listed below shall be brought and retained on board the fishing vessels, recorded, landed and counted against the quotas where applicable, except when used as live bait"*
>
> **Regulation (EU) No 1380/2013**

A 2021 EFCA evaluation of the Baltic Sea fisheries compliance with the Landing obligation showed that the overall compliance for herring and sprat was high, especially compared to the compliance levels estimated of trawled gears catching plaice and cod[11] "*overall, in most pelagic fleet segments targeting HER and SPR there was high compliance with the LO over the study period (2017 – 2018)*" (EFCA 2021). However, the LO has not been fully complied with (Valentinsson and Ringdahl 2019; Wennhage et al., 2021). Ineffective enforcement of Landing Obligation-measures can result in unwanted (dead or dying) fish being disposed of at sea – impeding the recovery of fish populations and also compromising scientists' ability to accurately monitor stocks.

The Commission states that "*Member States audited have not adopted the necessary measures to ensure effective control and enforcement of the landing obligation and significant undocumented discarding of catches by operators*" (COM, 2022). Furthermore, the Commission encourages Member States to "*make better use of the funds to ensure further innovation and actual use of more selective fishing gear and methods, to improve controls, and to obtain some value from unwanted catches*".

Misreporting and catch log uncertainties

ICES has identified apparent discrepancies in reported catches for several stocks, indicating issues of mis- or underreporting that introduce substantial uncertainties into stock assessments and associated management advice. Misreporting of herring and sprat has historically been a problem, and current evidence indicates that it continues. Due to the absence of representative data, the specific impacts of misreporting have not been quantified or incorporated into ICES stock assessments, significantly compromising the quality and accuracy of the assessment process.

According to ICES (2024e; 2024h), pelagic trawlers operating in subdivisions 24, 25, and 26 have in recent years reported substantial landings of flounder (exceeding 3,000 tonnes between 2020 and 2021, decreasing to approximately 500 tonnes by 2023). These catches are suspected to be misreported herring and sprat but have not yet been integrated into assessments for flounder, central Baltic herring, or Baltic sprat. These potentially erroneous data have not yet been integrated into assessments for flounder, central Baltic herring, or Baltic sprat.

ICES also notes that species misreporting between sprat and herring in the Baltic Sea is an ongoing problem which can affect the quality of stock assessments (ICES 2024g) work is ongoing to assess the extent of the misreporting, but ICES notes that "*misreporting undermines the data quality used in the assessment and introduces into the assessment and advice a level of uncertainty that cannot be quantified*". Additionally, assessments of central Baltic herring and Baltic sprat are possibly affected by misreporting with flounder:

11 Note that Baltic Sea cod is no longer a commercial target but was fished during the examined period 2017-2018.

> *"In recent years pelagic trawlers in subdivisions 24, 25, and 26 have reported landings of flounder in the catch (over 3 000 tonnes in 2020–2021 with a decline to approximately 500 tonnes in 2023). These catches are suspected to be misreported sprat and herring but have so far not been included in the flounder, central Baltic herring, or Baltic sprat".*
>
> **ICES, 2024h**

This misreporting places additional pressure on already depleted populations and reduces the reliability of ICES advice models, leading to less trustworthy catch advice. It is crucial to strengthen both onboard controls and control measures at landing sites to ensure reliable reporting of catches. The recent adoption of a new Control Regulation by EU Member States mandates Remote Electronic Monitoring (REM) in fisheries identified as high-risk for non-compliance with the Landing Obligation. Implementing REM in Baltic Sea herring and sprat fisheries should be a high priority.

An audit conducted by the European Commission found inconsistencies in catch reporting within pelagic fisheries, prompting several Baltic Sea Member States to receive instructions and recommendations aimed at improving their catch weighing and control systems. The European Commission issued criticism towards Sweden, for example, for not following the rules of the European Union in terms of weighing and catch registration, especially concerning the landings of industrial and pelagic catches (EC 2023). These problems were identified already in 2014 (Hentati-Sundberg, Hjelm, and Österblom 2014), but had not been addressed. The Commission expressed that the "*longstanding non-compliance highlighted in this report demonstrate a lack of commitment and a persistent failure by Sweden to address major issues that pose a significant risk to the objective of the Common Fisheries Policy (CFP) and undermine the effectiveness of the Community system to prevent, deter and eliminate 'illegal, unreported and unregulated fishing' (IUU fishing)*" (EC, 2023, p 1).

Given these persistent uncertainties and the lack of assured compliance with the Landing Obligation, it is advisable that total allowable catches (TACs) be set below the catch advice by a sufficient margin. This approach aims to ensure that continued illegal discarding and misreporting do not result in fishing levels exceeding sustainable limits.

Cross-sea region management Issue: North Sea Herring Fishery and Incidental Catch of Western Baltic Spring-Spawning Herring

The recovery of western Baltic spring-spawning herring (WBSSH) is being undermined by the North Sea autumn-spawning herring fishery, because the two stocks mix in the ICES Divisions 4.a and 4.b. The significant bycatch of WBSSH presents significant challenges, particularly in the eastern parts of ICES divisions 4.a and 4.b. ICES (2024) has issued clear advice emphasizing the urgency of minimizing WBSSH bycatch. The scientific body warned that WBSSH is harvested across three distinct management areas, and continued catches in any of these will hinder stock recovery.

ICES projects that, under the 2024 catch agreement and typical stock mixing, about four-fifths (≈ 81 %) of all western Baltic spring-spawning herring (WBSSH) taken in 2024 will come from the eastern North Sea (Divisions 4.a and 4.b). The remaining one-fifth (≈ 19 %) will be split between Baltic Subdivisions 20–21 and 22–24. Recent data show an average annual WBSSH by-catch of 3 756 t in the North Sea during 2021–2023, and 2024 removals are expected to stay higher there than inside Subdivisions 20–24. To prevent further delay in stock rebuilding, ICES recommends targeted management measures including area and seasonal closures in the North Sea. Without such additional restrictions in 2025, avoiding WBSSH bycatch will be practically impossible. This situation underscores the need for coordinated cross-regional management that explicitly accounts for stock mixing and tailors spatial-temporal controls to reduce pressure on vulnerable populations like WBSSH.

To translate this advice into practice, managers are encouraged to develop a dedicated rebuilding plan that brings the stock above B_{MSY} within the shortest biologically feasible timeframe; implement measures that protect and restore known spawning habitats and nursery areas and implement additional area- and/or season-specific restrictions on the herring fishery in the eastern parts of Divisions 4.a, 4.b, and Division 3.a, where incidental catches of WBSSH in the North Sea herring fishery are otherwise inevitable.

Precautionary management of forage fish in the Baltic Sea remains vital to securing both the ecological balance and the long term sustainability of Baltic fisheries. As described in this chapter, the legal architecture for precautionary, ecosystem-based fisheries management in the Baltic Sea is robust on paper, anchored in the CFP, the Baltic Multi-Annual Plan and the Marine Strategy Framework Directive, yet its execution remains fragmentary and, at times, contradictory. Although the EU Common Fisheries Policy sets a clear mandate for ecosystem-based fisheries management and sustainable catch levels, its implementation often falls short, particularly evident in the case of the Baltic Multiannual Management Plan (MAP), controversies surrounding Article 4.6, and the ongoing challenges of accurate reporting under the Landing Obligation. The European Council and Commission have struggled to reconcile socio-economic interests with more precautionary fishing opportunities for forage fish, and member states have not found tangible management measures to implement EBFM. As a result, key stocks remain in decline despite repeated scientific advice advocating more cautious catch limits. Strengthening enforcement, improving data quality, and upholding ecosystem-based principles at all levels of decision-making are crucial to reversing this trend and ensuring the long-term viability of both fish populations and fishing communities in the Baltic Sea.

Overview of catches

Baltic Sea forage fish stocks, 2024

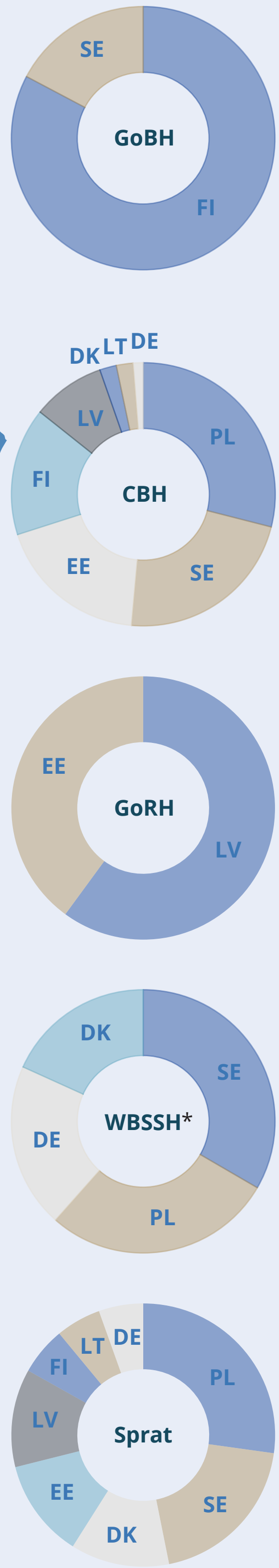


Figure 10. Overview of Baltic Sea sprat and herring caught by EU Member States in 2024 (in tonnes).
*Based on data in ICES advice sheets 2025 (ICES, 2025a-e, Tables 8, 9 or 11 with "History of commercial landings"). *WBSSH catch is shown as a sum of catches in Skagerrak, Kattegatt and SD 22-24. Note that WBSSH is currently fished exclusively as by-catches. Further, Russian catches (not shown) also contribute to the total catch of sprat and Central Baltic herring, in particular. The same data was also used as basis for the diagrams on the right for comparison of catches between countries.*

Chapter 6
Forage fish fishery

Fishery for sprat and herring in EU Member States around the Baltic Sea

Fisheries for forage fish are among the most extensive in terms of both volumes and value of the catch, not just in the Baltic Sea but also globally (FAO, 2020; STECF, 2023), contributing to global food security. Around the Baltic Sea, herring has a longstanding cultural importance and has sustained many coastal communities.

This section summarises the catches, consumption, economic importance, and management of Baltic herring and sprat in the EU Member States bordering the Baltic Sea (See Figure 10 for an overview of the Member States fishing each stock and catch numbers for 2024 and Supplemetary Figure 1-5 for an overview of historical catches). It draws on data from the latest Annual Economic Report on the EU Fishing Fleet provided by the Scientific and Technical Committee on Fisheries (STECF, 2024). Unless otherwise stated, this is the source for the information in the following country sections. In addition, for some countries, data from STECF were complemented by semi-structured interviews with national experts for added interpretation and clarification.

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Denmark

Overview of Danish fisheries

Historically, herring was so abundant and profitable in Danish waters that it was dubbed "gold," with anecdotes suggesting one could "walk across the sea" between Denmark and Sweden on the backs of herring. While herring remains important, especially in the North Sea, the sprat fishery has gained prominence, mainly for industrial uses like fishmeal production. This shift reflects broader changes in Danish fisheries, spurred by evolving fish populations, market demands, and the decline of once-dominant cod stocks.

Forage fish stocks of interest include:

Central and Western Baltic Herring, Baltic Sprat as well as forage fish stocks outside the Baltic Sea, including sandeel, Atlantic mackerel, and Norway pout.

Structure of the Danish fishing fleet

In 2022, the Danish fishing fleet included 1 989 registered vessels, of which 1 226 vessels were active. The fleet's composition has shifted over time. Compared to the 2013 - 2020 average, there was an 11% reduction in the number of vessels in 2021, but a 7% increase in tonnage and 6% in engine power, reflecting a trend towards fewer but larger and more powerful vessels (STECF, 2023).

Large-scale fisheries

In 2022, this fleet comprised 394 vessels.

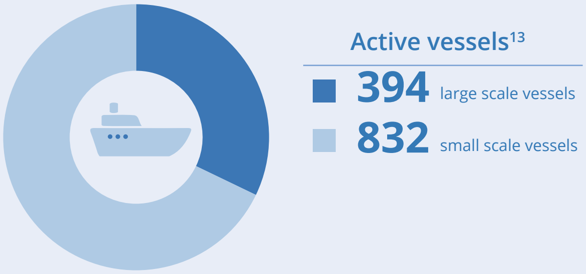
- **Location:** operates across a broader range of waters around Denmark, including the North Sea, the Baltic Sea, the Sounds, Kattegat, Skagerrak and beyond.
- **Landings value:** EUR 384 million in 2022, corresponding to 96% of the national landings value.

Small-Scale Coastal Fleet (SSCF)

In 2022, approximately 74% of the active fleet comprised vessels under 12 metres, which also made up a significant portion of the inactive vessels (STECF 2024).

- **Location:** primarily operates in the Baltic Sea, the Sounds, and Kattegat.
- **Landings value:** EUR 15 million in 2022 (31% decrease from 2021), representing 4% of the national landings value.

The SSCF has faced economic losses, with a 2022 gross profit of -EUR 2.0 million and net profit of -EUR 2.9 million. Declining quotas, especially due to the Baltic cod stock depletion,[12] have contributed to these struggles.



Fisheries for sprat and herring

In 2022, vessels between 24-40m and over 40 metres accounted for 65% of Denmark's landing value, despite making up less than 5% of the fleet (STECF, 2024). These vessels target Atlantic herring, cod[12], and mackerel for human consumption, while sprat, sandeel, and blue whiting go to fishmeal and fish oil.

In 2022, the Danish quotas for the most valuable species were: Atlantic herring (92 000 t), Norway lobster (9 000 t), Atlantic mackerel (22 000 t), European sprat (135 000 t), and plaice (38 000 t). Compared to 2021, the quota for Atlantic herring increased by 14% while the European sprat quota decreased by 31%.

12 Western Baltic cod, Eastern Baltic cod and Western Baltic herring are now only fished with by-catch quotas.
13 *Note:* The graphic illustrating the composition of active fleet is based on information from the STECF report, and does not only include vessels operating in the Baltic Sea (STECF, 2024).

Denmark

Atlantic cod quotas in the Baltic Sea have been drastically cut due to stock collapse. The UK decision to reserve Dogger Bank as a protected area for sea birds is expected to have an economic impact on Danish fisheries as they are no longer able to fish sand eel from the area.

Consumption & management

Fish consumption: Out of the Baltic Sea countries, Denmark has the highest consumption of fisheries and aquaculture products, 42.56 kg/inhabitant/year (EC, 2022).

Is forage fish eaten? Herring continues to be consumed, particularly in traditional forms like pickled herring, which remains a popular dish in Denmark, especially during certain seasons and holidays. However, the broader market for herring has shrunk, with fewer young people consuming it regularly. Efforts have been made to promote sprat consumption, such as campaigns to introduce sprat-based dishes at food festivals, but these efforts have met with limited success (Interview Denmark).

Fishmeal/oil production: Fishmeal production is a significant industry in Denmark, closely linked to the fisheries for herring and sprat. The country produces around 150 000 tons of fishmeal annually, with a substantial portion being used domestically for pig feed, pig framing being a major industry in Denmark. Denmark exports the rest globally, mainly to Norway and the UK, for instance to be used in salmon aquaculture. In 2023, Denmark was the world's 7th largest exporter of fishmeal and the world's 3rd largest exporter of fish oil.

Fishery managed with: Danish fisheries management uses ITQ schemes, gradually introduced since 2003, which have reduced fleet capacity but also sparked controversy over fishing quota concentration in the hands of a few large operators. In 2024, Remote Electronic Monitoring (REM) was implemented for the pelagic fleet to improve control and catch registration.

Managed by: Danish fisheries management is centralized and has shifted between ministries in the past, including Environment and Foreign Affairs. It currently falls under the Agriculture and Fisheries Ministry.

It can be noted that Denmark's fisheries management is less focused on Baltic fisheries management than other countries around the Baltic Sea as most of its fishing activities take place in other sea basins and are influenced by external factors such as Brexit and changes in access to Norwegian waters.

42.56 kg
fish & aquaculture products
per inhabitant per year

Unless otherwise stated, the Annual Economic Report on the EU Fishing Fleet provided by the Scientific and Technical Committee on Fisheries. (STECF 2024) is the source for the information in the country sections.

Estonia

Overview of Estonian fisheries

For the Estonian Baltic Sea fleet, sprat and herring are the top target species (or key species for the fishery) which have the highest generated value (EUR 5.8 million and EUR 5.3 million, respectively in 2022) as well as the highest landings weight. Cod, herring and sprat have been the main internationally regulated/managed fish species targeted by the Estonian Baltic Sea fishing fleet (STECF, 2024).

Forage fish stocks of interest include:
Central Baltic herring and Gulf of Riga herring. Sprat, mainly from the central/Eastern Baltic Sea.

Structure of the Estonian fishing fleet

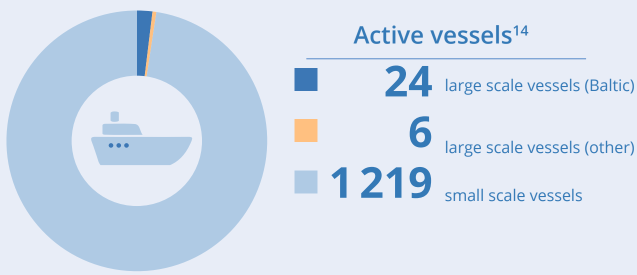
The active fleet divides into two segments: large-scale fisheries and small-scale coastal fisheries. The total (active) fleet comprised 1 249 vessels in 2022.

Pelagic Trawlers (24-40 meters)
The Baltic Sea pelagic trawlers are the most important in the Estonian fishing fleet.

- **Location:** 24 trawlers operating in the Baltic Sea and 6 trawlers in the NAFO and the Eastern Arctic.
- **Targets:** mainly sprat and herring.
- **Total live landings weight in 2021:** 43 663 t, which was a decrease of 3% compared to 2020.
- **Landed value and weight in 2022:** EUR 9.7 million, and landed weight of 46 174 tonnes.

Small-Scale Coastal Fleet (SSCF)
The SSCF is considerably larger than the large scale fleet in terms of vessels (1 219 vessels) (STECF 2024).

- **Location:** operates in coastal waters
- **Targets:** mainly targeted herring, perch and smelt. Mainly uses passive gears.
- **Landed weight in 2022:** landed (live weight) of 9 310 tonnes of seafood, a decrease of 21% compared to 2021.



Fisheries for Sprat and Herring

In 2022, Estonian Baltic Sea trawlers primarily targeted herring and sprat, landing most catches at Estonian ports for freezing or processing. Catch was either sold to fish freezing or processing companies or processed and marketed by fishing companies themselves. A portion was also landed in Latvia and Poland, with landings outside Estonia decreasing from 9% in 2021 to 7% in 2022. Ukraine has continued to be the primary export market, though some sales were also made to Belarus, Latvia and Lithuania.

The economic performance/profit for 2023 and 2024 is projected to be improved compared to previous years. The average first-sale prices of sprat and herring increased (by 71% and 52%, respectively in 2023) which likely contributes to the assumed profit growth (STECF, 2024).

14 *Note:* The graphic illustrating the composition of active fleet is based on information from the STECF report, and does not only include vessels operating in the Baltic Sea. Six large scale vessels from the Estonian fleet operate outside the Baltic Sea (STECF, 2024).

Estonia

Consumption & management

A paper by Tuomisto et al (2020) included case studies comparing herring consumption in Estonia, Sweden, Finland and Denmark, finding that Estonia has the highest consumption of Baltic herring out of the four countries and that 30% of "older" Estonians (>45 years of age) eat over 3.6 kg of Baltic herring per year, while the average was around 1 kg/year (Tuomisto et al., 2020).

Fish consumption: 4th highest of Baltic Sea EU Member States (16 kg) but lowest nominal household expenditure for purchasing fish and seafood out of the 8 countries. (EC, 2024).

Is herring eaten? Yes, for example, smoked and salted/marinated, can be included in the traditional beetroot salad (Rosolje). The "sprat sandwich" (Kiluvõileib), consisting of salted sprat on rye bread, is another example of how people eat sprat.

Is sprat eaten? Yes, sprat is also eaten, for example as the "sprat sandwich" (*Kiluvõileib*) where salted sprat is eaten on rye bread.

Employment in Estonian fishing industry: Decreased by 16% from 2021 to 2022. A majority of the persons in this sector also have other sources of income and do not fish full time.

Managed with: Landings volume quotas (ITQs) for trawlers and gear usage quotas ("ITE -Individual transferable effort") for coastal fisheries as the two main management tools. Fishing quotas are allocated according to the historic fishing rights.

Managed by: The Ministry of Regional Affairs and Agriculture (policy-making for commercial fishing), the Ministry of Climate (fisheries protection, stock reproduction, habitat restoration, and special permits), the Agriculture and Food Board (commercial fishing permits and vessel/catch registry), and the Environmental Board (recreational fishing permits and data collection).

16 kg
fish & aquaculture products per inhabitant per year

Unless otherwise stated, the Annual Economic Report on the EU Fishing Fleet provided by the Scientific and Technical Committee on Fisheries. (STECF 2024) is the source for the information in the country sections.

Finland

Overview of Finnish fisheries

In Finland, herring and sprat fisheries are significant, particularly in the northern and central parts of the Baltic Sea. Fishing operations primarily target small herring for fish feed and larger herring for human consumption. The fishery uses specific techniques, such as trawling at different depths to segregate catches based on size, thus optimising the use of herring for various markets. Implementation of the ITQ system has reshaped the landscape of Finnish pelagic fisheries. Since its introduction in 2017, the number of active trawlers has decreased by 30% (Interview Forage Fish, Finland).

Forage fish stocks of interest include:
Finland lands the top share of the Gulf of Bothnia Herring.

Structure of the Finnish fishing fleet

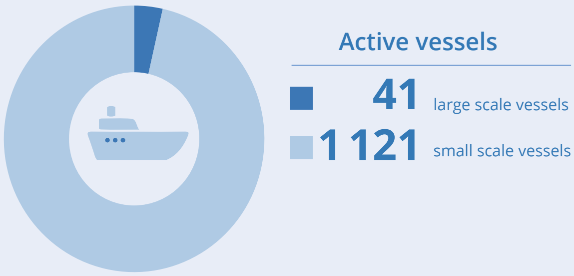
In 2022, the fishing fleet consisted of 1 162 active vessels and 2 119 inactive. The fleet structure is predominantly (96%) made up by a small-scale coastal fleet.

Large-scale fisheries (pelagic trawlers)
The Finnish large-scale fisheries are divided into three size categories: 24-40m (15 vessels in 2022), 18-24m (6 vessels in 2022), and 12-18m trawlers (20 vessels in 2022).

- In 2022, the 41 trawlers classified as large-scale fisheries (LSF) accounted for 72% of the fleet's capacity in terms of tonnage.
- **Location:** Baltic Sea, with emphasis on the Bothnian Sea, the Central Baltic as well as the southern Baltic Sea.
- **Targets:** mainly herring and sprat.

Small-Scale Coastal Fleet (SSCF)
The SSCF is considerably larger than the large scale fleet in terms of vessels (1 121 vessels) (STECF, 2024).

- **Location:** Baltic Sea, with emphasis on the Bothnian Sea, the Central Baltic as well as the southern Baltic Sea. Also operates along the Finnish coastline.
- The economic impact of the SSCF has been increasing as the value of LSF landings decrease.

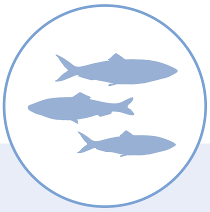


Fisheries for sprat and herring

Baltic herring and sprat are key targets for Finland's fisheries. 80% of the herring and 99% of the sprat landed by Finland was used for fodder or raw material for fishmeal. A total of 86 000 tonnes of seafood was landed in 2022, mainly consisting of herring and sprat. In 2021, Baltic herring accounted for the highest landed value at EUR 15.4 million, followed by European sprat at EUR 3.0 million. Pelagic trawlers targeting herring and sprat accounted for more than half of the total value landed by the Finnish fleet.

In 2022, the Finnish fleet landed 86 000 tonnes of seafood, valued at EUR 28.1 million. Most of this catch consisted of Baltic herring and sprat.

Finland



Quota reductions in pelagic stocks since 2018 have impacted the fleet's economic performance. Apart from quota cuts, smaller and leaner herring catches further complicated quota fulfilment. The major landing harbors are Uusikaupunki and Kasnäs, where the largest fishmeal factory in Finland is also situated (STECF, 2024).

Consumption & management

In 2015, much of Finland's herring and sprat was deemed unfit for human consumption due to EU dioxin regulations for seafood, which diverted forage fish catches to feed and fishmeal production, lowering prices fishers could get for them. To counter this, the government launched a program to promote domestic fish consumption, as using Baltic herring for food instead of feed could significantly improve profitability (Interview Forage Fish, Finland).

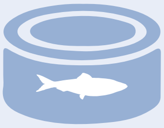
Fish consumption: Out of the Baltic Sea countries, Finland had the 3rd highest consumption of fisheries and aquaculture products, 23.77 kg/inhabitant/year, just under the EU average (EC, 2022).

Is forage fish eaten? Yes, herring has long been part of Finnish cuisine, traditionally smoked, fried, or canned, though consumption has declined. It remains a staple for Christmas and Midsummer, with September herring markets as cultural highlights. In the late 90s and early 2000s, per capita consumption of herring was over one kilogram annually, which has now dropped to approximately 300 grams (Interview Forage Fish, Finland).

Fishmeal/oil production: Fishmeal production in Finland is relatively recent, with the first factory established in 2016. Now, multiple factories support the domestic aquaculture, producing fishmeal and fish oil for feeding rainbow trout in Finland and Sweden, the surplus is exported within Europe. There has been a shift from utilising fishmeal for mink feed to use in aquaculture, especially rainbow trout farming (Interview Forage Fish, Finland).

Fishery managed with: In 2017, Finland introduced an ITQ system for trawlers, leading to a 30% drop in active vessels and reduced employment, especially in the pelagic sector, by 2021.

Managed by: Regional authorities handle implementation, control, and allocation of EMFAF resources, and the Ministry of Forestry and Agriculture does EU negotiations and shapes and enforces policies.



23.77 kg
fish & aquaculture products
per inhabitant per year

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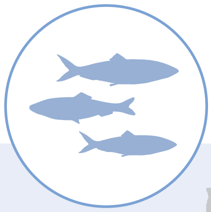
Germany



Overview of German fisheries

In Germany, herring and sprat fisheries are split between the Baltic and North Sea. Traditionally, the Baltic herring fishery, using pelagic nets and gillnets, was significant, especially in coastal areas. However, with the closure of targeted herring and cod fisheries in the western Baltic, sprat has become a primary target, but only a small portion of the sprat quota is landed in Germany. The German fleet in the Baltic has always been smaller than for other Baltic states, and in recent years, fleet numbers and full-time fisheries have further declined.

Forage fish stocks of interest include:
Western Baltic Herring (previously) and sprat.

Structure of the German fishing fleet

In 2022, the fishing fleet consisted of 1 174 vessels (316 of which were inactive). The fleet structure is predominantly small-scale vessels (STECF, 2024).

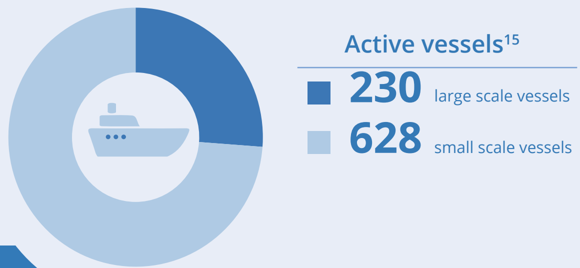
Large-scale fisheries

- **Size:** In 2022, the active large scale fleet consisted of 230 vessels.
- **Location:** The large scale fleet mainly operates in the North Sea.

Small-Scale Coastal Fleet (SSCF)

The SSCF accounted for 73% of the active fleet (628 active vessels) in 2022.

- **Location:** Primarily within the Baltic Sea.
- **Targets:** Have mainly been targeting Baltic herring and cod[14] but became more focused on plaice and sprat after the moratorium on Baltic cod fisheries and decrease in herring quotas.



Fisheries for sprat and herring

Traditional fisheries for herring in the Baltic have been significant but have declined sharply, with Germany's herring quota significantly reduced, particularly after the closure of targeted western Baltic herring fisheries. Small-scale coastal fisheries still maintain some herring operations due to exemptions (for boats under 12 meter using passive gears).

A shift has occurred from herring and cod to sprat and flatfish fisheries, which are less economically valuable. Most of the sprat caught by the German fleet is not landed in Germany but is instead landed and processed abroad, for example in Denmark. This trend further underscores the decline in the local fishery's economic significance.

Germany's pelagic fisheries in the Baltic are small compared to countries like Poland, Finland, and Sweden. Over the last years, a continuous decrease of the fleet has been observed, supported by cessation schemes, with most remaining vessels now being part-time operations, particularly in coastal areas.

14 Western Baltic cod, Eastern Baltic cod and Western Baltic herring are now only fished with by-catch quotas.
15 *Note:* The graphic illustrating the composition of active fleet is based on information from the STECF report, and does not only include vessels operating in the Baltic Sea. The majority of the German large scale vessels operate in the North Sea, while small scale vessels are mainly operating in the Baltic Sea (STECF, 2024).

Germany

It can be noted that the large-scale pelagic fleet, primarily controlled by one dominant company, significantly influences the German fisheries sector. This fleet, with its advanced technology and larger capacity, overshadows smaller fishing operations. This fleet focuses heavily on high-volume species like herring and sprat, which make up the majority of Germany's quotas. However, the actual distribution between the North Sea and the Baltic remains unclear due to a lack of detailed reporting. The presence of this large-scale fleet has also led to issues in data transparency and availability, complicating efforts to fully understand and manage the fisheries sustainably.

Consumption & management

Fish consumption: Out of the Baltic Sea countries, Germany has had one of the lowest consumptions of fisheries and aquaculture products, 13.08 kg/inhabitant/year (EC, 2022).

Is herring eaten? Herring has a strong cultural presence in Germany, particularly in the northern regions, where it is a staple in traditional dishes. Despite the decline in herring fisheries, there remains a significant local consumption of herring, with many traditional dishes continuing to be popular. The reduction in Baltic herring stocks has led to an increased reliance on North Sea herring to meet domestic demand.

Is sprat eaten? Sprat is less commonly consumed locally. There are a few traditional dishes that do use sprat, such as "Kieler Sprotten," a regionally protected dish where the sprat must be caught in the Bay of Kiel. However, due to high toxin levels, most of the sprat caught in the Baltic Sea is turned into fishmeal and fish oil rather than direct human consumption and sold outside Germany (interview Forage fish Germany).

Managed by: Management is handled by the Federal Ministry of Agriculture, Food and Regional Identity in Bonn and Berlin. Coastal areas up to 12 nautical miles fall under the jurisdiction of the federal states, specifically Schleswig-Holstein and Mecklenburg-Vorpommern for the Baltic Sea, while the Exclusive Economic Zone (EEZ) is managed at the national level. The management structure includes both federal and state-level decision-making processes, with the coastal states having significant control over their respective maritime areas. This sometimes leads to discrepancies and inefficiencies in implementing fisheries policies and protection measures (interview forage fish, Germany). Management efforts have included both support for remaining fisheries and buyout schemes to reduce the fleet size.

13.08 kg
fish & aquaculture products
per inhabitant per year

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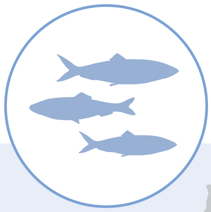
Latvia



Overview of Latvian fisheries

The Latvian fleet mainly targets European sprat and Atlantic herring in terms of weight (34 855 tonnes resp. 25 671 tonnes) and landed value (sprat at EUR 10.7 million and herring at 7.7 million out of a total landed value of EUR 19.9 million). The Latvian Baltic Sea fleet has been decreasing from 2013 to 2022. The weight of landings and value also decreased from 2013 to 2021, mainly due to the decrease in the CBH quota and average first market price for herring.

Forage fish stocks of interest include:
Gulf of Riga herring and Baltic sprat.

Structure of the Latvian fishing fleet

The Latvian fleet consisted of 193 active vessels, divided by length, fishing gear and operating area: segment trawlers (vessels between 24–40 m in length), trawlers (12–18 m) and small-scale coastal fisheries (SSCF) in the Baltic Sea and a smaller distant water fleet (5 vessels).

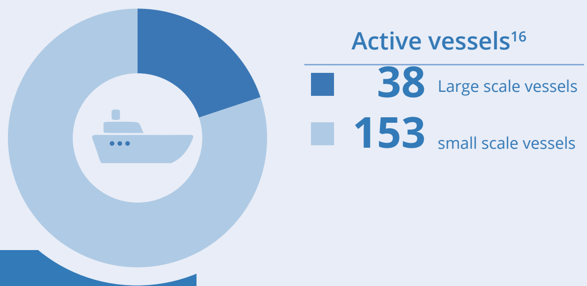
Large-scale fisheries

- **Location:** Mainly operates in the Baltic Sea, with trawlers predominantly in the Gulf of Riga and the distant water fleet.
- **Targets:** Mainly targets European sprat and Atlantic herring in the Baltic Sea.
- **Landed weight/value:** The Latvian large scale fleet contributed 95% of the total revenue in 2022.

Small-Scale Coastal Fleet (SSCF)

The number of active SSCF fleet vessels decreased by 27% between 2021-2022.

- **Location:** Baltic Sea, mainly operates along the Gulf of Riga coast using either polyvalent or passive gears.
- **Targets:** A variety of species, for example herring, round goby and European flounder, and European smelt, usually to be sold locally.



Fisheries for sprat and herring

Since sprat and herring are key species for the Latvian fisheries, their availability greatly affects the Latvian fleet's productivity (STECF 2024). The European sprat is the most landed species both in terms of value and weight, accounting for the majority of the total landings value and total landed weight .

Herring is the second most landed species in Latvian fisheries, fished from the Gulf of Riga and Central Baltic area. The average price of both sprat and herring increased from 2021 to 2022.

Latvian exports of seafood products to countries outside the EU increased by EUR 25.5 million from 2021 to 2022.

16 *Note:* The graphic illustrating the composition of active fleet is based on information from the STECF report (STECF, 2024).

Latvia

Consumption & management

Fish consumption: Latvia has the lowest fish consumption among the EU Baltic states, at 10.46 kg/inhabitant/year (EC, 2022).

Is forage fish eaten? Herring is a popular food fish. It is often eaten pickled together with potatoes and cottage cheese or sour cream. People in Latvia also eat sprat, to some extent. Both sprat and small herring are traditionally smoked and canned in oil or in tomato sauce.

Fishmeal/oil production: The major buyers of fresh fish caught by the Latvian fleet are processing enterprises, both domestic and from neighbouring countries.

Managed by: The Ministry of Agriculture handles legislation (in accordance with international obligations and rules of the CFP) as well as management of fish resources, while local municipalities handle management of fishing rights. The fleet's "economic effectiveness" depends on the quota given for sprat and herring as the main target species. In the past, Latvia has nearly fully used its fishing quotas allocated for European sprat and Atlantic herring (STECF, 2024).

10.46 kg
fish & aquaculture products per inhabitant per year

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Lithuania

Overview of Lithuanian fisheries

In 2022, Lithuania's fleet had 135 vessels, 75 of which were active and operating in the Baltic Sea or in distant waters. Most of the landings value came from horse mackerel and chub mackerel. For the pelagic trawlers (large-scale fleet) Baltic sprat accounted for most of the landed pelagic value, followed by herring at (87% and 13% of the landed pelagic value in the Baltic Sea, respectively).

Forage fish stocks of interest include:
Lithuania has a small TAC of Central Baltic Herring and Baltic sprat compared to other Baltic Sea countries. Some forage fish are landed by the distant water fleet.

Structure of the Lithuanian fishing fleet

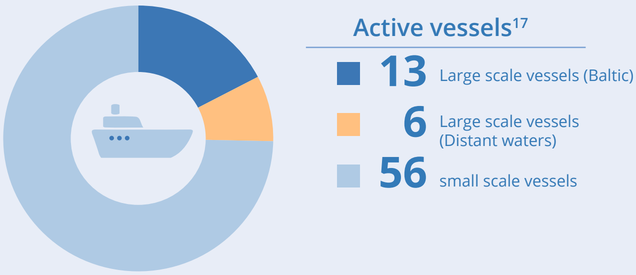
In 2022, the Lithuanian fleet consisted mainly of the Small-Scale Coastal Fleet segments. There is also a large-scale fleet operating in the Baltic Sea and a distant water fleet with demersal trawlers/ seiners and pelagic trawlers. The large scale fleet landed higher catch volumes than the small scale fleet (STECF, 2024).

Large-scale fisheries
Thirteen pelagic trawlers made up the entire large scale fleet in 2021 and 2022. The 2019 closure of the Baltic cod fishery severely affected Lithuanian demersal trawlers, which are no longer included in the current fleet structure (STECF, 2024).

Distant water fleet
There were 6 active vessels in the Distant water fleet in 2021 and 2022 which operated in the Eastern Central Atlantic (area 34) or occasionally in the North Atlantic or the North-East Atlantic, and mainly targeted Atlantic horse mackerel and chub mackerel.

Small-Scale Coastal Fleet (SSCF)
Mainly vessels under 10 metres that operate coastally using passive gears. One vessel was a 24-40 metres netter fishing in the Baltic Sea. The segment also includes vessels with a length of 10-12 metres that operate in the coastal Baltic Sea.

- **Size:** 56 out of the 75 active vessels in the fleet in 2021 and 2022.
- **Location:** Operates in the coastal areas of the Baltic Sea.



Fisheries for sprat and herring

Pelagic fisheries in Lithuania primarily focus on European sprat and Atlantic herring in the Baltic Sea (small share compared to other Baltic Member States). Since the closure of the cod fisheries, small pelagic species have become the main source of income for Lithuania's large-scale fleet. The weight and value of landings from the Baltic Sea decreased from 2021 to 2022, mainly due to the significant decline in the herring quota. Sprat made up 87% (EUR 3.21 million) of the total value landed by the LSF in the Baltic Sea, while Baltic herring made up 13% (EUR 0.5 million). However, the biggest landed value for Lithuania's fleet comes from other pelagics, landed by the distant water fleet.

17 *Note:* The graphic illustrating the composition of active fleet is based on information from the STECF report, and does not only include vessels operating in the Baltic Sea. For the Lithuanian fleet, some large scale vessels (orange) operate in distant waters (STECF, 2024).

Lithuania

Consumption & management

Fish consumption: Consumption of fisheries and aquaculture products in Lithuania is on the lower side compared to other EU Baltic Sea member states, with an average of 13.90 kg/inhabitant/year (EC, 2022).

Is forage fish eaten? In Lithuania, people eat herring in many forms: fried, baked, or served with sour cream, mushrooms, beets or potatoes. Herring, pollock and mackerel are popular saltwater species to eat throughout the country and herring also has a traditional spot on the Christmas table. Herring, sprat and salmon are the main processed fish in Lithuania.

Trade: Landings from the distant-water fleet are all exported. The large-scale fleet exports the majority (85%) of its Baltic landings, mainly to Denmark. The small scale fleet landings are sold locally, with a portion distributed to Latvia and the internal market for fresh production.

Fishery managed with: Total Allowable Catches are used for TAC species, including sprat and herring. Fisheries are also managed using individual transferable quotas to allocate fishing rights to different fishing companies, including those in the coastal Baltic Sea, the open Baltic Sea and long-distance fisheries.

13.9 kg
fish & aquaculture products
per inhabitant per year

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Poland

Overview of Polish fisheries

The Polish fishing fleet has been relatively stable over recent years, with a slight increase in engine power and capacity driven by changes in the deep-sea segment. The fleet primarily operates in the Baltic Sea, targeting a variety of species. European sprat and Atlantic herring are important species, both by volume and value, of catches by a wide margin. The fleet make-up is expected to change considerably over the coming years as there will be a large scrapping scheme, which will be followed by a recalibration of fisheries management in Poland.

Forage fish stocks of interest include:
Poland has the largest share of the Baltic Sprat, the second largest share of the Central Baltic Herring, and a small share of the WBSSH.

Structure of the Polish fishing fleet

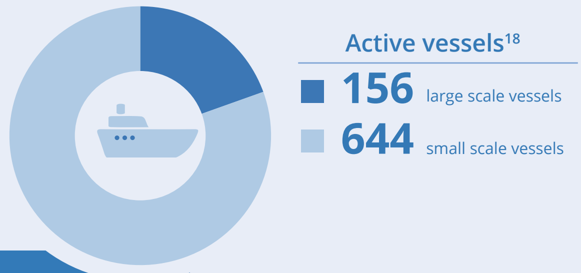
The fleet is divided into two primary segments: large-scale fisheries (LSF) and small-scale coastal fisheries (SSCF) and has 825 vessels in total. There was no remarkable change in fleet structure in 2022.

Large-scale fisheries
Pelagic trawlers play a crucial role in Poland's fisheries.

- **Size:** In 2022, 156 vessels operated in this segment.
- **Location:** Baltic Sea (and 2 vessels in the North and Central Atlantic).
- **Targets:** Mainly Baltic sprat and herring in the Baltic Sea.
- **Landings value:** the segment had a total landed value of EUR 28.2 million in 2022, a decrease from 2021.

Small-Scale Coastal Fleet (SSCF)
The decline in Baltic cod stocks and changes in herring quotas have been significant factors affecting the small scale fleet segment (STECF, 2024).

- **Size:** 644 vessels in 2022.
- **Target:** A variety of species, with herring and flounder being the most important.
- **Location:** operates exclusively in the Baltic Sea.



Fisheries for sprat and herring

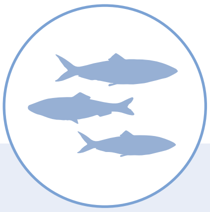
Polish pelagic fisheries primarily focus on the European sprat and Atlantic herring, both of which are crucial to the country's fishing industry. These species are fished both for domestic consumption but more significantly contribute to the economic output of the fishing sector.

European sprat remains the most landed species in terms of volume. In 2021, sprat landings increased by 7% in volume and in value.

Herring is the second most landed species in terms of volume. However, landings of herring decreased by 35% in volume in 2022, primarily due to lower Total Allowable Catches (TACs) set for Baltic herring (STECF 2024). The 2019

18 *Note:* The graphic illustrating the composition of active fleet is based on information from the STECF report, and does not only include vessels operating in the Baltic Sea. The Polish fleet is mostly active in the Baltic Sea but two large scale vessels operate outside (STECF, 2024).

Poland



closure of the Eastern Baltic cod fishery severely affected the demersal fleet, particularly the SSCF. Formerly a key part of Poland's fishing economy, cod's decline forced the fleet to shift toward alternative species like herring and sprat.

Consumption & management

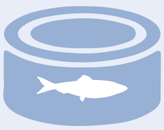
Poland's fisheries management is undergoing major changes due to declining fish stocks and EU regulations associated with them. Under the European Maritime, Fisheries and Aquaculture Fund, about 200 vessels (mostly small-scale) are expected to be scrapped, reducing the fleet by around 25%. The management strategy includes waiting for a new fleet structure before discussing the reallocation of fishing quotas under Article 17 of the CFP.

Fish consumption: Fish consumption in Poland is low compared to most other Baltic Sea countries, 13.11 kg/inhabitant/year (EC, 2022).

Is forage fish eaten? Herring is the most consumed species, followed by pollock and mackerel; Poland is one of the few countries in the Baltic where (canned) sprat is eaten as well. Herring and sprat consumption is linked to unique cultural practices. People eat canned sprat with bread while herring is a key part of Polish cultural cuisine, famously paired with vodka (a dish known as “zakąski”) and served during festive occasions such as Christmas and Śledzik (Herring Night), the last day before Lent.

Fishmeal/oil production: The Polish fish processing industry has showed robust performance, with a production value of EUR 3.6 billion in 2022 (STECF, 2024).

Fishery management: Polish fisheries are managed through a combination of Total Allowable Catches (TACs) and individual quotas. Cod, sprat and Central Baltic herring quotas were distributed to users based on the vessel size (there are six vessel length groups) or based on historical rights (in case of salmon and Western Baltic herring). Small-scale fisheries (vessels under 8 or 12 m in sprat fisheries) are exempt from the quota system.



13.1 kg
fish & aquaculture products per inhabitant per year

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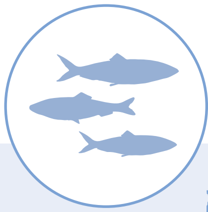
Sweden



Overview of Swedish fisheries

The Swedish fishing fleet targets both pelagic and demersal fish, and operates mainly in the Baltic Sea, the Skagerrak, and Kattegat. In 2021, Herring was still the primary target in terms of landed volume and value for the Swedish fleet, followed by Atlantic mackerel and European sprat. Sweden landed a total weight of 153 000 tonnes of seafood in 2021 and had a landed value of EUR 115 million (STECF 2023; Bergenius et al 2018).

Forage fish stocks of interest include:
Large shares of the Baltic sprat and Central Baltic Herring, as well as smaller shares Bothnian herring. Forage fish stocks outside the Baltic are also fished.

Structure of the Swedish fishing fleet

A range of vessel types targeting different species make up the highly diversified fleet, split into large-scale fisheries (LSF) and small-scale coastal fisheries (SSCF).

Large-scale fisheries

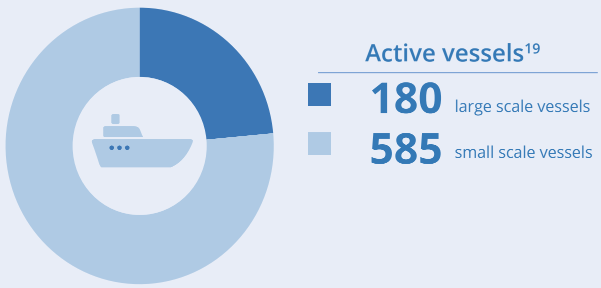
The large-scale fisheries have been shrinking (207 vessels in 2013 to 180 in 2022). LSF are divided into:

- Demersal trawl seines (18–24 m): 33 vessels targeting herring, sprat, cod, lobster, and Northern prawn.
- Demersal trawl seines (24–40 m): 15 vessels, mainly in the Baltic Sea, Skagerrak, Kattegat, and the North Sea, targeting sprat and herring but also some demersal species. This segment remains highly profitable, accounting for 88% of total landings in weight.

Vessels using active gears contributed most of the landed catch in terms of both value and weight, and accounted for 97–99% of the total catch by weight and 85-90% by value between 2013–2022.

Small-Scale Coastal Fleet (SSCF)

The SSCF has been unprofitable (a net loss of EUR -3.3 million in 2021) and has declined from 743 vessels in 2013 to 585 in 2022.



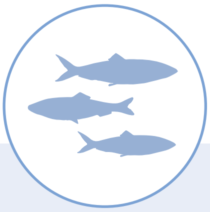
Fisheries for sprat and herring

During 2013–2015, Swedish commercial fishing landed 88 different species. Three species, herring, sprat and sandeel, stood out as they accounted for over 89% of total landing weight by Swedish fisheries (Bergenius et al 2018).

Sweden has the second-largest Baltic sprat catch in the EU, after Poland (ICES 2023e). The Swedish pelagic fishery is a combination of various single-species and mixed fisheries (e.g. single-species fishing targeting sandeel and mackerel and mixed fishing targeting herring and sprat in the Baltic Sea) Fishing is seasonal, with coastal quotas fished year-round and Bothnian Sea quotas mainly targeted in winter, spring, and early summer (Bergenius et al 2018).The total Swedish commercial catches in the

19 *Note:* The graphic illustrating the composition of active fleet is based on information from the STECF report, and does not only include vessels operating in the Baltic Sea. Parts of the Swedish fleet operates e.g. in Skagerrak, Kattegat, and the North Sea (STECF, 2024).

Sweden



sea (i.e. not just for the Baltic Sea) in 2022 amounted to just over 139 000 tons (live weight), which was a decrease of approximately 9% (14 000 tonnes) compared to 2021. Lower catches of herring and sandeel, due to reduced quotas, are the primary reason for the smaller quantities. The Swedish cod catch also remains at very low levels because of the ban on cod fishing in the Baltic Sea (SCB, 2023).

Consumption & management

The Swedish media has discussed Baltic herring fisheries relatively frequently in recent years, particularly as concerns have been raised over the decline of the stock status, the lack of catches that are suitable for human consumption and availability of larger fish for production of the traditional fermented herring (Hornborg & Langeland, 2025).

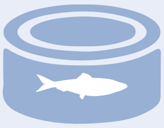
Fish consumption: Out of the Baltic Sea countries, Sweden has the second highest consumption of fisheries and aquaculture products, with 25.2 kg/inhabitant/year (EC, 2022).

Is forage fish eaten? People in Sweden eat herring as a traditional dish, for example pickled, fried or fermented. Pickled herring is popular around Christmas, Easter and Midsummer, often together with potatoes, sour cream, rye bread, chives and spirits. Sprat, on the other hand, is not commonly used for human consumption in Sweden. The fermented herring (surströmming/ "sour herring", i.e. lightly salted and fermented Baltic Sea herring) is a Swedish specialty.

Dioxins: Baltic herring (especially larger individuals as the compounds accumulate over time) can contain dioxins and PCBs exceeding EU limits. Sweden has a derogation allowing domestic sales of larger herring (over 17 cm) regardless of contaminant levels, though exports of non-compliant fish are prohibited. The Swedish Food Agency advises limiting consumption, particularly for children and women of childbearing age (Livsmedelsverket, 2023).

Fishmeal/oil production: The main seafood production for Sweden comes from the fisheries for pelagic species, with herring and sprat as the main target species (Hornborg 2023). The Danish processing industry is a big actor for processing of Baltic herring and sprat from Swedish landings, primarily processed into fishmeal and fish oil (Hornborg & Langeland, 2025).

Management: A new management system for demersal fisheries was introduced in 2017 due to the landing obligation, "*yet the system for demersal fisheries is still missing transferability like a proper ITQ system*" (STECF, 2024).



25.2 kg
fish & aquaculture products
per inhabitant per year

Unless otherwise stated, the Annual Economic Report on the EU Fishing Fleet provided by the Scientific and Technical Committee on Fisheries. (STECF 2024) is the source for the information in the country sections.

Chapter 7
Conclusions and recommendations

Forage fish are vital to the Baltic Sea ecosystem and hold high economic importance, both as target species for fisheries and as prey for commercially and recreationally important fish species. However, forage fish are currently facing significant challenges in the form of the combined stress from overfishing, pollution, habitat degradation, eutrophication, and climate change. Recognizing and addressing these challenges is essential for protecting forage fish themselves, as well as the broader biodiversity and ecological integrity of the Baltic Sea. Current scientific literature, summarised in the literature review of this report, highlights the importance of forage fish as a prey species and the changing balance of the Baltic ecosystem, while also listing a range of stressors affecting fish in the Baltic Sea.

Overfishing is one important factor affecting forage fish, even though other factors also contribute. As listed in Chapter 4, eutrophication, pollution and climate change and other factors also contribute significantly to the status of forage fish stocks, meaning fishing is not the only culprit. However, the presence of these other pressures does not justify continued overfishing, especially when stocks are already severely weakened. Fisheries management must take these multiple stressors into account and reduce fishing pressure accordingly to allow forage fish populations to recover.

Uncertainty, misreporting and advice

It is worth noting that unintentional overfishing can occur due to uncertainty in stock assessments and the models used, which may lead to overestimations of stock size and to quotas being set too high, which can worsen the decline. In the face of continued or increasing climate variability, which is harder to mitigate, the management should err on the side of caution (Thayer et al 2020).

Uncertainties due to misreporting should also be taken into account, particularly the known misreporting between sprat and herring, as well as between flounder and forage fish, (even if these may have a comparatively small impact), as they further distort stock assessments for stocks that are already in poor condition. Misreporting leads to inaccurate stock assessments, underscoring the importance of having a buffer on fishing limits which allows for some uncertainty without causing severe overfishing.

The advice given by ICES is produced in response to specific questions asked by the EU Commission (Berkow et al. 2024; Pew, 2024). If the questions are too narrow, scientific assessments focus solely on individual populations and catch levels, omitting broader ecological concerns. Under policy recommendation 7 below, we provide suggestions on changes to the request for ICES advice on fishing opportunities.

Ecosystem based and precautionary management

An ecosystem perspective is essential. Focusing on species one at a time has led to management actions that overlook the health of the wider marine ecosystem and the growing challenges posed by factors such as climate change. As shown in the literature reviewed in Chapter 3, forage fish play a central role in the marine ecosystem, and this must be factored into fisheries management and decisions for fishing quotas. Continued research on ecosystem-level reference points is also needed (Morrison et al., 2024).

Additionally, it is important to consider information in the full advice sheet provided for each stock and not just the headline advice[20] when taking decisions on fishing opportunities. For instance, important information about the low sprat recruitment is not mentioned in the headline advice but appears first on page 3 under "*Issues relevant to the advice*":

> *"The three most recent year classes (2021 – 2023) are among the lowest in the time series. Forecasts for 2026 assume a much higher recruitment than has been observed in these three years, resulting in an expected increase in biomass in 2026. If this assumption were too optimistic, biomass could decrease below biomass reference points."*
>
> **ICES, 2024g**

The latest advice[21] was more promising, indicating that the 2024 year class is strong but this assessment is based on one single acoustic survey and was distributed mainly in northeastern areas of the Baltic (ICES, 2025), which increases the uncertainty of its future contribution to the overall sprat biomass.

When stocks show some sign of improvement, such as in the 2024 assessment of the Central Baltic herring, where a relatively strong year class from 2022 appears to have led to an increase in biomass (ICES 2024e), management decisions should still be made with precaution in mind. The CBH improvement could be explained by the reduced fishing pressure of this stock in the previous years, and does not indicate that the stock is ready for an immediate increase in fishing activity as the stock is still at quite a low level.

A study in the journal Science compared biomass estimates with updated hindcast estimates for 230 stocks and concluded that stock assessment models in many cases overestimate the productivity of stocks which are overfished or located in areas with rising temperatures whereas assessments of sustainably fished stocks were generally accurate. The authors stress that the "*high uncertainty and bias in modeled stock estimates warrants much greater precaution by managers*" (Edgar *et al.* 2024). Decisions based on overestimates of a stock's size could impact the stock negatively.

Considering the unique challenges of the Baltic Sea and of its forage fish stocks, fisheries management needs to be precautionary and give the stocks room to rebuild, instead of being managed to be fished to their maximum limits. The implementation of an ecosystem-based approach to Baltic Sea fisheries necessitates the management of pelagic forage species beyond traditional maximum sustainable yield parameters, incorporating their trophic functionality, prey-predator dynamics, genetic diversity, size/sex/ weight aspects and their habitat requirements. While increased or continued fishing on vulnerable stocks may offer short-term economic benefits, such actions are not sustainable in the long term. To protect forage fish and help the Baltic Sea stocks recover, action must be taken to decrease stress on these populations and the ecosystem as a whole. An ecosystem-based approach is essential in order to account for the interactions among species, the crucial role of forage fish in a healthy ecosystem.

Ecosystem changes, interactions and diversity loss

With less sprat and herring present, and a decline in predation pressure, species like stickleback may thrive while larger predators suffer, leading to cascading ecological effects (Olin et al., 2022). Continued monitoring of the connections between fish populations in the Baltic is important in order to provide the best advice for management of these stocks, especially considering the changing climate. Similarly, continued studies of diet and food availability is also important, especially where planktivore competition could affect growth and/or condition of these fish.

20 ICES provides an "advice sheet" for each stock where the upper part of the first page is referred to as the "headline advice".
21 Note that ICES advice for fishing opportunities for 2026 was not yet published at the time of writing the bulk of this report.

It is also important to take into account both the proportions of older fish in the stocks (Griffiths et al., 2024) and the genetic diversity that can be lost if not managed properly. In a recent publication showing a "new", fast growing and type of herring which feeds on fish is present in the Baltic Sea. Goodall et al. call for cautious management, warning that the genetic diversity and unique subpopulations can be lost with a high fishing pressure, which is "*particularly important for the Baltic Sea, where the ecosystem depends on a few species and trophic interactions are easily disturbed*" (Goodall et al., 2024). Protecting and restoring key areas such as spawning grounds and nursery areas is also important. ICES advice (ICES 2024d), highlights the need for conservation efforts targeting WBSSH spawning areas, and similar measures would likely benefit other herring stocks as well.

Post 2020 we've seen substantive progress by scientific advisory bodies in integrating ecosystem-based fisheries data into advice sheets and management recommendations, with concurrent increased recognition among policy stakeholders regarding the necessity of ecosystem-based fisheries implementation for successful stock recovery initiatives. The subsequent section presents a non-exhaustive compilation of potential policy instruments that may facilitate the transition toward ecosystem-based fisheries management paradigms for sprat and herring populations in the Baltic Sea.

Key recommendations

Considering the importance of forage fish in the Baltic Sea ecosystem, implementing ecosystem-based management strategies is imperative to restore ecological resilience and ensure the sustained delivery of socio-economic benefits. To achieve these objectives, we recommend the following policy interventions:

1. Precautionary fishing limits

- Reduce fishing limits well below F_{MSY} to account for ecosystem uncertainties, species interactions and catch misreporting.
- Maintain precautionary fishing limits until spawning-stock biomass is at healthy levels for at least three consecutive years. Premature quota increases risk setting back fragile stock recovery.
- Always set fishing limits in line with the legal provisions, including Article 4.6 of the Baltic multiannual plan, which ensures that the risk of stocks falling below critical levels (below B_{lim}) is less than 5 %.
- Address bycatch issues, such as the western Baltic herring catches in the North Sea herring fishery, through area-specific and seasonal fishing restrictions.

2. Initiate Stock Recovery Plans

- Prioritise the three vulnerable Baltic herring populations for immediate, time-bound recovery plans.
- Consider following the ICES guidance,[22] by using specific biomass thresholds that trigger recovery measures, and setting shorter recovery target timelines to allow for rapid stock recovery.

3. Preserve the genetic diversity of herring populations

- Shift from single-stock to population and sub-population levels management by developing strategies for Central Baltic and Gulf of Bothnia herring that divide current Total Allowable Catch into multiple, spatially explicit management units aligned with documented genetic population structure to protect vulnerable and distinct spawning components.
- Increase research on the distinct population structures and genetic diversity of Baltic forage fish.
- Set fishing limits and implement measures that rebuild a healthy age and size structure of forage fish populations, as required by the EU Marine Strategy Framework Directive.

4. Protect and restore critical spawning habitats

- Implement habitat restoration in known spawning grounds and nursery habitats.
- Use spatial measures/seasonal closures in the relevant areas during spawning periods.
- Promote further scientific research into spawning periods and areas for sprat and herring populations.
- Collect improved data on migration routes, growth and maturity differences among the various spawning components and sub-populations to tailor local conservation measures.

22 ICES. 2023. Workshop on guidelines and methods for the design and evaluation of rebuilding plans for category 1-2 stocks (WKREBUILD2).

5. Improve compliance, monitoring and data quality

- Fully implement and enforce the Landing Obligation and catch reporting rules.
- Make Remote Electronic Monitoring (REM) on vessels mandatory.
- Implement independent port sampling and weighing with third-party inspectors for pelagic vessels to mitigate catch misreporting.

6. Continue research and monitoring of environmental stressors, diet and food web interactions

- Perform continuous studies on diet preferences for herring and sprat, and competition between them. Introduce regular monitoring of plankton, as availability, distribution and species composition of large zooplankton, for example, affect the size and condition of herring.
- Continue to study the interaction with sticklebacks and effects of the surge in their numbers (as prey for large herring, as predators of eggs, and as competitors).
- Continue research on the effects of climate change and eutrophication on recruitment, health and condition of sprat and herring.
- Update and improve data related to natural mortality to account for ecosystem changes, such as decreased cod predation, and adjust the assumed natural mortality currently used in ICES stock assessments accordingly.

7. Shift to an ecosystem approach to fisheries advice & address knowledge gaps

- Expand the request for ICES advice beyond single-species catch limits to incorporate multi-species ecosystem interactions.
- Improve the structure of scientific advice on fishing opportunities to better highlight the uncertainties and risks.
- Change the request for ICES advice on fishing opportunities to:
  - a) aim for rapid recovery of fish populations, particularly depleted or at-risk stocks, within a concrete timeframe and for maintaining them above sustainable levels in the near future,
  - b) ensure that the headline advice is in line with legal obligations,
  - c) prevent or minimise the risk of fish populations falling below safe biological limits, consistent with the legal so called "5% rule" in the Baltic multiannual plan,
  - d) fully reflect ecosystem dynamics and needs, as well as multispecies considerations,
  - e) deliver on all relevant elements of Good Environmental Status under the Marine Strategy Framework Directive, such as healthy population structures and/or food web integrity (i.e. leaving enough food in the sea for other marine life), in line with an ecosystem-based approach to fisheries management, and
  - f) provide sufficiently precautionary alternative catch options where a full incorporation of these aspects is not yet possible, to minimise risks to stocks and the overall ecosystem.

Considering the current state of the Baltic Sea ecosystem, the overall decline that can be seen in many species and the continued issues related to climate change and other stressors in the region, key species such as the unique forage fish populations adapted to the particular brackish waters of the Baltic Sea need to be managed in a much more precautionary way that ensures resilience. Improved management of Baltic sprat and herring stocks offers clear benefits, not only for the health of the Baltic Sea ecosystem and the recovery of its predators, but also for the viability of fisheries in the long term.

Chapter 8
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Appendix

Supplementary Figure 1 - History of Gulf of Bothnia herring catches caught in EU Member States.

Supplementary Figure 2 - History of Central Baltic herring catches caught in EU Member States.

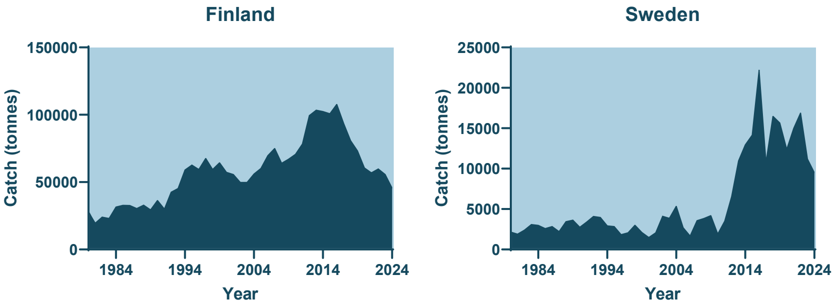
Supplementary Figure 3 - History of Gulf of Riga herring catches caught in EU Member States.

Supplementary Figure 4 - History of Western Baltic herring caught in EU Member States.

Supplementary Figure 5 - History of sprat catches caught in EU Member States.

History of commercial catches of Gulf of Bothnia herring in subdivisions 30–31

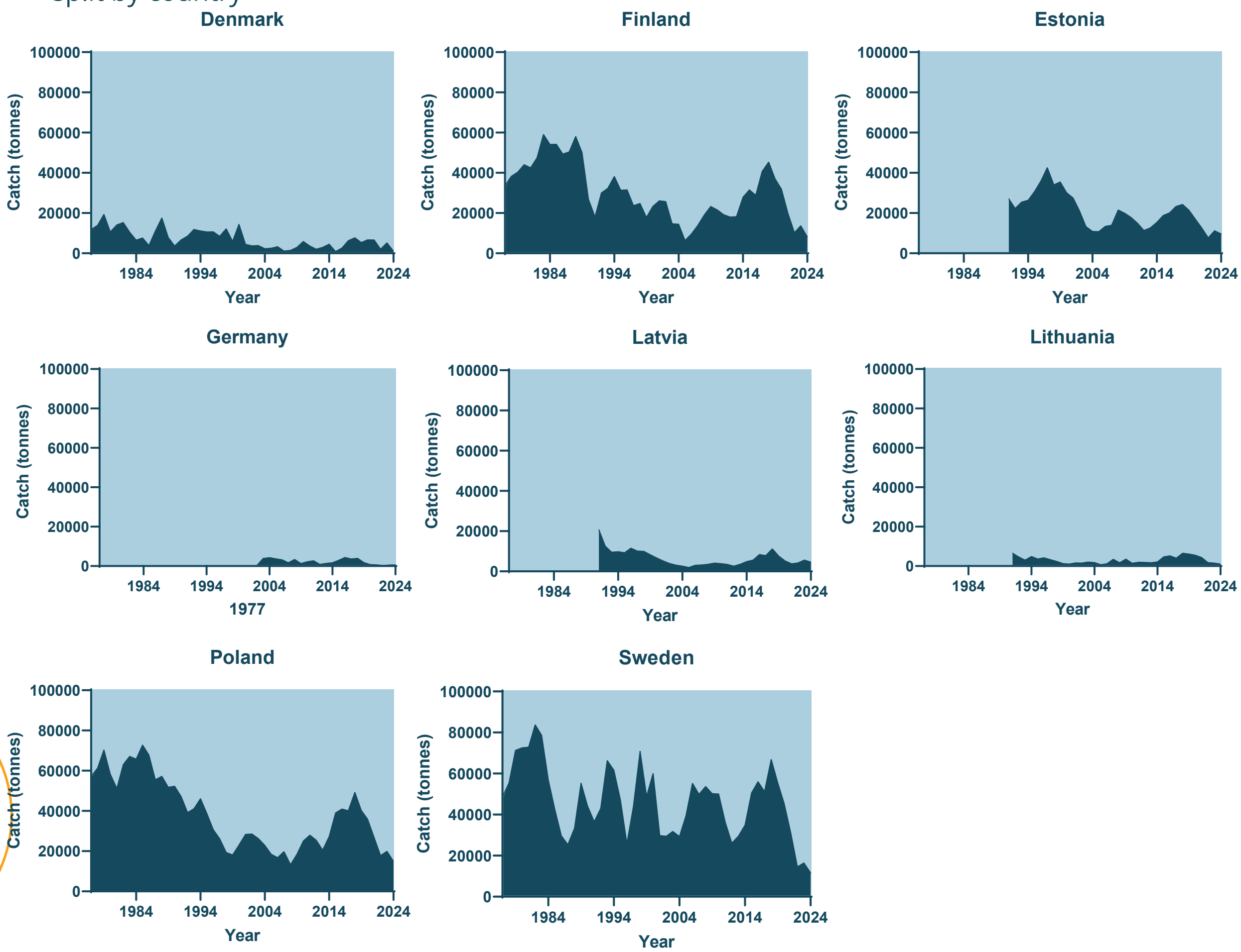
split by country



Supplementary Figure 1. History of Gulf of Bothnia catches caught in EU Member States participating in the fishery from 1980–2024. Based on data from ICES (ICES 2025d), Table 8, *"Herring in subdivisions 30 and 31. History of ICES commercial catches by subdivision (SD) for each country participating in the fishery."* For Estonia, Latvia and Lithuania, data are presented from 1992 and onwards.

History of commercial catches of Central baltic herring in subdivisions 25–29 and 32, excluding the Gulf of Riga

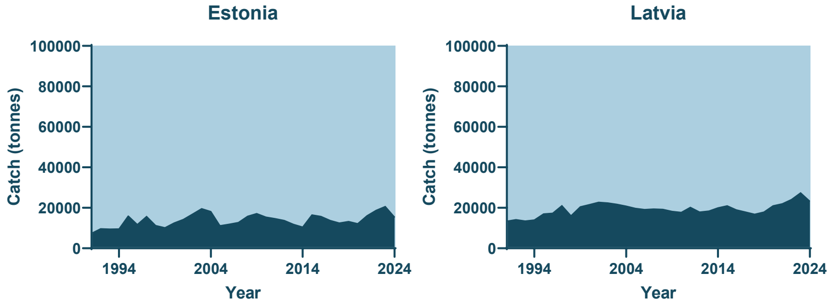
split by country



Supplementary Figure 2. History of Central Baltic herring catches caught in EU Member States participating in the fishery from 1977–2024. Based on data from ICES (ICES 2025c), Table 8, *"Herring in subdivisions 25–29 and 32, excluding the Gulf of Riga. History of commercial catch and landings; official catches are presented for each country participating in the fishery."* For Estonia, Latvia and Lithuania, data are presented from 1992 and onwards.

History of commercial catches of Gulf of Riga herring

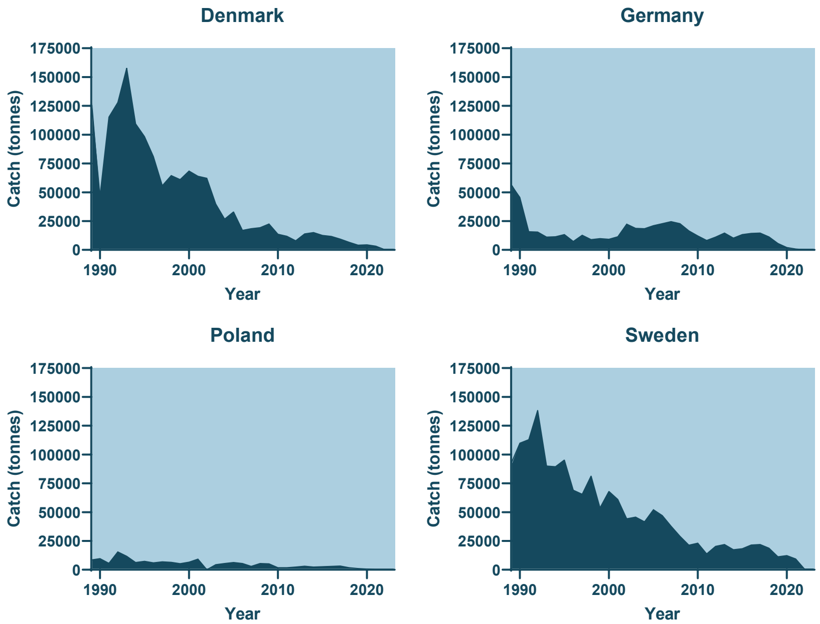
split by country



Supplementary Figure 3. History of Gulf of Riga herring catches caught in EU Member States participating in the fishery from 1991–2024. Based on data from ICES (ICES 2025a), Table 8, *"Herring in subdivision 28.1. ICES estimates of total catches of herring in the Gulf of Riga by country. All weights are in tonnes."* For Estonia, Latvia and Lithuania, data are presented from 1992 and onwards.

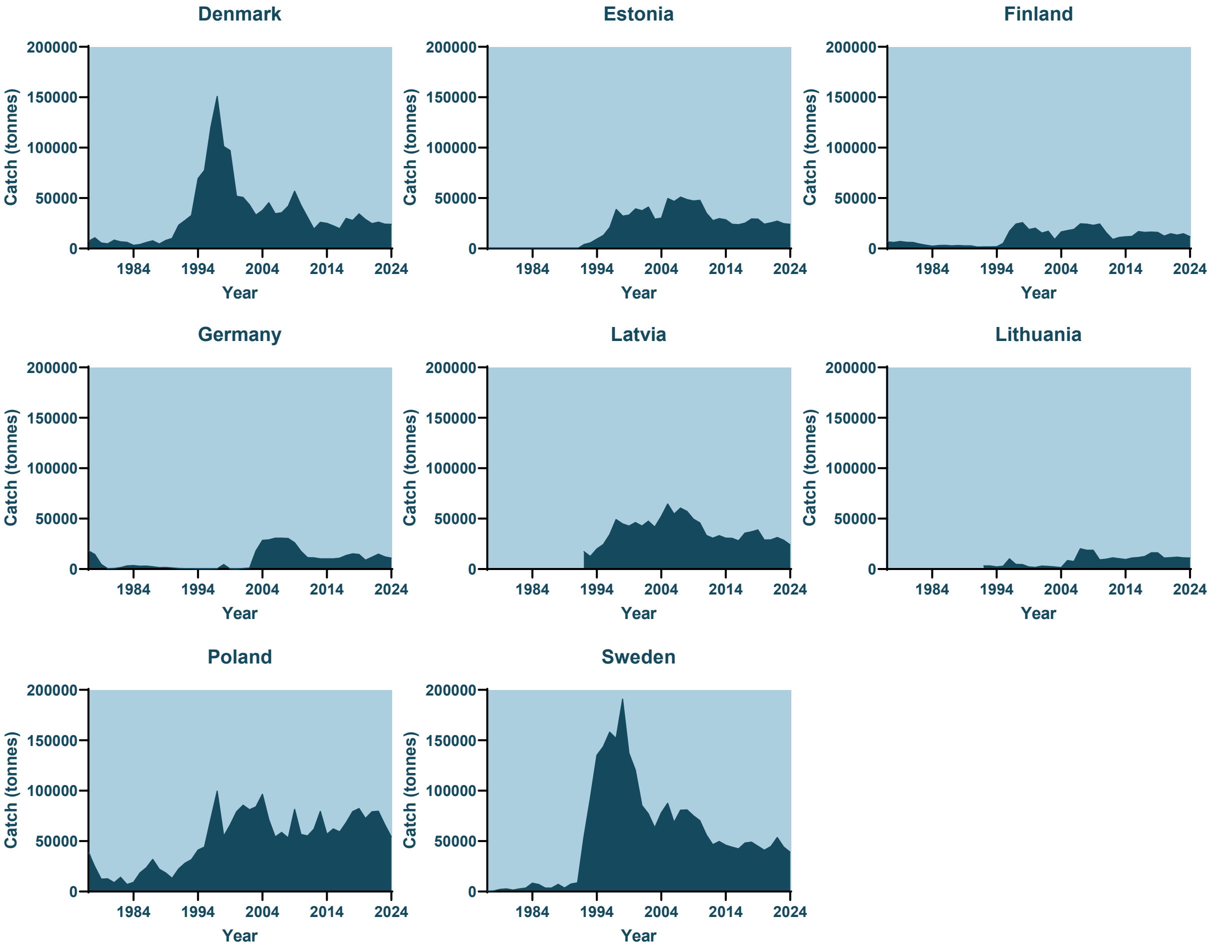
History of commercial catches of Western Baltic spring spawning herring

split by country

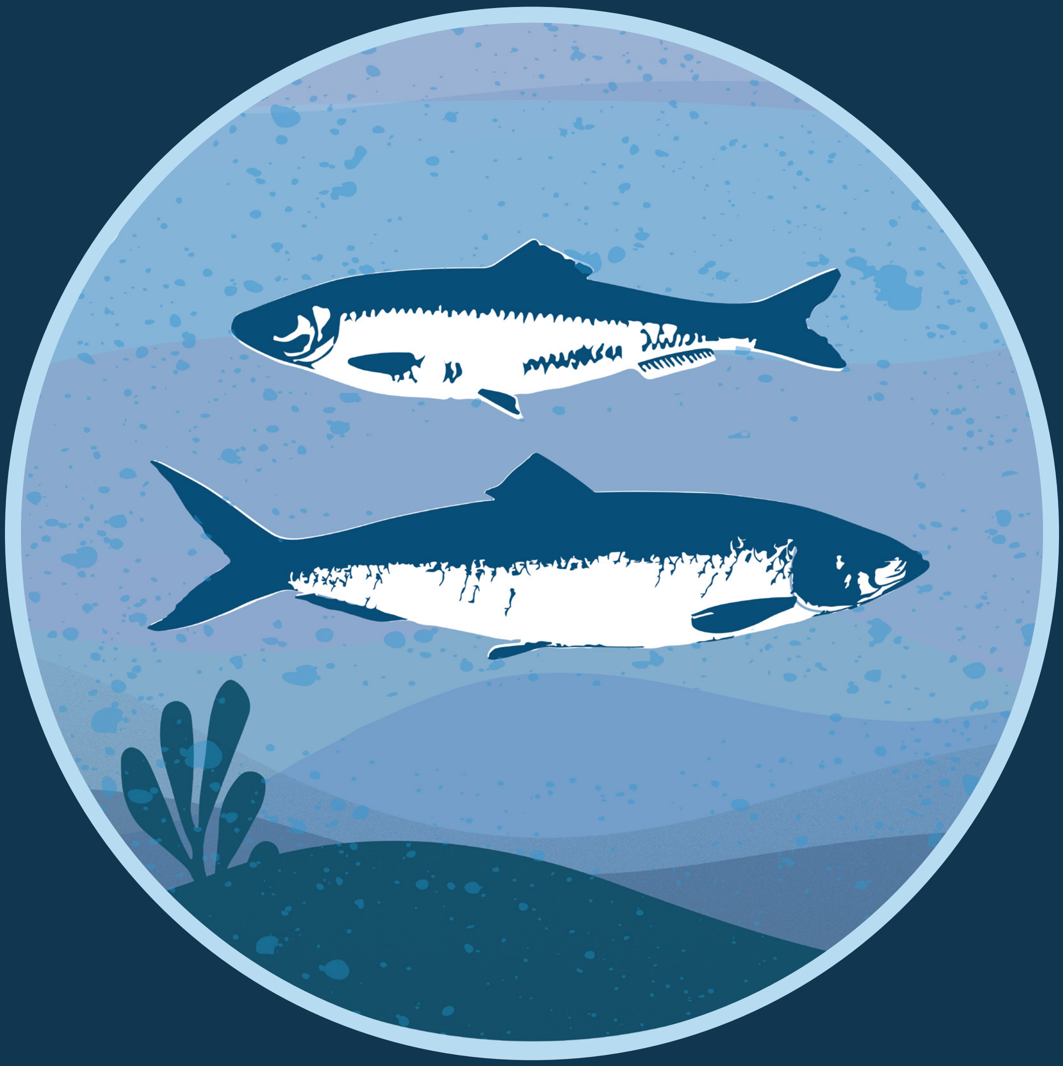


Supplementary Figure 4. History of Western Baltic herring catches caught in EU Member States participating in the fishery from 1989–2024. Based on data from ICES (ICES 2025b), Table 11, *"Herring in subdivisions 20–24. History of commercial catch by area and country as estimated by ICES for all herring stocks caught within the management area for subdivisions 20–24. Values prior to 2002 are rounded."* For Estonia, Latvia and Lithuania, data are presented from 1992 and onwards.

History of commercial catches of Baltic Sea sprat
split by country



Supplementary Figure 5. History of sprat catches caught in EU Member States participating in the fishery from 1977–2024. Based on data from ICES (ICES 2025e), Table 9, *"Sprat in subdivisions 22–32. History of ICES catches presented for each country participating in the fishery."* For Estonia, Latvia and Lithuania, data are presented from 1992 to 2024 (prior to this, the sum of landings by Estonia, Latvia, Lithuania, and the Russian Federation were presented together.



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