4.1 Baltic Sea Ecoregion – Ecosystem overview

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Ecoregion description

The Baltic Sea is one of the largest brackish water bodies in the world, covering 420 000 km^2. It is a semi-enclosed shallow sea with an average depth of 60 m, where one third of the area is less than 30 m deep (Figure 1). This ecoregion has many islands and a long and diverse coastline, especially in the northern areas. It is characterized by strong temperature and salinity gradients, from relatively warmer and saline waters in the southwestern part to cold and almost freshwater in the northernmost parts. In addition, there is strong permanent vertical stratification for much of the Baltic Sea. The northernmost parts are covered by ice in winter. Based on its bathymetry and hydrology, the Baltic Sea can be sub-divided into three main areas:

- The transition area, consisting of the Belt Sea and the Arkona Basin;
- The central Baltic Sea, consisting of the deep areas of the Bornholm Basin, Gdansk Deep, Gotland Basin and the Gulf of Riga; and
- The northern Baltic Sea, including the Gulf of Bothnia and the Gulf of Finland and the Archipelago Sea.

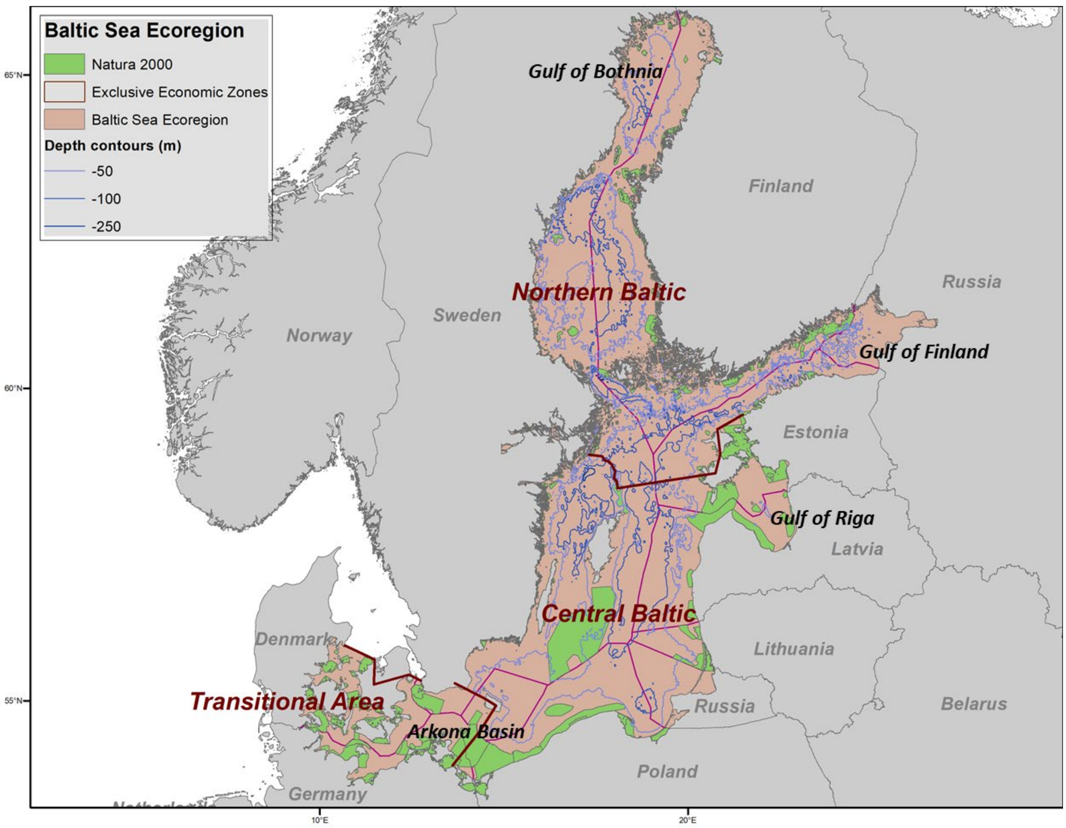

Figure 1 The Baltic Sea ecoregion, showing EEZs and larger Natura 2000 sites.

Management and governance institutions

Nine countries border the Baltic Sea, and a further five countries are partly within the catchment area (Figure 2). The catchment area has a total population of around 85 million. All countries bordering the Baltic Sea, except Russia, are EU Member States, and all countries and the EU are contracting parties of the Convention on the Protection of the Marine Environment in the Baltic Sea (the Helsinki Convention). The convention establishes the Baltic Marine Environment Protection Commission, commonly referred to as the Helsinki Commission or HELCOM. HELCOM has adopted the Baltic Sea Action Plan (BSAP) to restore good ecological status of the marine environment by 2021. The focal issues of the BSAP are eutrophication, biodiversity conservation, hazardous substances, and maritime activities. The goals of the BSAP to a large degree overlap with those of the EU's Marine Strategy Framework Directive (MSFD) and the Water Framework Directive (WFD). This overlap has resulted in strong coordination in the implementation of measures.

Policies regarding commercial fisheries in the Baltic Sea are regulated under EU's Common Fisheries Policy (CFP) and bilaterally with Russia. Recreational fisheries are mostly managed at the national level.

Fisheries advice is provided by ICES, the European Commission's Scientific, Technical and Economic Committee for Fisheries (STECF), the Baltic Sea Advisory Council (BSAC), and BALTFISH. BALTFISH is a regional body involving the eight EU Member States bordering the Baltic Sea, which submits joint recommendations to the European Commission. BSAC is an advisory body composed of representatives from the commercial fisheries and other interest groups, mainly environmental NGOs.

In the Baltic Sea, the protected areas network is a combination of HELCOM Baltic Sea Protected Areas (BSPAs) that were established to protect valuable marine and coastal habitats and the Natura 2000 network of the EU Birds Directive and EU Habitats Directive (Figure 1) that are protecting certain natural habitats and species. Many of BSPAs and Natura 2000 sites overlap. The network of MPAs in the Baltic Sea is gradually expanding and is now close to 15% of the total sea area.

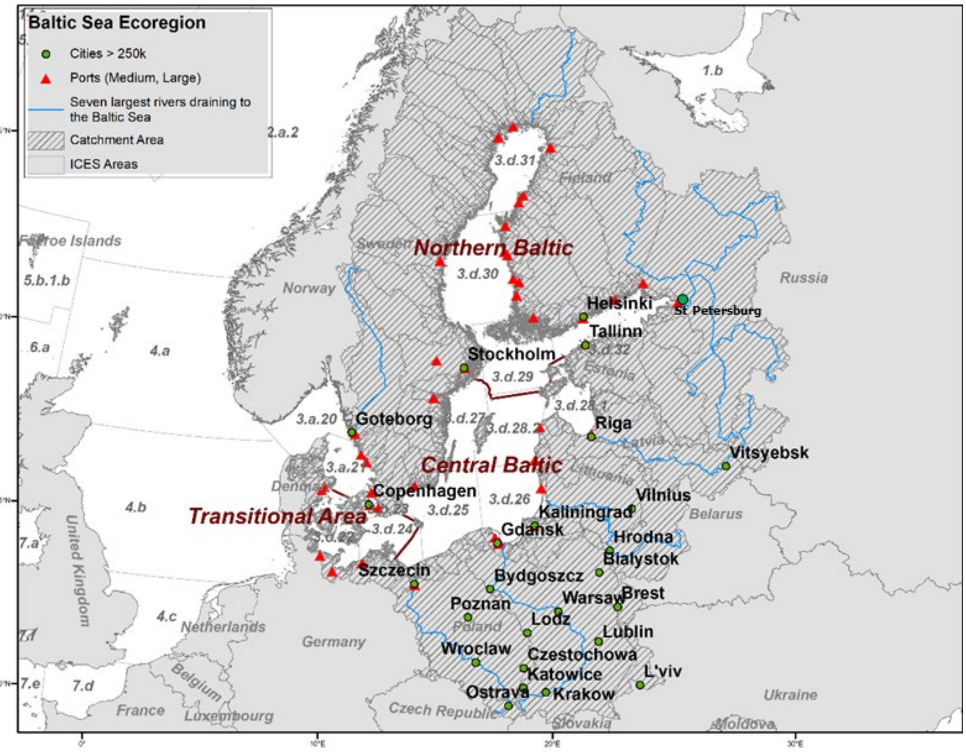

Figure 2 Catchment area for the Baltic Sea ecoregion, showing major cities, ports, and ICES areas.

Key signals within the environment and the ecosystem

Many species and habitats of the Baltic Sea are not in good condition, according to recent assessments. This affects foodweb functionality, reduces the resilience and resistance against further environmental changes, and diminishes prospects for socioeconomic benefits, including fishing opportunities. Key signals are:

- The overall loading of nutrients has decreased markedly due to improved management, but annual nutrient inputs still exceed regionally agreed goals in the central Baltic Sea, the Archipelago Sea, and the Gulf of Finland. Nutrient concentrations in the water column and sequestered in the sediments remain relatively high, and phosphorus is increasing in some areas. As examples of the consequences of this nutrient load, blue-green algal blooms are common in offshore areas and there is excessive filamentous algal growth in many coastal areas.
- The extent of deep-water areas with poor or no oxygen, caused by a combination of eutrophication and a reduced frequency of inflows of saline and oxygen-rich water from the North Sea, remains high.
- Climate-driven changes in water temperature (including changes in ice cover) and salinity will have an increasing influence on the ecosystem's structure and function.
- Contaminant levels remain elevated, and the overall contamination status has been at the same level for the past two decades, but many potential contaminants are not monitored. Some of the main contaminants have been reduced (e.g. DDT, dioxins, and PCBs).
- The rate of observed introduction of non-indigenous species has more than doubled in the 21st century.
- Overall fishing effort fell by approximately 50% from 2004 to 2012. Discarding still exists, even though it is largely illegal.
    - The spawning-stock biomass (SSB) of most pelagic stocks has increased and is above or close to the biomass reference points. An exception is the western Baltic herring stock. Both sprat and herring are experiencing overfishing (fished at greater than F_{MSY}).
    - Both Baltic cod stocks are exploited above F_{MSY}. The SSB of western Baltic cod has been below the limit reference point for at least ten years. The SSB of eastern Baltic cod is decreasing, with the value for 2018 being the lowest observed in the time-series. Its size structure and condition factor have deteriorated markedly without signs of improvement.
    - The status of European eel continues to be critical.
- Disturbance of seabed habitats due to physical abrasion from mobile bottom-contacting fishing gears occurs mostly in the southern Baltic Sea and may reduce benthic diversity and biomass depending on the substrate type.
- Structural shifts in the open-sea foodweb (including phytoplankton and zooplankton communities) of the central Baltic Sea occurred in the late 1980s and early 1990s. These were attributed to changes in abiotic conditions, such as increasing water temperature and hypoxia, and decreasing salinity, in combination with overfishing of eastern Baltic cod, in particular, during years characterized by low reproductive success of cod. Since then, the open-sea system has been dominated by small pelagic fish, such as sprat.
- Changes in coastal fish communities over the past decades have been linked to increasing water temperatures, decreasing salinities, and eutrophication. Increasing abundances of fish from the carp family (*Cyprinidae*) and decreases in piscivorous fish have been seen in many coastal areas during the past decade.
- In general, those seabird species eating sprat and herring have increased in number, while several that feed on the benthos are decreasing, possibly partly caused by bycatch in static net fisheries.
- Grey seal populations have had a high growth rate over the past few decades following the cessation of hunting in the 1980s, but this has levelled off in recent years. The growth rate of the southern Baltic harbour seal population has also been high.

Pressures

The five most important pressures on the Baltic Sea are identified as: nutrient and organic enrichment, selective extraction of species, introduction of contaminating compounds, introduction of non-indigenous species, and abrasion and substrate loss (Figure 3). The main pressures described below are defined in the ICES Technical Guidelines.

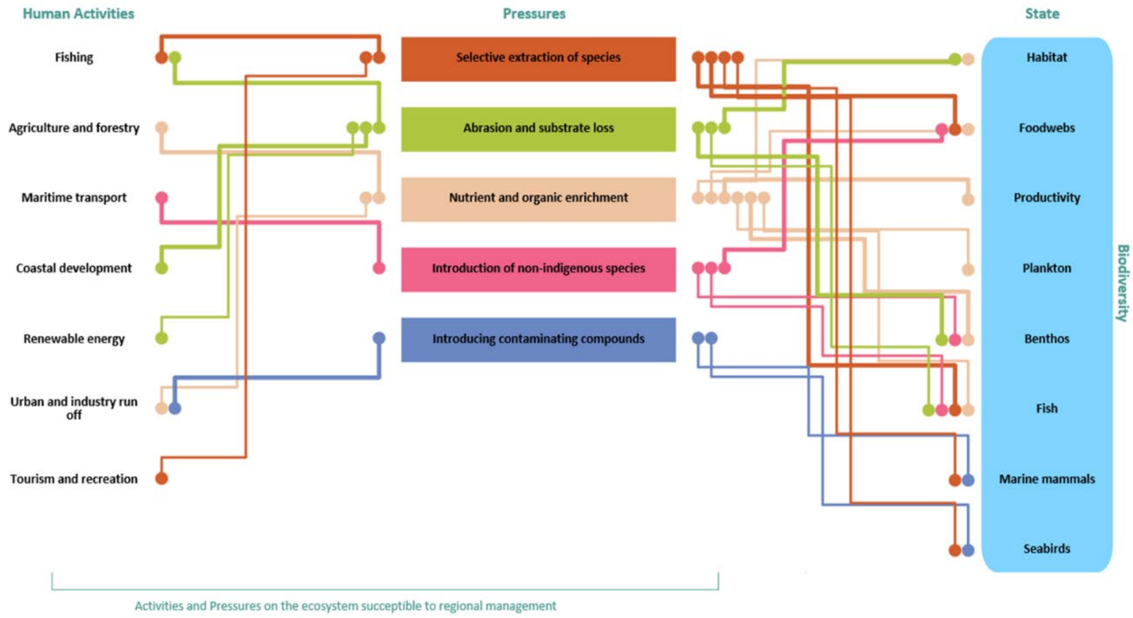

Figure 3 Baltic Sea ecoregion overview with the major regional pressures, human activities, and ecosystem state components. The width of lines indicates the relative importance of main individual links (the scaled strength of pressures should be understood as a relevant strength between the human activities listed and not as an assessment of the actual pressure on the ecosystem). Climate change affects human activities, the intensity of the pressures, and some aspects of state, as well as the links between these.

Nutrient and organic enrichment

Nitrogen and phosphorus loads reached peaks around 1980 at about 3.1 and 5.8 times the preindustrial loads, respectively. These high nutrient inputs, which increased strongly after 1950 (Figure 4), caused eutrophication of the Baltic Sea. Nitrogen loads have dropped by a quarter and phosphorous loads have halved since 1980, mostly due to better sewage treatment. Current nitrogen loads are comparable to the inputs in the 1970s, while phosphorus is approximately at levels seen in the 1950s. Eutrophication remains one of the major pressures on the Baltic ecosystem, having both direct and indirect impact.

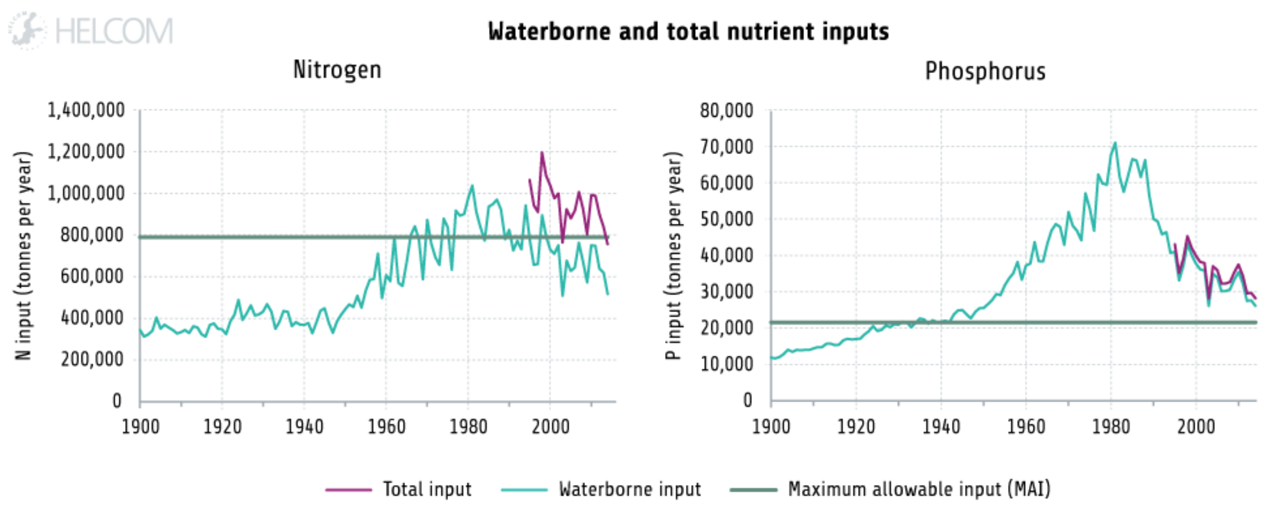

Figure 4 Waterborne and total nutrient inputs to the Baltic Sea. The horizontal green line indicates the maximum allowable input defined in the Baltic Sea Action Plan.

Nutrient loads still exceed the goals of the HELCOM Baltic Sea Action Plan in the central Baltic Sea and the Gulf of Finland; further load reduction has been agreed by HELCOM.

Due to the high nutrient input, water column nutrient concentrations increased from the beginning of the 20th century, by 1.7 times for nitrogen and by 2.6 times for phosphorus. During the 1990s, increases in nutrient concentrations halted in most areas (Figure 5). With the exception of the eastern Gotland Basin, nitrogen concentrations declined. Phosphorus concentrations, however, remained at high levels or even increased when compared with 2007–2011. Phosphorus is retained in the Baltic Sea sediments, resulting in a longer residence time than nitrogen and long-lasting effects of past phosphorus loading. With nutrient concentrations remaining at high levels, the intensity of summer phytoplankton blooms did not change after 1990.

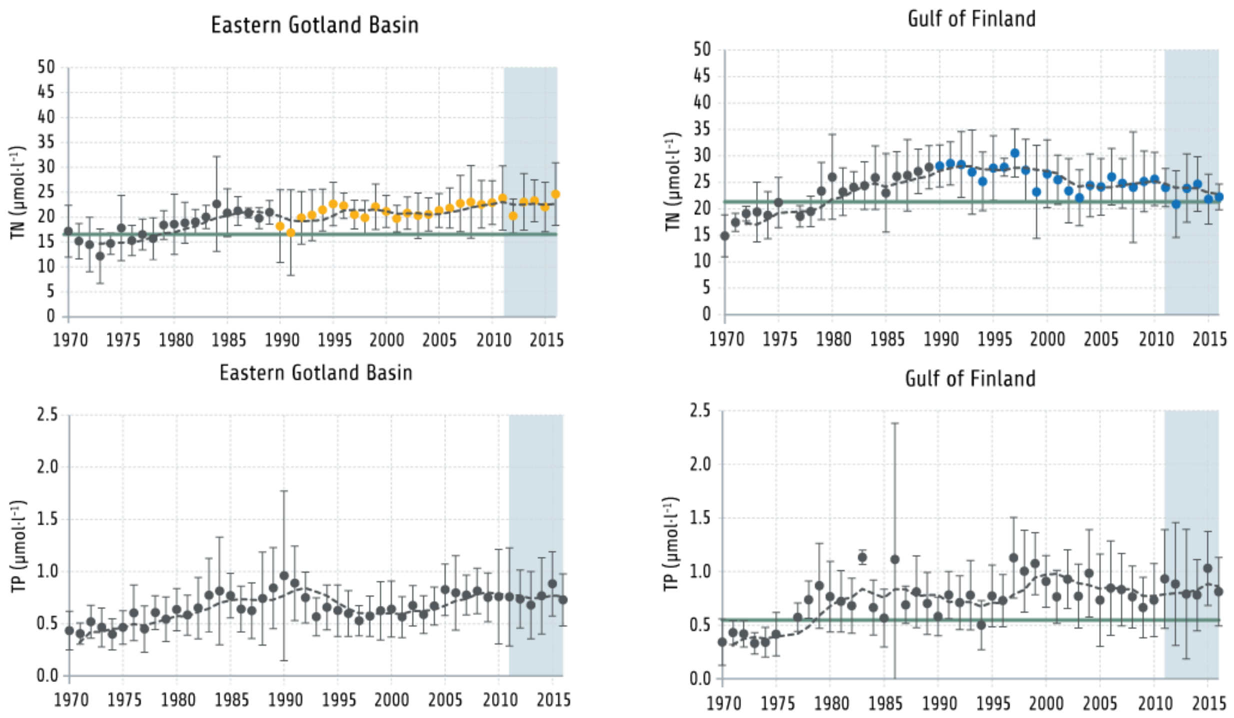

Figure 5 Total nitrogen (top) and phosphorus (bottom) concentrations in the eastern Gotland Basin and the Gulf of Finland. Horizontal green lines indicate Baltic Sea Action Plan targets.

Selective extraction of species, including incidental non-target catch

Fisheries are the main activity contributing to selective extraction of species in the Baltic Sea. The principal species targeted in the commercial fishery are cod *Gadus morhua*, herring *Clupea harengus*, and sprat *Sprattus sprattus*, which constitute about 95% of the total catch. Other species having local economic importance are salmon *Salmo salar*, plaice *Pleuronectes platessa*, dab *Limanda limanda*, brill *Scophthalmus rhombus*, turbot *Scophthalmus maximus*, European flounder *Platichthys flesus*, Baltic flounder *Platichthys solemdali*, pikeperch *Sander lucioperca*, pike *Esox lucius*, perch *Perca fluviatilis*, vendace *Coregonus albula*, whitefish *Coregonus clupeaformis*, eel *Anguilla Anguilla,* and sea trout *Salmo trutta*. The overall fishing effort in the Baltic Sea decreased by approximately 50% from 2004 to 2012 (Figure 6). The ICES fisheries overview for the Baltic contains detailed information on the fisheries. The impact of the EU landing obligation has not yet been evaluated, but is likely to change the effect of fisheries on the ecosystem.

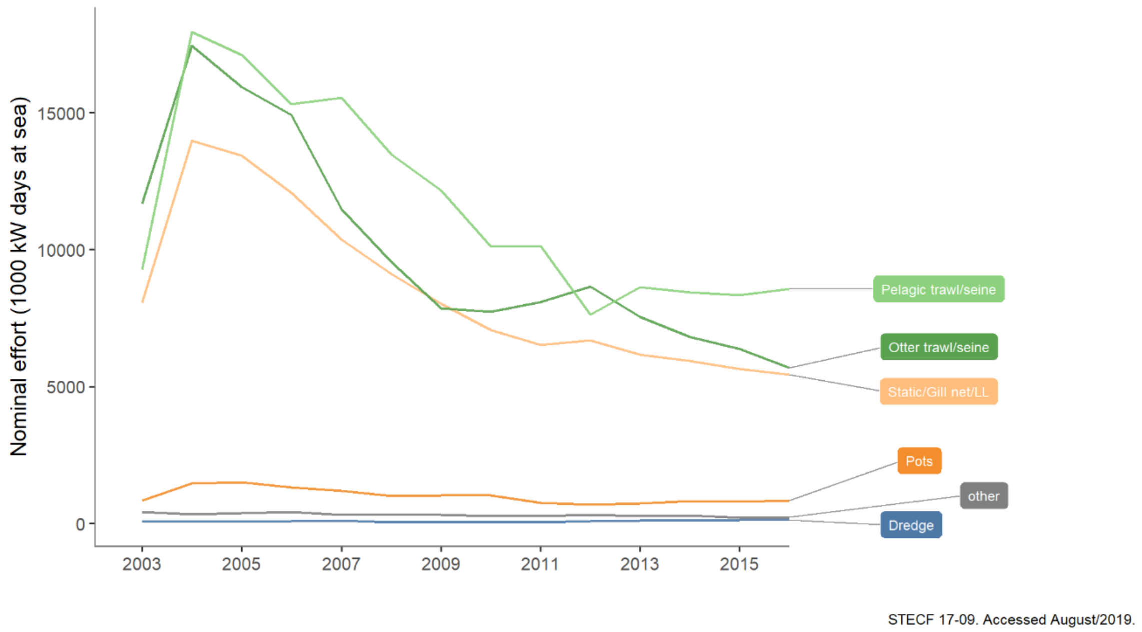

Figure 6 Baltic Sea fishing effort (thousand kW days at sea) in 2003–2016 by EU vessels (except those of Finland and Estonia, see Figure 3), by gear type. Note: this dataset is unavailable from 2016 onwards.

Landings

Since the early 1950s, landings of herring and sprat from the pelagic fisheries have dominated the total landings of fish from the Baltic Sea (Figure 7). A decrease in sprat landings in the late 1970s, followed by a decline in cod landings in the late 1980s, led to a marked decline in total landings. Pelagic landings increased in the early and mid-1990s, reflecting an increase in sprat abundance during this period. Since 2003, total Baltic Sea landings have remained fairly stable (Figure 7) despite declining fishing effort. In many areas, recreational catches of coastal species outnumber the commercial catches.

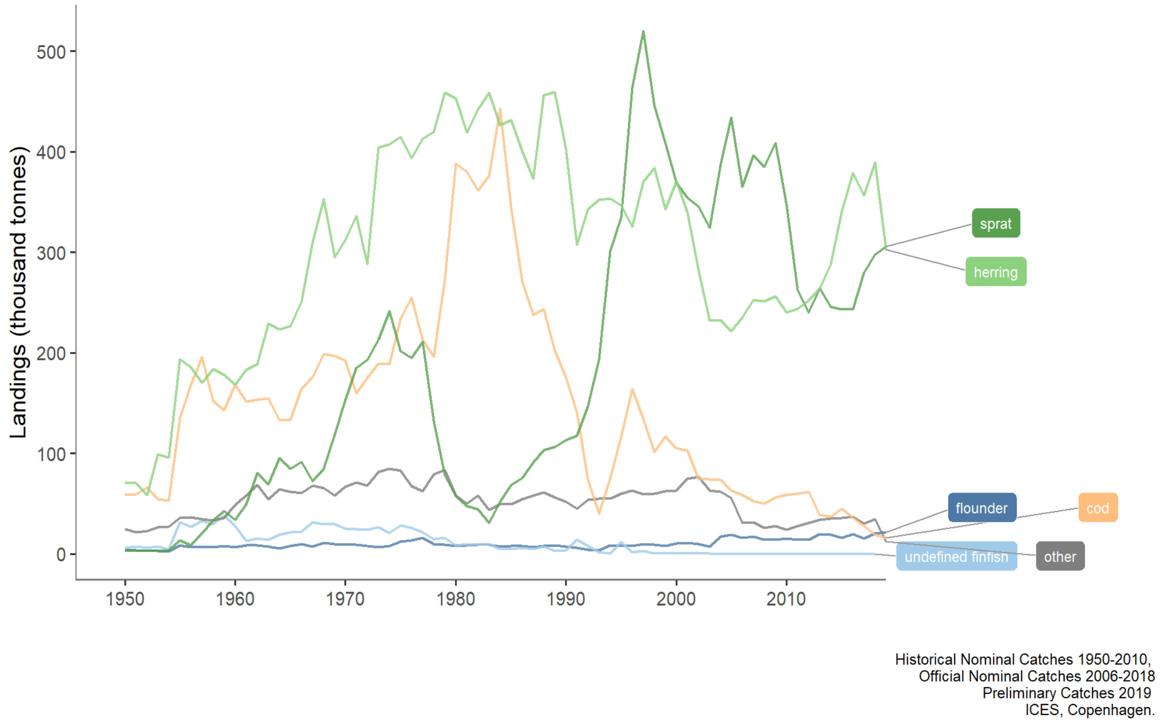

Figure 7 Landings (thousand tonnes) from the Baltic Sea in 1950–2019, by species. The five species with the highest landings are displayed separately; the remaining species are aggregated and labelled as “other”. The “undefined finfish” category is due to inadequate reporting in early years

Impacts on commercial stocks

The two major pelagic fish stocks (central Baltic herring and Baltic sprat) are fished above F_{MSY}. The other assessed herring stocks are also fished above F_{MSY} and both stocks are therefore experiencing overfishing, except for Gulf of Riga herring. The mean F for the pelagic fish stocks has decreased in the late 2000s, but has increased in the last few years (Figure 8).

There are two main commercially exploited demersal fish stocks in the Baltic Sea, namely the western Baltic cod and the eastern Baltic cod. The fishing mortality (F) of both cod stocks is above F_{MSY}. It is hypothesized that the reduced mean size and growth of the eastern Baltic cod stock since the 1990s is due to size-selective fishing, reduced size at maturation, poor condition of cod, hypoxia, and parasite infestation.

In general, benthic fish stocks (flatfish species that live on the seabed, such as flounder) show a reduction of overall F since 2010, but an increase in the last few years.

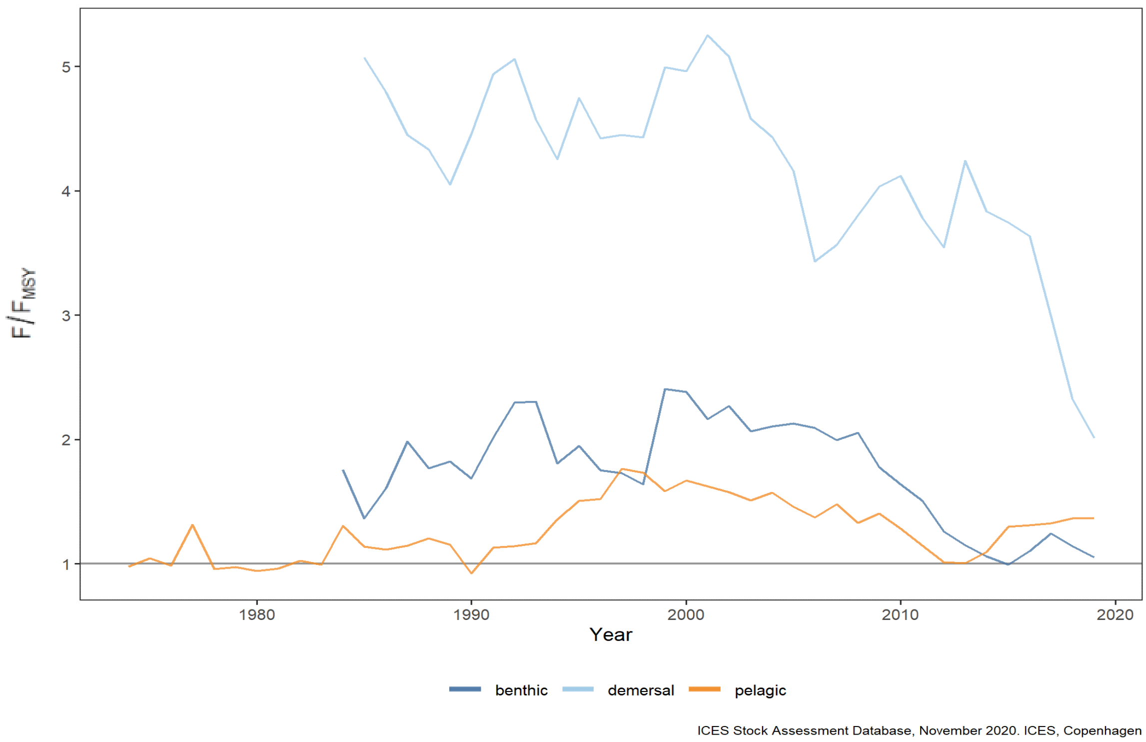

Figure 8 Time-series of annual relative fishing mortality (F to F_{MSY} ratio) for benthic, demersal, and pelagic stocks. Table A1 in the Annex details which species belong to each fish category.

Discards

Discarding still occurs in the Baltic, though it is illegal for the major commercial fisheries. For example, for the eastern Baltic cod stock, discards were still estimated at 3238 tonnes in 2017, despite a landing obligation since 2015. Discarding was at similar levels in 2016 and constituted 11% of the total catch in weight.

Impacts on foodwebs and regime shift

Fishing has changed both foodwebs and the community structure in the Baltic Sea. Sudden changes occurred in the foodweb of the central Baltic ecosystem in the late 1980s and early 1990s which, in addition to abiotic changes, can be partly explained by unsustainable fishing pressure.

Impact on spatial distribution and fisheries in the southern Baltic

Sprat and herring are important food items for cod, but at present, the main part of their biomass is distributed north of the distribution area for eastern Baltic cod (Figure 9). The fishery for sprat occurs throughout the range of the stock. ICES has advised that a spatial management plan is developed for fisheries that catch sprat, with the aim to improve feeding conditions for cod.

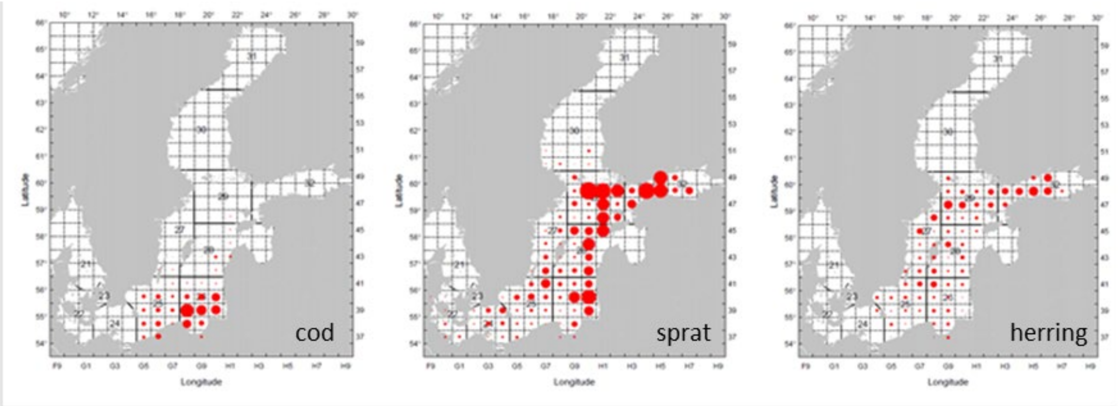

Figure 9 Left: Eastern Baltic cod ≥ 30 cm in the Baltic international trawl survey (BITS, in numbers h^{-1}) in the 4th quarter 2017. Middle: Sprat (ages between 1 and 8) in the Baltic international acoustic survey (BIAS, in numbers) in the 4th quarter 2017. Right: Herring in subdivisions 25–29 and 32, excluding the Gulf of Riga, from the BIAS survey (BIAS, in numbers) in the 4th quarter 2017. Note that all figures are based on number of individuals and not on biomass. The BIAS survey does not cover the Gulf of Bothnia or the Bothnian Sea.

Impacts on threatened and declining fish species

ICES has advised that all anthropogenic impacts, including recreational and commercial fishing on eels, should be reduced to as close to zero as possible in order to conserve this critically endangered species.

Impacts on seabirds and marine mammals

Drowning in fishing gear is considered to be a significant source of anthropogenic mortality for long-tailed duck, scoters, divers, and some other waterbirds, especially in wintering areas with high densities of waterbirds. Estimates in the early 2000s indicate that between 100 000 and 200 000 waterbirds were being landed as bycatch annually in nets in the Baltic and North seas, mostly in the Baltic. Diving waterbirds are especially vulnerable to being entangled in gillnets and other types of static nets.

Drowning in fishing gear is considered to be the main cause of anthropogenic mortality for harbour porpoise populations in the Baltic Sea, and is also a concern for grey seals.

Hunting

Hunting was the main reason for a drastic decline in grey seal and ringed seal populations in the early 1900s. In the 1970s and 1980s, seals were protected by all countries in the Baltic Sea region. After recovery of the populations, controlled hunting is allowed. The highest permissible annual quota is currently around 2000 grey seals, 230 ringed seals, and 235 harbour seals. White-tailed sea eagle *Haliaeetus albicilla* and cormorant *Phalacrocorax carbo* almost disappeared from the Baltic Sea in the early 1900s due to hunting or intentional killing.

Sea ducks have traditionally been hunted, with the most common target species in the Baltic Sea being common eider *Somateria mollissima* and long-tailed duck *Clangula hyemalis*. The average annual number of hunted individuals of these two species in recent years has been around 37 000 and 16 000, respectively.

Introduction of contaminating compounds

Levels of contaminants in many parts of the Baltic Sea are elevated compared with most European seas. The overall contamination status has not changed markedly in the past two decades. Generally the levels of some contaminants that were previously of concern are improved today, for example hexachlorocyclohexane (HCH, lindane) and dichlorodiphenyltrichloroethane (DDT) and its metabolites. Contaminants that degrade very slowly and are expected to be long-lasting in the ecosystem include mercury, flame retardants (PBDEs), dioxins, and PCBs. The latter two are of special concern for the fishing sector and for food provision.

Generally, there is a long recovery time in the environment for contamination that has taken place in the past, with a continuous risk that sediment-deposited contaminants will be remobilized.

Oil spills have decreased in all sub-basins of the Baltic Sea over the past decades. However, increasing maritime traffic leads to continued risk that single oil spills introduce large amounts of oil to the environment.

Caesium (Cs-137), deposited after the accident at the Chernobyl nuclear power plant in 1986, is now at acceptable levels in some sub-basins and can be expected to be so in all of the Baltic Sea by 2020.

Introduction of non-indigenous species

The ecoregion has a total known number of 173 non-indigenous (NIS) and cryptogenic (of unknown origin) species. Since the beginning of the 21st century the apparent annual introduction rate has been almost two times higher (3.2 and 1.4 species per year, respectively; Figure 10) than between 1950 and 1999.

The ballast water of ships and hull fouling are the main vectors of primary introductions, followed by natural spread of NIS introduced via rivers and the North Sea. Most of the NIS originate from the North American east coast, the Ponto-Caspian region, and East Asia. Introductions of subtropical NIS have been increasing recently.

The observed ecological impacts include (a) changes in the physio-chemical habitat of sediments and water, (b) declines in abundance/biomass of several native species, and (c) changes in foodwebs. Other key impacts include fouling of industrial installations, water supply systems, boats, and fishing gear.

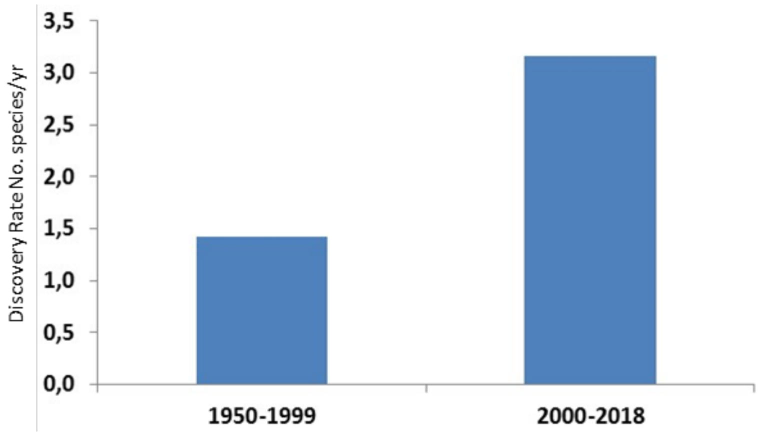

Figure 10 Annual rates of new non-indigenous and cryptogenic (of unknown origin) species in the Baltic Sea during 1950–1999 and 2000–2018.

Abrasion and substrate loss

Disturbance of seabed habitats due to physical abrasion from mobile bottom-contacting fishing gears occurs mostly in the southern parts of the Baltic Sea (Figure 11). This is mainly abrasion from otter trawls targeting demersal and benthic fish. Abrasion may affect the surface (top 2 cm of sediments) or the subsurface (> 2 cm). Few studies examine the impact of fishing-related abrasion on benthic communities in this part of the Baltic Sea, but from neighbouring regions, such as the North Sea and Kattegat, it is known that frequent disturbance by bottom trawls reduces benthic diversity and biomass and changes the composition of benthic species. Some of the trawled parts of the Baltic Sea are also affected by low oxygen concentrations at the seabed (Figure 15). Oxygen depletion can induce burrowing organisms to migrate to the sediment surface, making them potentially more vulnerable to trawling disturbance. For areas with even lower concentrations of oxygen, bottom trawling is unlikely to have any marked effects on habitats as the benthic biomass has already been reduced by hypoxia.

Using vessel monitoring system (VMS) and logbook data, ICES estimates that mobile bottom trawls used by commercial fisheries in the 12 m+ vessel category have been deployed over approximately 59 075 km^2 of the ecoregion in 2018. This corresponds to ca. 14.8% of the ecoregion's spatial extent (Figure 11).

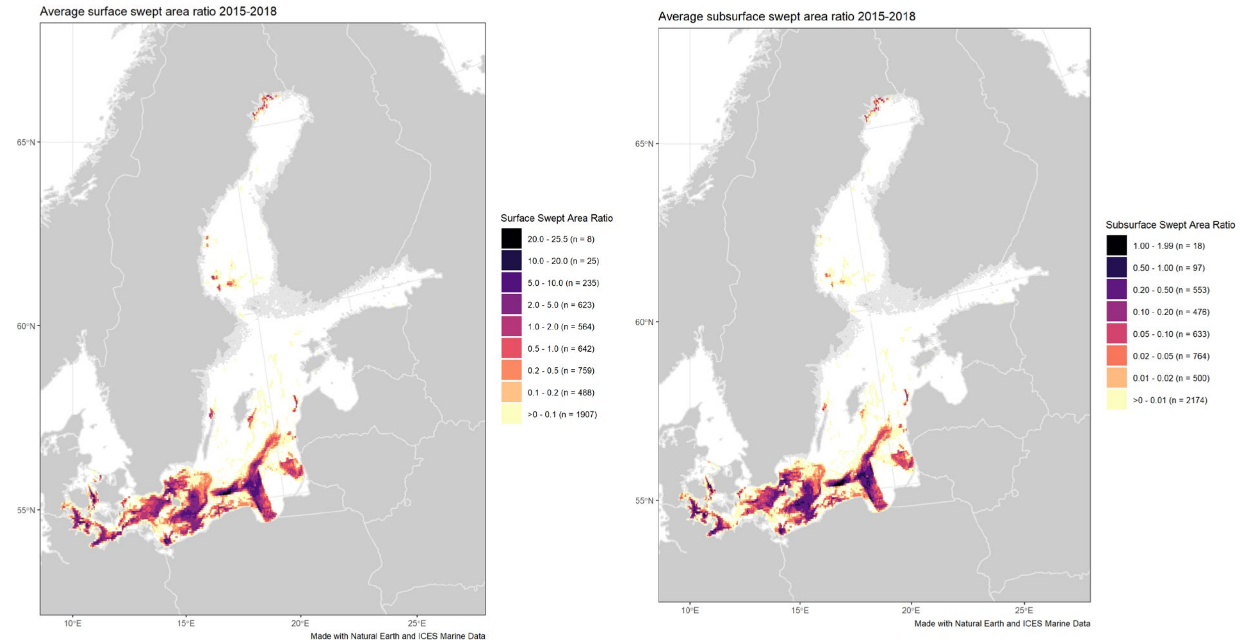

Figure 11 Average annual surface (left) and subsurface (right) disturbance by mobile bottom-contacting fishing gear (bottom otter trawls, bottom seines, beam trawls) in the Baltic Sea during 2015–2018, expressed as average swept area ratios (SAR).

Habitat loss in the Baltic Sea is connected to human activities such as sand extraction, dredging and deposit of dredged material, harbours and marinas, and to a lesser extent offshore installations and mariculture. Less than 1% of the Baltic Sea seabed is assessed as potentially lost due to human activities.

Climate change impacts

Climate change has already influenced aspects of the Baltic Sea ecosystem. A warming trend in sea-surface waters has been clearly demonstrated. Remote sensing data for the period 1990–2008 indicate that the annual mean sea surface temperature (SST) increased by up to 1°C per decade, with the greatest increase in the northern Bothnian Bay and large increases in the Gulf of Finland, the Gulf of Riga, and the northern central Baltic.

A change towards milder ice winters has been observed over the past one hundred years. In particular, the annual maximum ice extent has decreased and the length of the ice season has become shorter.

Based on projections from regionally downscaled climate models, we are likely to expect large-scale alterations in the hydrography, biogeochemistry, and physical properties of the Baltic Sea during this century, including long-term changes in temperature, ice cover, salinity, oxygen, nutrient concentrations, and primary production. There are likely to be consequent direct and indirect responses of phytoplankton, zooplankton, benthos, fish, seabirds, and habitats.

At the global level, current greenhouse gas emissions are most closely following the IPCC Regional Concentration Pathway (RCP) 8.5 scenario. Within the Baltic Sea, this scenario projects a 2.5°C to 4.0°C sea surface warming above mean conditions for the years 2050–2099, with the highest increases seen in coastal areas (Figure 12).

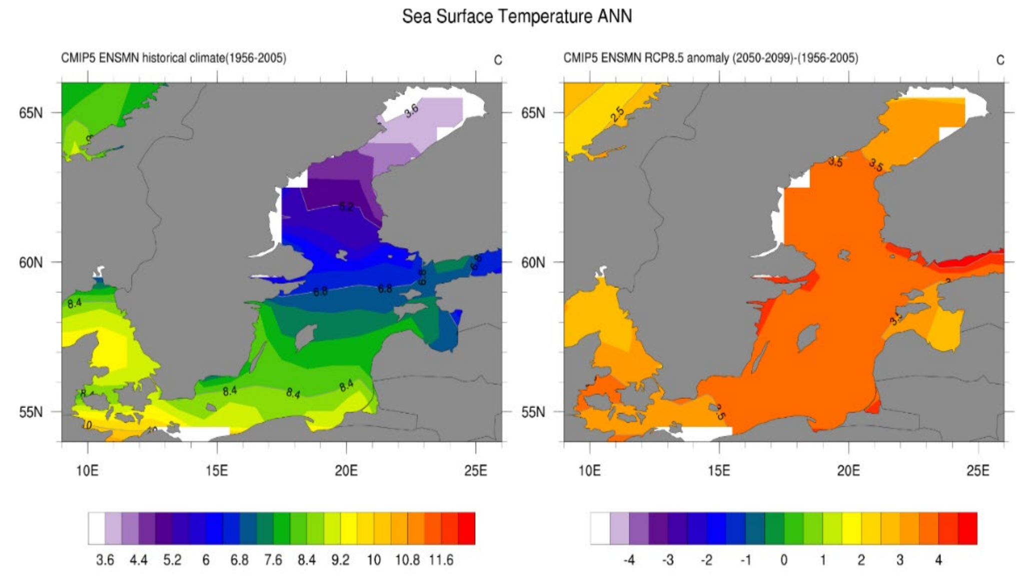

Figure 12 Ensemble mean sea surface temperature from the 5th Coupled Model Intercomparison Project (CMIP5) interpolated on a 1×1 grid for the entire year in the Baltic Sea ecoregion. (Left) Historical SST for the 1956–2005. (Right) Difference in the mean climate in the future time period (RCP8.5: 2050–2099) compared to the historical reference period.

State of the ecosystem

Substrate and water

The Baltic Sea is a young ecosystem formed after the latest glaciation, continuously undergoing postglacial successional changes and diversification. It is a semi-enclosed, non-tidal ecosystem and has distinct latitudinal and vertical salinity gradients. There is strong permanent vertical stratification for much of the Baltic Sea. Substrate distribution (Figure 13) is affected by water movement. Muddy sediments and occasionally sand are most common in the deeper parts, whereas rocky and mixed sediments can occur in near-shore and wave-exposed areas. The southern parts, including the Belt Sea, are connected to the Kattegat and show salinity levels around 25–30. Surface salinity levels in the central Baltic Sea are around 7–8, dropping to around 5 at the entrances to the northern Gulfs. In the most northern and eastern parts of the Baltic Sea, conditions are close to those of freshwater.

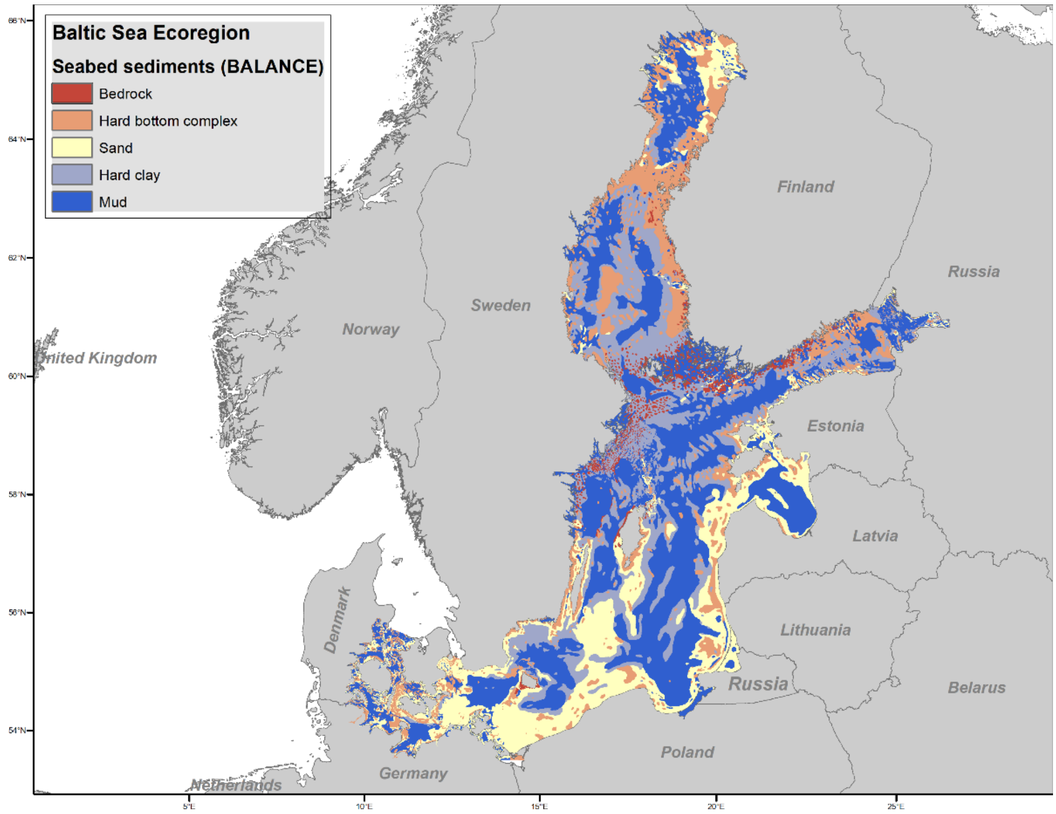

Figure 13 Major substrates on the shelf of the Baltic Sea (http://maps.helcom.fi/website/mapservic)

Oxygen concentrations are low in many areas, notably in deeper basins. In shallower coastal parts of the Baltic Sea, hypoxia may occur during the summer months in connection with high water temperatures. Nutrient input to the Baltic is the major cause of both anoxia and hypoxia. The extent of the affected areas (Figure 14) varies in relation to the intensity and frequency of the major inflows of water from the North Sea. Starting from the beginning of the 1990s, the frequency of the major inflows from the North Sea dropped from one event every second or third year to one event per decade.

In 2017, the areal extent of the oxygen depletion in the Baltic Sea (Figure 15) remained widespread, with hypoxic waters (< 2 ml l^{-1} O_2) representing about 28% of the area and 22% of the volume of the central Baltic and the Gulf of Finland.

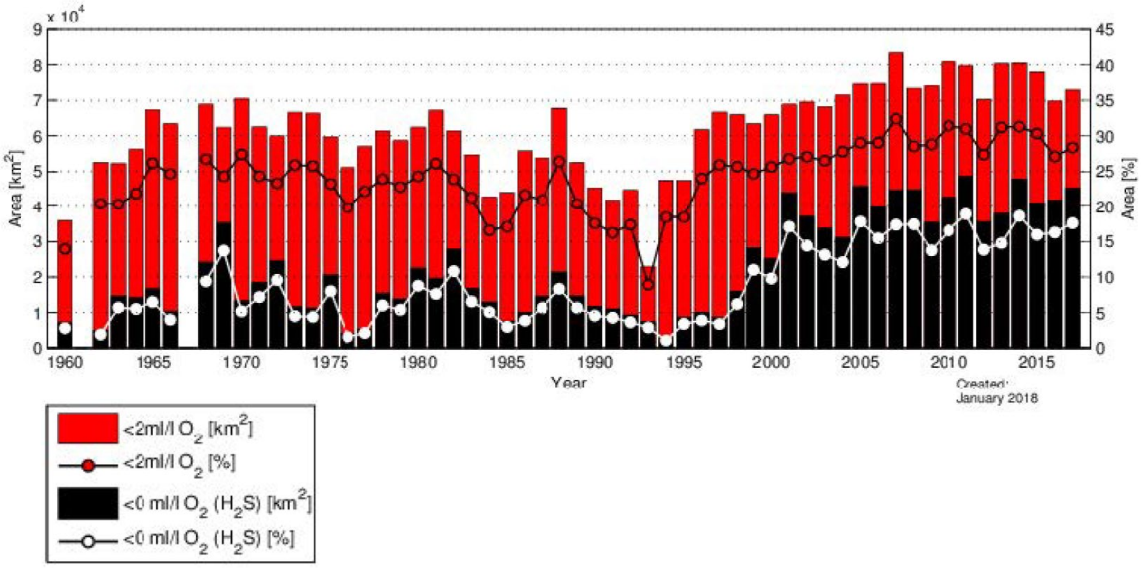

Figure 14 Extent of hypoxic and anoxic bottom water in the central Baltic and Gulf of Finland in August to October, 1960–2017.

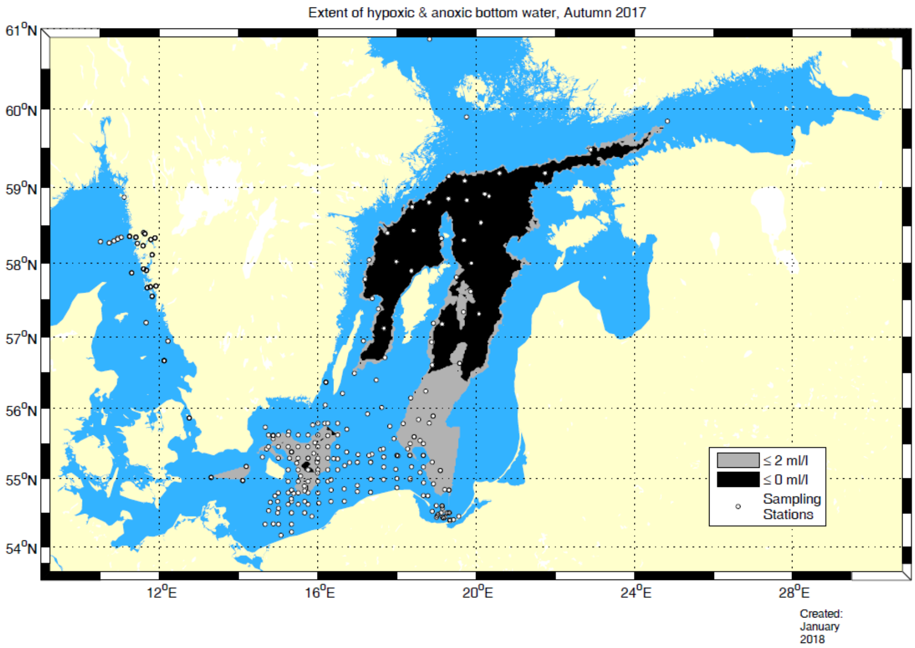

Figure 15 Distribution of areas in open sea with anoxic and hypoxic conditions (Autumn 2017).

Foodwebs

The open Baltic Sea foodweb is characterized by low vertebrate species richness as relatively few fish species are tolerant of its brackish water conditions. The fish fauna are typically characterized by a single predatory fish (cod) and its pelagic prey (herring and sprat), and also by three-spined stickleback in some areas. In contrast, the coastal foodwebs are more complex and species rich. In the late 1980s and early 1990s, the open central Baltic went through an ecosystem regime-shift due to environmental and anthropogenic changes, where cod biomass collapsed and that of sprat increased steeply. Simultaneously, changes were observed in the zooplankton composition. Due to its shallow nature, the benthic-pelagic coupling is an important mechanism in transferring energy within the Baltic Sea foodweb. The intensity of eutrophication in the Gulf of Bothnia is less than in other parts of the Baltic Sea, with a large part of the energy transferring to higher trophic levels coming from the microbial loop.

Productivity

The pelagic primary production in the Baltic Sea ranges from 100 to 175 mg C m^{-2} y^{-1}, depending on the sub-basin. Phytoplankton productivity, total biomass, and species composition show strong seasonality. Around half of the annual carbon fixation takes place during the spring. The proportion of diatoms to dinoflagellates in the phytoplankton has distinct seasonal and spatial patterns as well as decadal-scale trends and has been ascribed to climate-related factors, particularly the harshness of winter. The diatom/dinoflagellate ratio reflects the change in the dominant energy transfer pathway into the pelagic or benthic foodwebs as sedimentation of diatoms is much faster than that of dinoflagellates.

The spring bloom is terminated by nitrogen limitation in most of the Baltic Sea; consequently, the pelagic community switches to a functionally more diverse community around May–June. A shift towards earlier, more prolonged spring blooms (but with lower average biomass) has taken place in the central Baltic Sea over the past 20 years. Chlorophyll concentrations have remained essentially unchanged during the past few decades (1990–2016), with the exception of the westernmost parts of the Baltic Sea, where it shows decreasing trends. On a decadal scale, the Baltic Sea summer phytoplankton community composition has gone through a gradual shift, most notably an increase in species richness, with subsequent effects on ecosystem functions. Some of this increase in species richness may be due to anthropogenic vectors.

Phytoplankton blooms are a natural phenomenon in the Baltic Sea ecosystem, with blooms in late summer dominated by nitrogen-fixing cyanobacteria. However, due to eutrophication the phytoplankton blooms become more frequent and extensive. In the coastal areas of the northern Baltic Sea, the symptoms of eutrophication are seen as e.g. decreased water clarity and an increased amount of filamentous algae.

Zooplankton

Salinity is one of the major factors regulating zooplankton community composition, occurrence, and abundance in the brackish Baltic Sea. The dominant zooplankton groups are copepods, cladocerans, and rotifers, which occur within their preferred salinity ranges. Climate change and decadal-scale variability have modified the hydrographic conditions and decreased the salinity in large parts of the Baltic Sea over the last 50 years (Figure 16). In the coastal zone, these changes have resulted in a shift in species composition, from a dominance of large copepods of marine origin to freshwater cladocerans and rotifers. In the open sea, such compositional changes are less pronounced and diverge between sub-basins. For example, the total abundance of copepods (overlaying some decadal variability) shows an increasing trend, particularly in the Gulf of Finland. Changes in the ratio of abundance of the marine calanoid copepods, *Pseudocalanus acuspes* and *Acartia bifilosa* (which prefer brackish conditions), have not been observed (Figure 16). Instances of high *Pseudocalanus* abundance are more pronounced in the southern Baltic Sea (exemplified by the Arkona basin) and coincide with major saline inflow events. For the ratio of cladocerans to copepods, different patterns have occurred between southern and northern parts of the Baltic Sea. In the Gulf of Finland, this ratio has clearly decreased in the past ten years, probably due to decreased abundances of most marine cladoceran species. In the southern Baltic Sea, there is no clear trend.

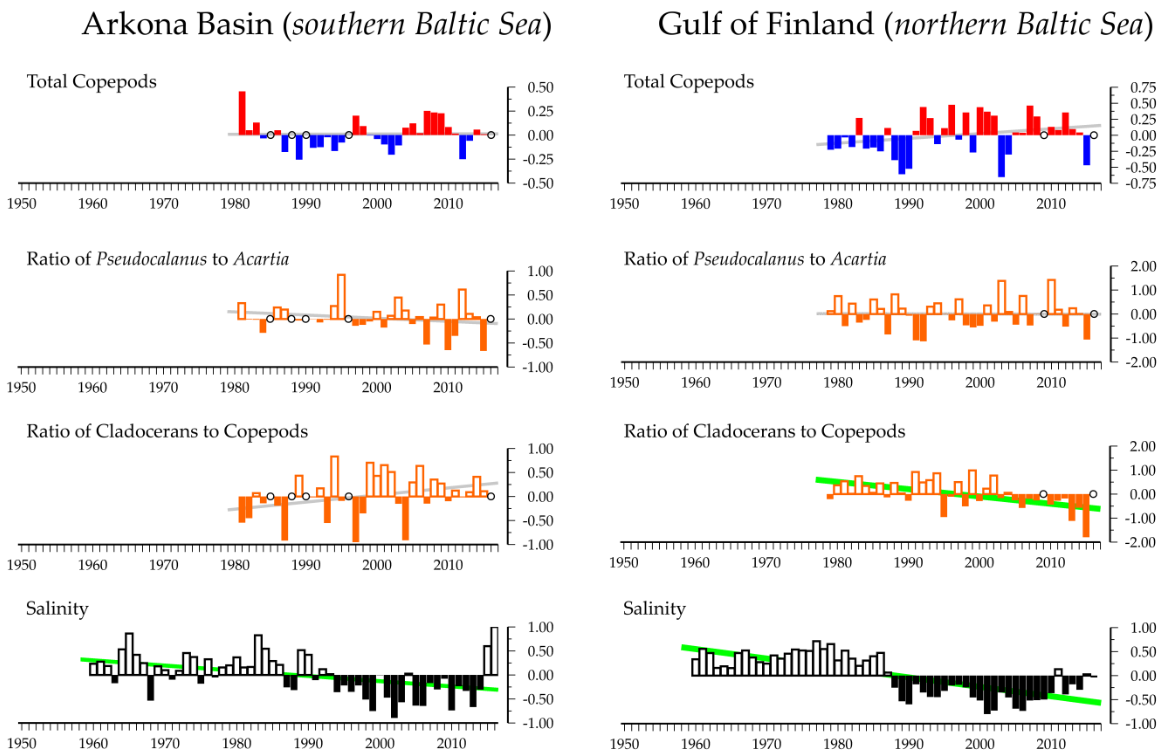

Figure 16 Comparison of long-term dynamics in total copepods, ratio of *Pseudocalanus* to *Acartia*, and ratio of cladocerans to copepods together with salinity trends as observed in the Arkona Basin and the Gulf of Finland.

Benthos

As a consequence of the salinity gradient, the number of marine benthic species significantly decreases towards the northern Baltic Sea and inner coastal waters, and the dominance of freshwater species increases. As a result, benthic communities in the southwestern part of the Baltic Sea are much more diverse than communities further north. Benthic life is scarce or absent in many deeper basins below the halocline, particularly after longer periods without any saline water inflow, due to seasonal and permanent oxygen depletions. Hypoxia and anoxia in bottom waters of both deep and shallower areas lead to impoverished communities and altered foodwebs. The polychaetes *Marenzelleria* spp. are some of the most successful invasive species in the Baltic Sea. In many areas, these polychaetes dominate the composition of the benthic communities, and may even increase the functional diversity, as deep bioturbators influencing sediment nutrient fluxes.

Fish

Around 230 fish species have been recorded in the Baltic Sea (including the Kattegat and the Sound), of which 90 reproduce regularly in the Baltic Sea and the Sound. Thirty to forty freshwater fish species occur in the inner Baltic Sea and coastal areas.

The composition and diversity of the open-sea fish community is structured along the salinity gradient, with a higher diversity in the west compared to the east and north. Up to 80% of the biomass in the open-sea fish communities is shared between three species: cod, herring, and sprat. In the late 1980s and early 1990s the regime shift in the open-sea pelagic ecosystem was evident by a shift from a cod-dominated system to one dominated by sprat and herring. Trends in fishing pressure are presented in the "Selective extraction of species" section.

For most of the pelagic stocks in the Baltic Sea, the spawning-stock biomass has increased since 2000 and is now above, or close to the biomass reference points used in stock assessments. An exception is the western Baltic cod stock, for which the biomass is below B_{lim} (Figure 17).

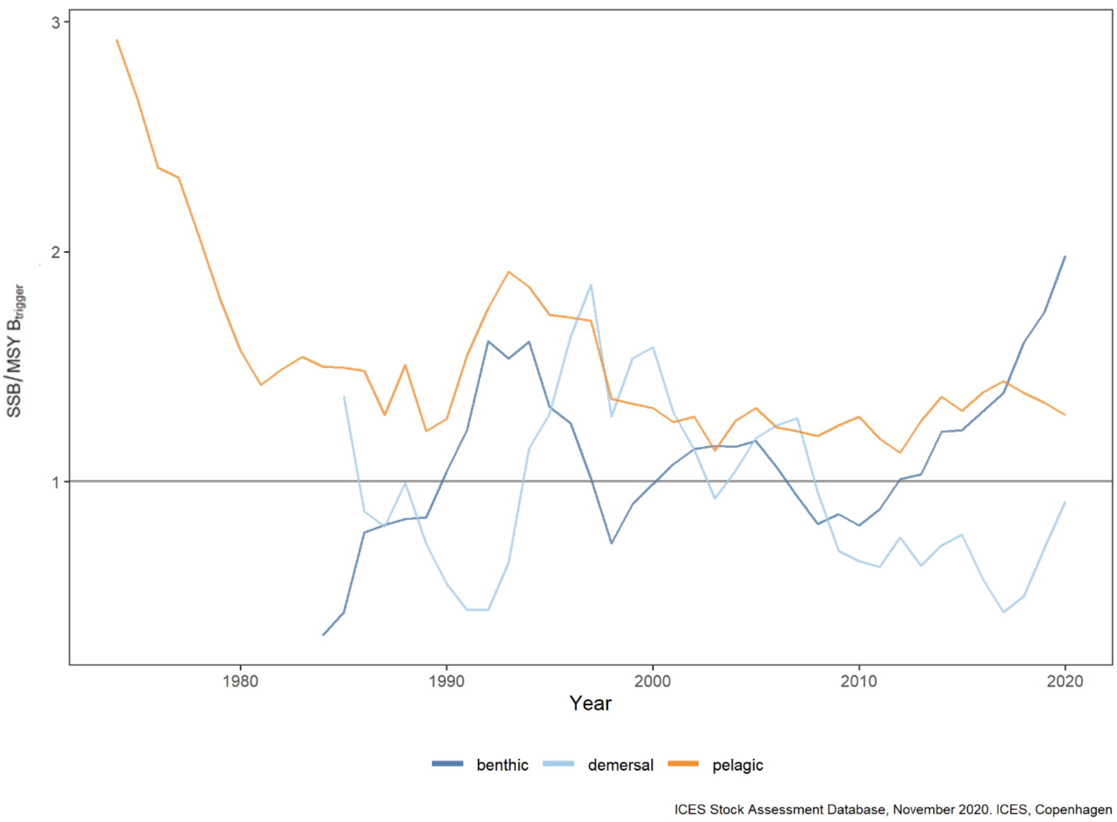

Figure 17 Time-series of annual relative spawning-stock biomass (SSB to MSY $B_{trigger}$ ratio) by fisheries guild for benthic, demersal and pelagic stocks. Table A1 in the Annex details which species belong to each fish category.

The SSB of western Baltic cod has been below the limit reference point (B_{lim}) since 2008, which has also led to a reduced reproductive capacity. However, because of one strong year class in 2016 an increase is seen in later years. The eastern Baltic cod stock is decreasing, and the stock size in 2018 is the lowest observed in the time-series (since 2003). The SSB is below $B_{trigger}$, although the stock status is uncertain due to lack of analytical assessment and problems with age reading. The eastern Baltic cod population structure has deteriorated in recent years and shows no improvement. Since 2017, the biomass based on the two latest surveys shows a decline in most length groups, with the decrease being especially strong for the biomass of eastern Baltic cod in length classes above 40 cm. The declining eastern Baltic cod condition (Figure 18) has been linked to limited food availability as well as hypoxia and selective fishing pressure.

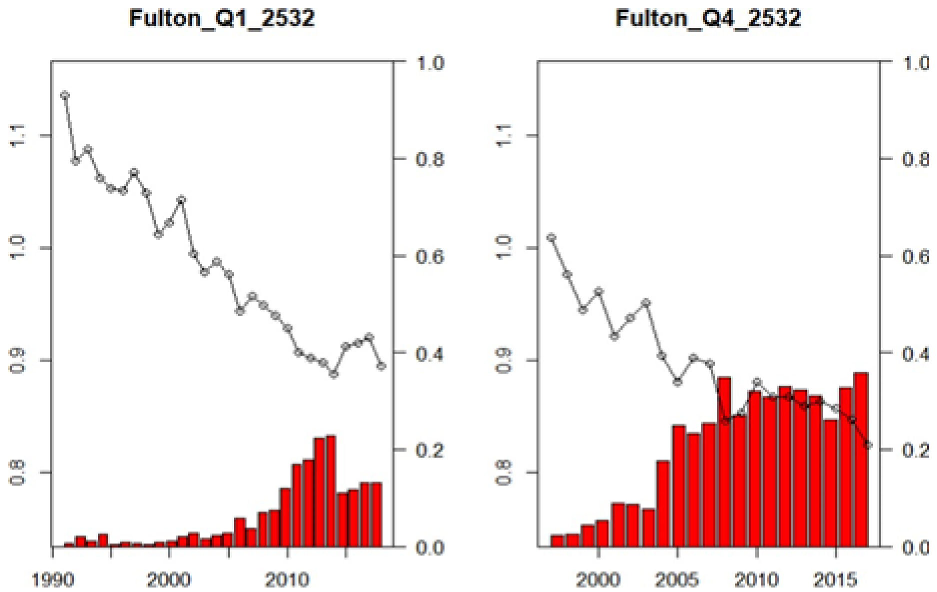

Figure 18 Eastern Baltic cod average condition (Fulton K) for the 40–60 cm length group in the Q1 and Q4 BITS survey in subdivisions 25–32. The lines show mean values for Fulton K, the bars show the proportion of cod at Fulton K < 0.8. A Fulton K value below 0.8 is assumed to indicate starvation.

Coastal fish communities (waters < 20 meters deep) often show a greater species diversity than open-sea fish communities, due to the addition of freshwater species (perch, pikeperch, pike, whitefish, and cyprinids) and the introduced round goby *Neogobius melanostomus*. The coastal communities have a more local population structure and response to environmental signals. Changes in the species composition of coastal fish communities in past decades are linked to an increasing water temperature and decreasing salinity. In many areas, the increasing trend in the abundance of cyprinids and a concurrent decrease in piscivorous fish indicate a deteriorating ecosystem status, although this trend has shown some signs of improvement in more recent years. Increased levels of nutrients favour cyprinids and pikeperch. The abundance of the three-spined stickleback *Gasterosteus aculeatus*, an important species for the coastal ecosystem functioning and a resource competitor with other pelagic fish, has increased in the past decade. Flounders are key benthic fish in the central and southern Baltic Sea, particularly in coastal areas.

Salmon and sea trout are fished in coastal and open waters of the Baltic Sea. The harvest rate of salmon has decreased considerably since the beginning of the 1990s. Since 1997, total wild smolt production has increased tenfold in the Bothnian Bay. This area is the largest contributor to the overall smolt production in the Baltic Sea. Despite the overall increase in wild smolt production, there was a decline in post-smolt survival from the late 1980s until the mid-2000s.

Seabirds

Many species of seabirds breed on the coasts of the Baltic Sea. Different species have shown different trends in breeding numbers: nine species have declined, ten have increased, nine were stable, and the trend was uncertain in one species. The greatest declines in breeding numbers were observed in common eider *Somateria molllissima* and great black-backed gull *Larus marinus*. Three species that feed mainly on herring and sprat (common guillemot, razorbill, and Arctic tern) have increased in number over recent decades. White-tailed sea eagle and great cormorant have increased, following the cessation of hunting and the decline in persistent pollutants.

The Baltic Sea is an important wintering area for many species, including the globally threatened long-tailed duck, velvet scoter *Melanitta fusca*, and Steller's eider *Polysticta stelleri*. These three species have been declining in number during the last 25 years, as have many other benthic-feeding species.

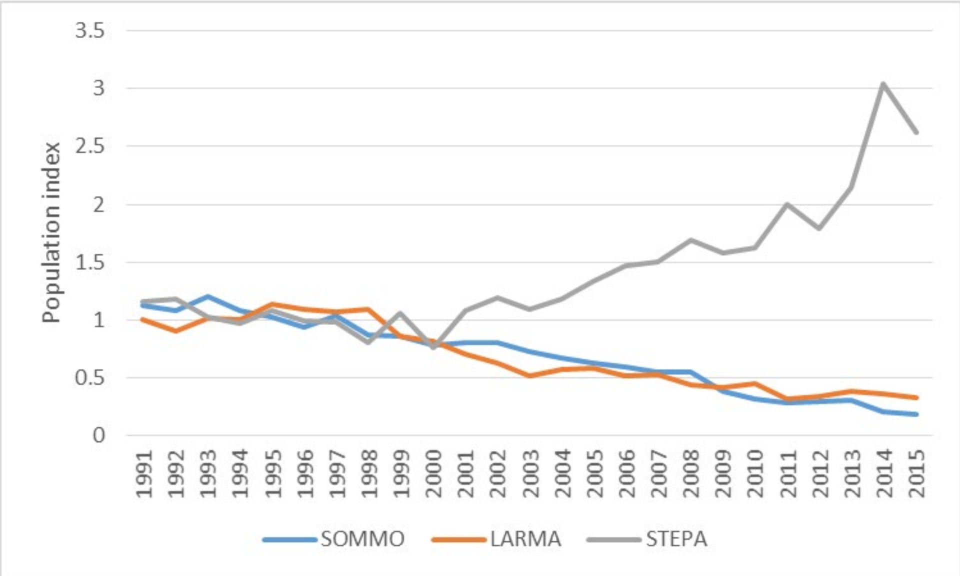

Figure 19 Development in the breeding populations of common eider (SOMMO), great black-backed gull (LARMA), and Arctic tern *Sterna paradisaea* (STEPA) in the Baltic Sea in the period 1991–2015.

Marine mammals

Three seal species occur regularly in the Baltic Sea: grey seal *Halichoerus grypus*, harbour seal *Phoca vitulina*, and ringed seal *Phoca hispida*. Grey seals occur throughout the Baltic Sea and the population grew rapidly from 2000 to 2014, before levelling off at above 30 000 individuals. Harbour seals mainly occur in the southern Baltic Sea and the population in this area had an estimated growth rate of 8.4% between 2002 and 2014. The neighbouring Kalmarsund population had a lower growth rate. The population of ringed seal in the Gulf of Finland is low, at around 100 animals, and is listed as vulnerable by IUCN. This is probably due to recent lack of ice for breeding during the winter. The Bothnian Bay population of ringed seal exceeds 10 000 animals.

The only cetacean species to occur regularly in the Baltic Sea is the harbour porpoise *Phocoena phocoena*. East of the Transition Area (Figure 2), a large population decline has occurred in the past 50–100 years. With an estimation of 447 individuals (95% CI: 90–997), this population is listed as critically endangered by IUCN. The Belt Sea population has a much higher abundance, estimated at 40,475 (95% CI: 25,614-65,041).

Species listed on the HELCOM Red List for the Baltic Sea

Based on assessments in 2013 by HELCOM, two species of fish and one bird are classified as "Regionally Extinct" in the Baltic Sea: Atlantic sturgeon *Acipenser oxyrinchus*, common skate *Dipturus batis*, and gull-billed tern *Gelochelidon nilotica.* Nine species or populations are classified as "Critically Endangered", fifteen species or populations are classified as "Endangered", thirty-eight as "Vulnerable", and thirty species or populations are classified as "Near Threatened" (Table 1).

Table 1 Species on the HELCOM Red List for the Baltic Sea.

Scientific Name	Threat Category
Benthic invertebrates	
Haploops tenuis	Endangered
Clelandella miliaris	Vulnerable
Cliona celata	Vulnerable
Deshayesorchestia deshayesii	Vulnerable
Epitonium clathrus	Vulnerable
Haploops tubicola	Vulnerable
Hippasteria phrygiana	Vulnerable
Hippolyte varians	Vulnerable
Lunatia pallida	Vulnerable
Macoma calcarea	Vulnerable
Modiolus modiolus	Vulnerable
Nucula nucleus	Vulnerable
Parvicardium hauniense	Vulnerable
Pelonaia corrugata	Vulnerable
Scrobicularia plana	Vulnerable
Solaster endeca	Vulnerable
Stomphia coccinea	Vulnerable
Abra prismatica	Vulnerable
Atelecyclus rotundatus	Vulnerable
Boreotrophon truncatus	Near Threatened
Corophium multisetosum	Near Threatened
Corystes cassivelaunus	Near Threatened
Inachus dorsettensis	Near Threatened
Mya truncata	Near Threatened
Sabella pavonina	Near Threatened
Alderia modesta	Near Threatened
Amauropsis islandica	Near Threatened
Seabirds	
Gelochelidon nilotica	Regionally Extinct
Gavia arctica (wintering population)	Critically Endangered
Gavia stellata (wintering population)	Critically Endangered
Charadrius alexandrinus	Critically Endangered
Anser fabalis fabalis (wintering population)	Endangered
Calidris alpina schinzii	Endangered
Clangula hyemalis (wintering population)	Endangered
Larus melanocephalus	Endangered
Melanitta nigra (wintering population)	Endangered
Podiceps grisegena (wintering population)	Endangered
Polysticta stelleri (wintering population)	Endangered
Xenus cinereus	Endangered
Rissa tridactyla (breeding/wintering)	Endangered/Vulnerable
Cepphus grylle grylle/Cepphus grylle arcticus	Critically Endangered/Vulnerable
Podiceps auritus (breeding/wintering)	Vulnerable/Near Threatened
Melanitta fusca (breeding/wintering)	Vulnerable/Endangered
Somateria mollissima (breeding/wintering)	Vulnerable/Endangered
Larus fuscus fuscus	Vulnerable
Mergus serrator (wintering population)	Vulnerable
Philomachus pugnax	Vulnerable
Arenaria interpres	Vulnerable
Aythya marila	Vulnerable
Hydroprogne caspia	Vulnerable
Charadrius hiaticula hiaticula	Near Threatened
Hydrocoloeus minutus (wintering population)	Near Threatened

Scientific Name	Threat Category
Limosa limosa	Near Threatened
Oenanthe oenanthe	Near Threatened
Tringa totanus	Near Threatened
Vanellus vanellus	Near Threatened
Actitis hypoleucos	Near Threatened
Aythya fuligula	Near Threatened
Calidris temminckii	Near Threatened
Branta bernicla hrota (wintering population)	Near Threatened
Fish and lamprey species	
Dipturus batis	Regionally Extinct
Acipenser oxyrinchus	Regionally Extinct
Squalus acanthias	Critically Endangered
Thymallus thymallus	Critically Endangered
Anguilla anguilla	Critically Endangered
Lamna nasus	Critically Endangered
Molva molva	Endangered
Anarhichas lupus	Endangered
Coregonus maraena	Endangered
Raja clavata	Vulnerable
Salmo salar	Vulnerable
Salmo trutta	Vulnerable
Gadus morhua	Vulnerable
Galeorhinus galeus	Vulnerable
Merlangius merlangus	Vulnerable
Petromyzon marinus	Near Threatened
Melanogrammus aeglefinus	Near Threatened
Merluccius merluccius	Near Threatened
Scophthalmus maximus	Near Threatened
Zoarces viviparus	Near Threatened
Aspius aspius	Near Threatened
Cyclopterus lumpus	Near Threatened
Enchelyopus cimbrius	Near Threatened
Lampetra fluviatilis	Near Threatened
Lota lota	Near Threatened
Marine mammals	
Phocoena phocoena	Critically Endangered/Vulnerable
Phoca vitulina vitulina	Vulnerable/Least Concern
Phoca hispida botnica	Vulnerable
Lutra lutra	Near Threatened

Sources and acknowledgments

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The maps and GIS products produced by the ICES Secretariat used data from:

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2. Depth contours. *General Bathymetric Chart of the Oceans (GEBCO).*
3. Ecoregions. *International Council for the Exploration of the Sea (ICES); http://gis.ices.dk/geonetwork/srv/eng/catalog.search#/metadata/4745e824-a612-4a1f-bc56-b540772166eb.*
4. Ports. *National geospatial-intelligence agency; https://msi.nga.mil/NGAPortal/MSI.portal?_nfpb=true&_pageLabel=msi_portal_page_62&pubCode=0015*
5. Cities. *World Cities (ESRI).*
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8. Catchment Area. *European Environment Agency (EEA). European Topic Centre on Inland, Coastal and Marine waters (ETC/ICM).*
9. Substrate maps. *HELCOM; http://maps.helcom.fi/website/mapservic.*
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Annex A

Table A1 Stocks with analytical assessments and guilds included in Figures 8 and 17. Detailed information on the fisheries of the Baltic Sea is provided on the Baltic Sea Fisheries Overviews.

Stock code	Stock name	Fishery guild
bwq.27.2425	Flounder (Platichthys spp) in subdivisions 24 and 25 (west of Bornholm and southwestern central Baltic)	Benthic
ple.27.21-23	Plaice (*Pleuronectes platessa*) in subdivisions 21-23 (Kattegat, Belt Seas, and the Sound)	Benthic
ple.27.24-32	Plaice (*Pleuronectes platessa*) in subdivisions 24-32 (Baltic Sea, excluding the Sound and Belt Seas)	Benthic
sol.27.20-24	Sole (*Solea solea*) in subdivisions 20-24 (Skagerrak and Kattegat, western Baltic Sea)	Benthic
cod.27.22-24	Cod (*Gadus morhua*) in subdivisions 22-24, western Baltic stock (western Baltic Sea)	Demersal
cod.27.24-32	Cod (Gadus morhua) in subdivisions 24-32, eastern Baltic stock (eastern Baltic Sea)	Demersal
spr.27.22-32	Sprat (*Sprattus sprattus*) in Subdivisions 22-32 (Baltic Sea)	Pelagic
her.27.28	Herring (*Clupea harengus*) in Subdivision 28.1 (Gulf of Riga)	Pelagic
her.27.25-2932	Herring (*Clupea harengus*) in subdivisions 25-29 and 32, excluding the Gulf of Riga (central Baltic Sea)	Pelagic
her.27.3031	Herring (*Clupea harengus*) in Subdivisions 30 and 31 (Gulf of Bothnia)	Pelagic
her.27.20-24	Herring (*Clupea harengus*) in subdivisions 20-24, spring spawners (Skagerrak, Kattegat, and western Baltic)	Pelagic

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