State of the Baltic Sea

– Second HELCOM holistic assessment 2011–2016

Baltic Marine Environment Protection Commission

STATE OF THE BALTIC SEA
– HOLISTIC ASSESSMENT –

Monitoring & assessment

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SPICE
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The basis for the assessment of status of the Baltic Sea are the HELCOM core indicators and associated threshold values. In this context the following has been agreed:

Regarding threshold values
"At this point in time, HOLAS II indicators and threshold values should not automatically be considered by the Contracting Parties that are EU Member States, as equivalent to criteria threshold values in the sense of Commission Decision (EU) 2017/848 laying down criteria and methodological standards on good environmental status, but can be used for the purposes of their Marine Strategy Framework Directive obligations by those Contracting Parties being EU Member States that wish to do so."

Regarding testing of indicators
Note that some indicators and/or their associated threshold value are still being tested in some countries and may be further developed in HELCOM as a result of the outcome of the testing. In some cases the results may show that the indicator is not suitable for use in a specific sub-basin. These indicators are marked in the assessment report and the results should be considered as intermediate.

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THIS STATE OF THE BALTIC SEA report provides an update on the environmental situation in the Baltic Sea for the period 2011–2016. The report captures a 'moment' in the dynamic life history of the Baltic Sea, aiming to support an adaptive and regionally coordinated management to improve the environmental status of the Baltic Sea.

The report highlights a broad range of aspects, covering the state of the ecosystem, environmental pressures and human well-being. Some results are based on the achievements of long-term HELCOM monitoring and assessment, whereas others are presented regionally for the first time. HELCOM core indicators form the basis for the assessment. The indicators assess the status of selected elements of biodiversity and human-induced pressures on the Baltic Sea against regionally agreed threshold values, based on current knowledge and available data for the assessment. In addition, integrated assessments for biodiversity, eutrophication and contamination status are made, based on the core indicators. For marine litter, underwater sound, and seabed loss and disturbance the assessment is descriptive since HELCOM core indicators are still under development. Trends over time and spatial aspects are included, as far as data are available, in order to indicate potential future developments and geographic areas of key importance for the assessed themes. Results from economic and social analyses are included for themes where information at the regional scale is available.

The results show that, although signs of improvement in the state of the Baltic Sea are seen in some cases, the Baltic Sea Action Plan goals and ecological objectives have not yet been reached (Figures ES1-ES2). Further development of actions to improve environmental status is of high relevance, and already agreed actions are to be implemented or continued. In addition, it is noted that some measures already put into operation have not yet been in place long enough to have an effect. For measures such as the reduction of nutrient loads it will take several decades before the full effects can be measured in the environment.

The assessment provides key information for taking further steps to reach good environmental status for the Baltic Sea and strengthen the implementation of the HELCOM Baltic Sea Action Plan by 2021. The assessment may also serve as a regional baseline for implementing the UN Sustainable Development Goals as well as serve the purposes of the EU Marine Strategy Framework Directive for those countries around the Baltic Sea that are EU Member States.

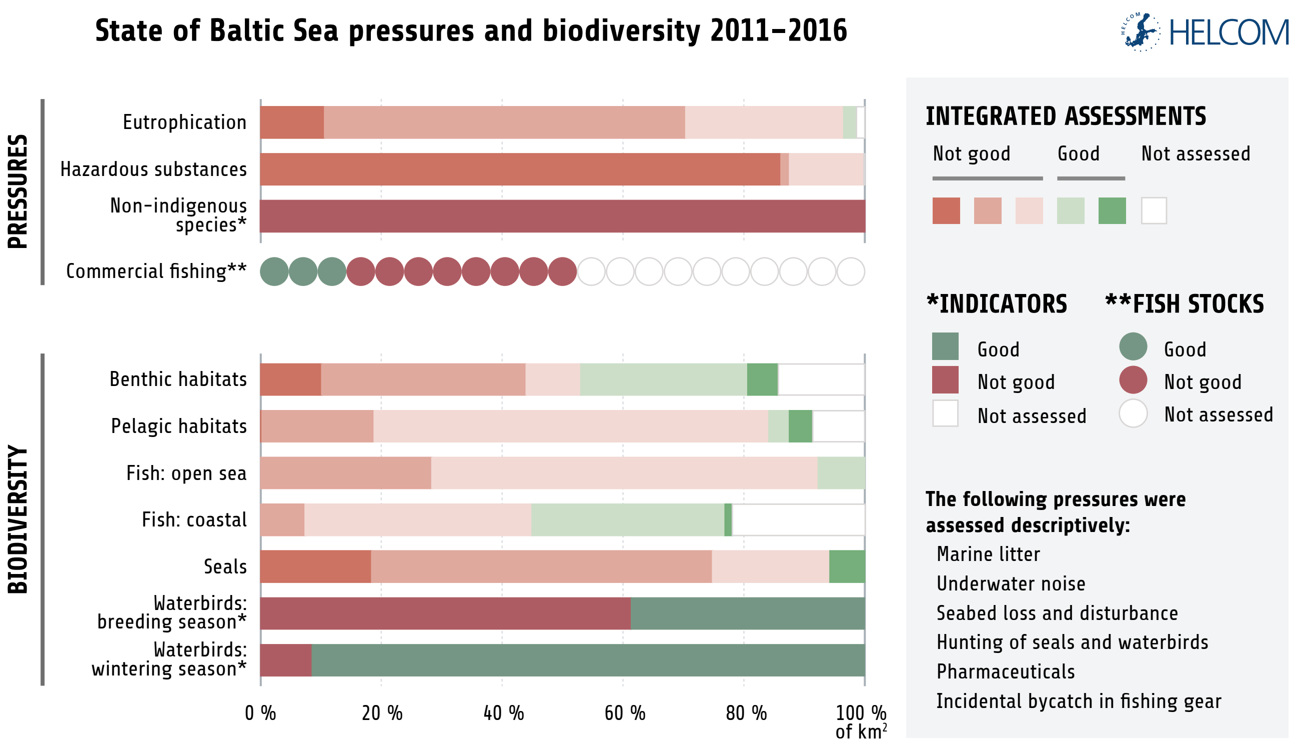


Figure ES1.
Summary of the assessment of pressures and status for the Baltic Sea showing the proportion of area covered by different assessment status categories (based on square kilometres). For commercial fishing, the summary shows status of fish stocks. Integrated assessment results (eutrophication, hazardous substances, benthic habitats, pelagic habitats, fish, and seals) are shown in five categories. Assessment results based on indicators (commercial fishing, non-indigenous species, and waterbirds) are shown in two status categories.

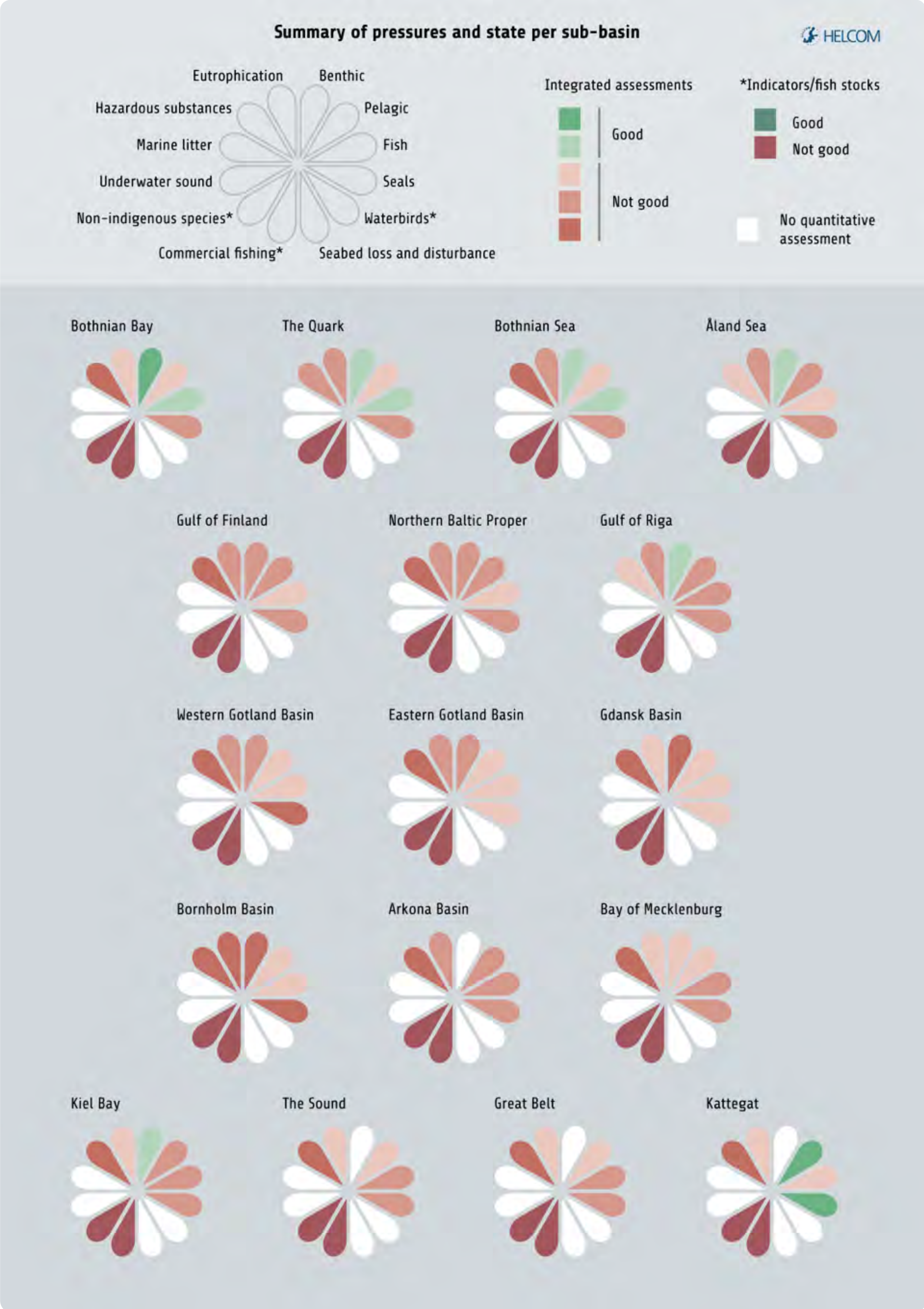
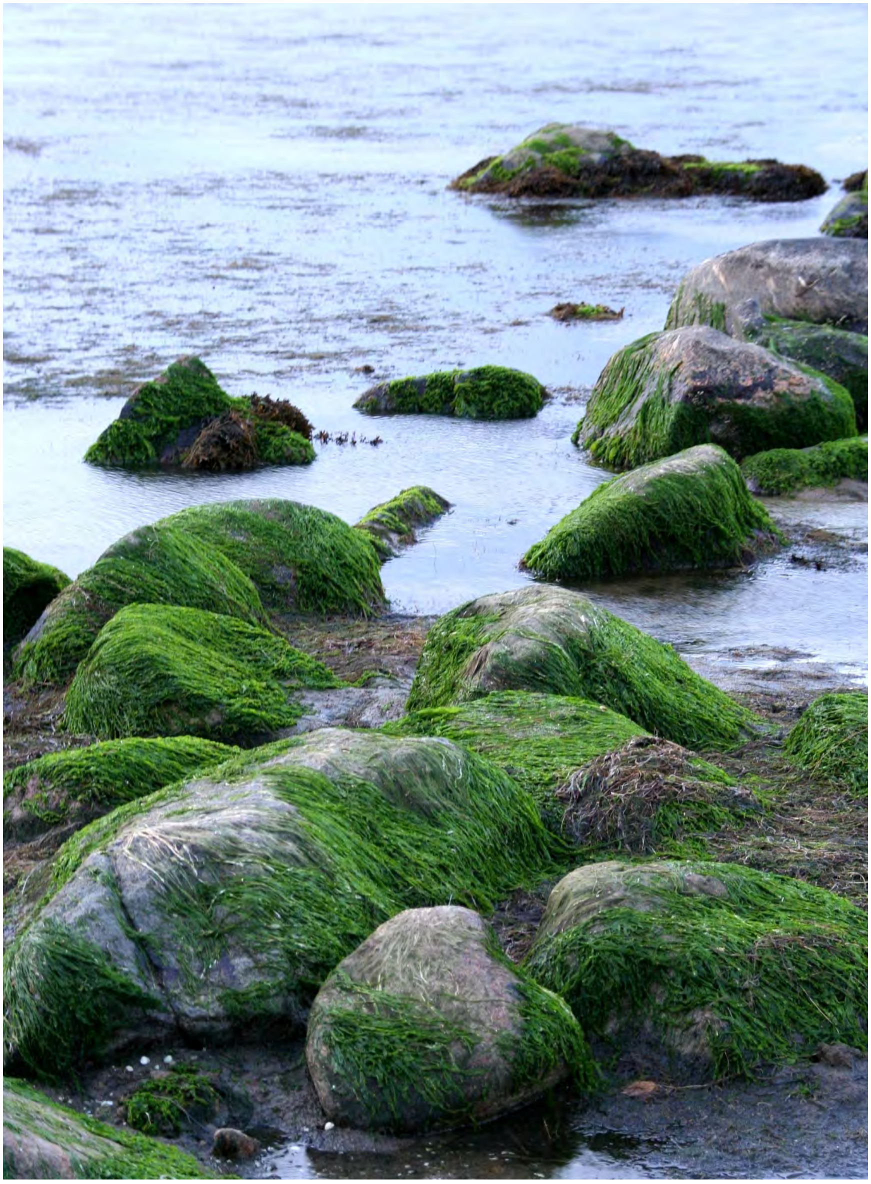


Figure ES2.

Summary of the assessment of pressures and status by sub-basins the Baltic Sea. For each sub-basin, each petal refers to a pressure or biodiversity ecosystem component according to its position in the flower shape, as shown in the figure legend. White petals are shown when no assessment is available, or when the assessment is currently incomplete. For marine litter, underwater sound, and seabed loss and disturbance, descriptive information provided in the report. Integrated assessment results are shown in five categories for eutrophication, hazardous substances, benthic habitats, pelagic habitats, open sea fish, and seals. Waterbirds are not assessed at integrated level (see Figure ES4 for indicator results). For commercial fishing, the petal colours correspond to the status of the fish stock in the worst status in that sub-basin. Non-indigenous species are assessed at the Baltic Sea scale, and the same indicator result is shown for all sub-basins. An overview of all assessment results by indicators and sub-basins, including results for waterbirds in coastal areas, is shown in Figures ES3-4.

Pressures on the Baltic Sea

The Baltic Sea is one of the world's largest brackish water areas. It is inhabited by both marine and freshwater species, but the number of species is low compared to most other seas due to the low salinity. The drainage area is inhabited by around 85 million people, who influence the status of the Baltic Sea via human activities on land and sea. Due to the limited level of water exchange, nutrients and other substances from the drainage area accumulate in the Baltic Sea and are only slowly diluted. The status of seven distinct pressures on the Baltic Sea are assessed in this report (Figure ES3). In addition, a particular concern for the Baltic Sea is the wide and increasing distribution of areas with poor oxygen conditions in the deep water. Climate-related increases in water temperature and decreases in salinity are further expected to affect the distribution of species over time, as well as their physiology and food availability.



Eutrophication

Eutrophication has been evident in the Baltic Sea for many decades, due to past high and still excessive inputs of nitrogen and phosphorus. Ninety-seven percent of the Baltic Sea area[1] is affected by eutrophication and twelve percent is assessed as being in the worst status category. Inputs of nutrients from land have decreased, but the effect of these measures are not yet generally reflected in the status of the marine environment. The eutrophication status has deteriorated in four out of the seventeen open sea assessment units since the last five year period (2007–2011), and improved in one. Only a few coastal areas are currently unaffected by eutrophication, but an improving trend is seen in some indicators and sub-basins.

Hazardous substances

Levels of contaminants are elevated and continue to give cause for concern. However, the number of improving trends outweighs the number of deteriorating trends in the monitored hazardous substances. The integrated contamination status is mainly influenced by polybrominated flame retardants and mercury, together with cesium, deposited after the accident at the Chernobyl nuclear power plant in 1986. Levels of radionuclides are now at acceptable levels in some sub-basins and can be expected to be so in all of the Baltic Sea by 2020. Acute pollution events from oils spills have decreased.

Marine litter

HELCOM is developing core indicators for assessing marine litter, but they are not yet operational and thus no assessment of status has been possible at this time. Beach litter monitoring is ongoing in several countries, showing that the number of beach litter items ranges from around 50 on reference beaches to up to 300 on urban beaches, per 100 metres of shoreline. Plastic litter is a special concern due to its risk to the environment and its slow rate of degradation. Around 70 % of the litter items in the Baltic Sea are derived from plastic materials.

1 Baltic Sea including the Kattegat.

Greifswalder Bodden, a basin in the southwestern Baltic Sea, off the shores of Germany in the state of Mecklenburg-Vorpommern.

Underwater sound

Underwater sound is a widely distributed pressure in the Baltic Sea, caused by various human activities. Areas with high levels of continuous sound mainly coincide with areas of high vessel traffic. Up to 1,700 impulsive sound events were registered in 2011-2016. The majority of these stem from explosions, whilst around eleven percent are linked to pile driving in connection to construction work. It is not known how many marine species are impacted by underwater sound, and thus no assessment of status has been possible at this time.

Species removal by fishing and hunting

Three out of nine assessed commercial fish stocks are in good status with respect to both biomass and fishing mortality rates. Eight stocks are currently lacking an evaluation with respect to both of these aspects. Hunting of marine mammals and birds is minor. Seals are generally protected, but hunting is permitted in some countries, restricted to populations above a limit reference level and with a positive growth rate. Waterbirds are hunted in some countries, whereas in others they have strict protection.

Non-indigenous species

Around 140 non-indigenous species have so far been recorded in the Baltic Sea. Of these, 12 are new for the Baltic Sea during 2011–2016. In addition, an unknown number of previously arrived non-indigenous species have expanded their distribution range to new sub-basins in the Baltic Sea. The regional objective is that there should be no primary introductions of non-indigenous species due to human activities during an assessment period and thus, good status is not achieved.

Seabed loss and disturbance

Less than one percent of the Baltic Sea seabed was estimated as potentially lost due to human activities, while roughly 40 % of the Baltic Sea seabed was estimated as potentially disturbed during the assessment period. The estimates are based on the spatial extent of human activities but have not been linked to pressure intensity. Hence, no assessment of adverse effects on the seabed has been made at this time.

Stormy Baltic Sea in Lesnoy, Kaliningrad, Russia.

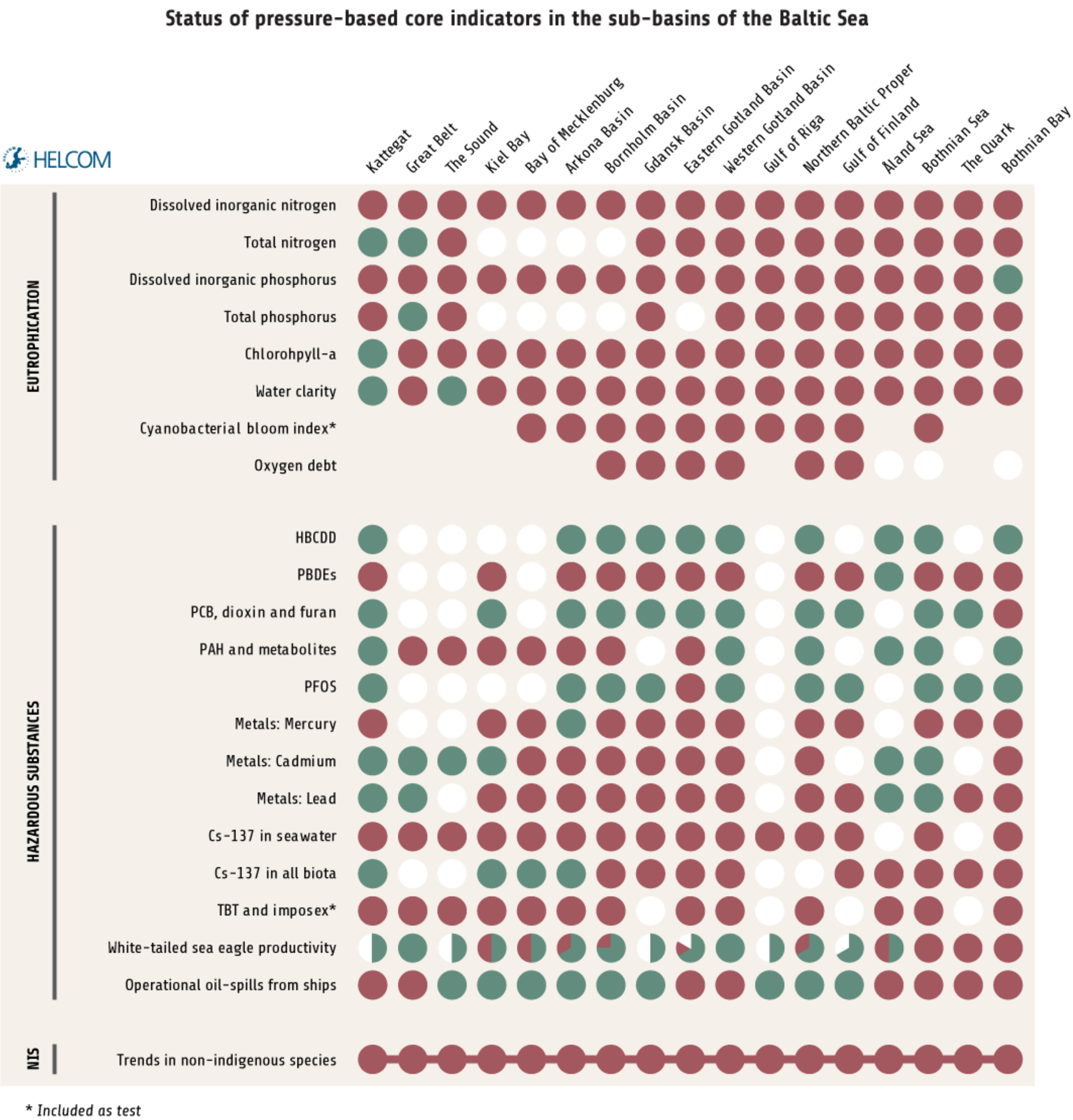


Figure ES3.
Status of pressure-based core indicators for eutrophication, hazardous substances and non-indigenous species by sub-basin. Green circles indicate good status, red circles indicate not good status, and white circles indicate that the core indicator is applicable or relevant to the sub-basin, but has not been assessed. Empty points indicate that the indicator is not applicable or relevant. For coastal indicators, pie charts show proportion of coastal assessment units per sub-basin in good status (green), not good status (red) and not assessed (white).

Biodiversity

For the biodiversity core indicators there are cases of inadequate status in all levels of the food web; only a few core indicators have acceptable levels in part of the Baltic Sea, and none of them in all assessed areas. The results for different indicators are not directly comparable, as their assessment methods have been developed independently. However, the overall results suggest that the environmental impact on species in the Baltic Sea are far-reaching and not restricted to certain geographic areas or certain parts of the food web (Figures ES4-5).

Habitats

For benthic habitats, there is indication of good status in six of thirteen assessed open sea areas, based on estimates limited to soft bottom habitats. Coastal areas show good status in about one third of the assessed Baltic Sea region. Pelagic habitats are assessed based on core indicators representing primary productivity, and in some sub-basins also zooplankton. Based on the available indicators, open-sea pelagic habitats achieve good status only in the Kattegat. Coastal pelagic habitats show good integrated status in about one fifth of the assessed areas. The assessments of habitats are still under development and additional elements will be included in the future.

Fish

The assessment of fish from a biodiversity perspective indicates good status in about half of the assessed coastal areas. In the open sea, good status is achieved only in the Bothnian Bay. Two out of five assessed pelagic fish stocks (herring in the central Baltic Sea and the Gulf of Bothnia) have good status, and one of four assessed demersal stocks (plaice). Core indicators for the migratory species salmon and sea trout show mixed results with strong geographical differences. Eel is critically endangered.

Mammals

Among the marine mammals, grey seals and harbour seals show increasing population sizes. Of the three harbour seal management units in the HELCOM area, only the Kattegat population shows good status. The population of ringed seal in the Gulf of Finland is in a critical state. The population is sensitive to climate change, and is decreasing, currently represented by around 100 animals.

A particular concern is the Baltic Proper population of harbour porpoise, with a population size recently estimated at around 500 animals. The Kattegat-Belt-Sea-Western Baltic subpopulation was also assessed by HELCOM as threatened, albeit with a lower threat status "vulnerable" and the sub-population is stable.

Waterbirds

Waterbirds are assessed based on the abundance of species during the breeding and the wintering seasons, respectively, focusing on coastal areas. The results suggest good status at Baltic Sea scale for both waterbird indicators, although more differentiated results are evident at the finer geographic scale. Waterbirds in open sea areas were not included in the indicators. Many bird species in open sea areas show strong Baltic-wide declines. An overall assessment of birds was not possible.

Food web aspects

Since species are dependent on each other in the food web, an insufficient environmental status in one part of the ecosystem is expected to also impact on other species. Changes in nutritional status, growth rate or size structure are particularly important indications of changes in the overall functionality of the food web. Further work is required for an indicator-based assessment of food web status in the Baltic Sea. However, available data for some geographic areas and species indicate a decreased nutritional status and size structure in fish (such as Eastern Baltic cod), decreased nutritional status in mammals (such as grey seal) and in some areas a decreased size structure in zooplankton, all pointing towards a deteriorating food web status.

Flounder lives by the seafloor in many parts of the Baltic Sea.
© Wolf Wichmann

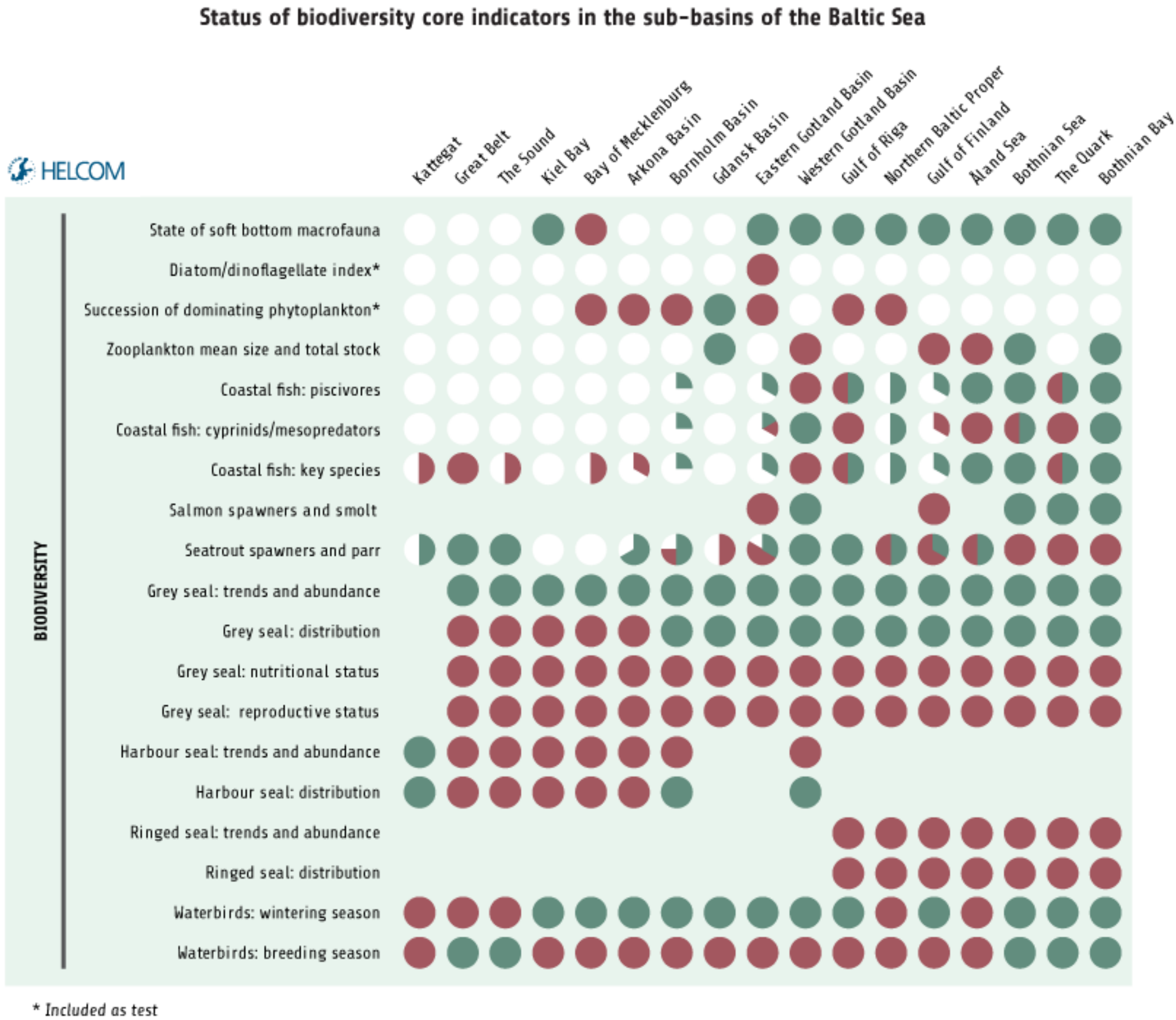


Figure ES4.
Status of biodiversity core indicators by sub-basin. Green circles indicate good status, red circles indicate not good status. White circles indicate that the core indicator is applicable for the sub-basin, but has not been assessed. Empty points indicate that the indicator is not applicable. For coastal indicators, pie charts show proportion of coastal assessment units per sub-basin in good status (green), not good status (red) and not assessed (white).

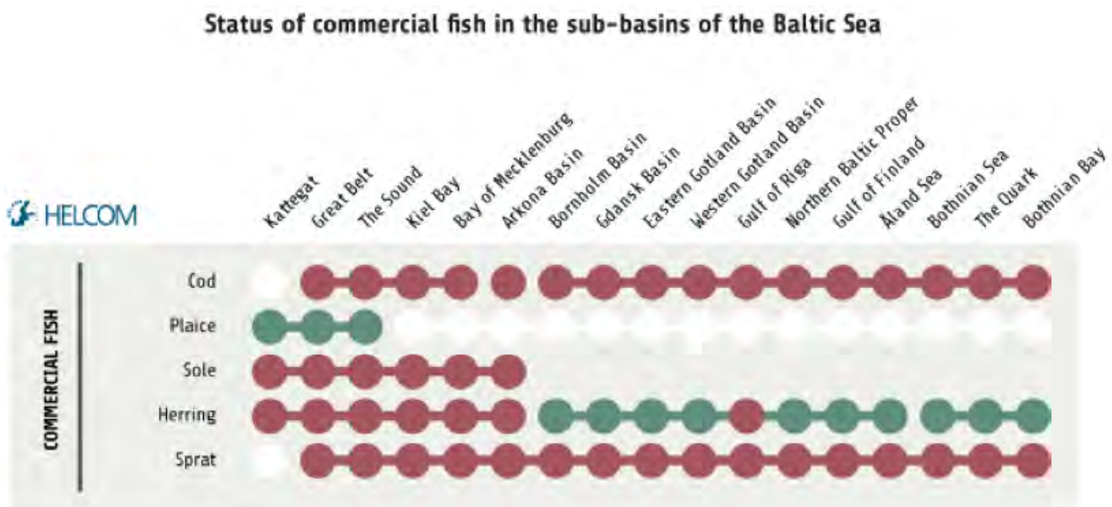


Figure ES5.
Status of commercial fish based on the assessment of fishing mortality and stock size (spawning stock biomass) using data from ICES (2016a). Green circles indicate good status for both these indicators, red circles indicate that at least one of the indicators did not achieve good status. White circles indicate that the assessment is applicable for the sub-basin, but is not yet available. For each species, the lines connect sub-basins which are assessed by the same stock. Empty points indicate that the assessment is not relevant for that sub-basin. Species with no available assessment results are not included.

Cumulative impacts and spatial aspects

The indicator-based assessments show the status of pressures when assessed individually, without comparing their total impact or how much they overlap with sensitive habitats. The Baltic Sea Impact Index is an assessment component that additionally describes the potential cumulative burden on the environment in different parts of the Baltic Sea. The assessment makes use of more detailed spatial information than can be provided by the core indicators. The results show that the highest potential environmental impacts currently occur in the southwestern Baltic Sea, and that the pressures resulting in most impact on species are concentrations of nutrients and contaminants, non-indigenous species, and the extraction of fish. Other pressures have high influence on specific species and species groups locally, but are less widely distributed.

Impacts on human well-being

Human activities in the Baltic Sea and its drainage area contribute to pressures that act on the Baltic Sea environment but are also in many cases dependent on a healthy state of the marine environment. The cost of degradation with respect to eutrophication in the Baltic Sea region is estimated to result in total losses of around 3.8–4.4 billion euros annually. In other words, citizens' welfare would increase by this much each year if good eutrophication status were achieved. Estimates for selected biodiversity components suggest that citizens' welfare would increase by 1.8–2.6 billion euros annually in the Baltic Sea region if the state of marine vegetation and fish stocks improved to a good status. The current recreational benefits of the Baltic Sea are estimated at around 15 billion euros annually. Meanwhile, current loss of recreation values, due to the deterioration of the marine environment, are estimated at around 1–2 billion euros annually.

Beach chair on a Baltic Sea beach.

The Baltic Sea in Northern Europe is surrounded by nine countries: Denmark, Germany, Poland, Lithuania, Latvia, Estonia, Russia, Finland and Sweden. As long as people have lived in the area, the Baltic Sea has provided a strong connection between these countries and a source of human livelihood. The countries also share the challenge of managing the pressures resulting from human activities, in order to lessen their impacts on biodiversity and ecosystem function. For HELCOM, maintaining good ecosystem health is a core area of regional collaboration. The State of the Baltic Sea report provides an update on the environmental state in the Baltic Sea during 2011–2016, as a basis for follow-up on environmental objectives and for creating a common knowledge base for the further development of Baltic Sea environmental management.

In support of the ecosystem approach, this second holistic regional report provides key information on the current state of the Baltic Sea environment, based on regionally agreed data and assessment methods. The report aims to answer questions such as: Which ecosystem components and areas do not achieve a good status? What are the major pressures in these areas? What are the underlying human activities? How is human welfare affected by the current state of the sea? Are there areas of risk in relation to future expansion of activities? The information provides a follow-up on current environmental state of the Baltic Sea and a basis for further decisions to reach the good environmental status for the Baltic Sea that environmental policies aim for.

1.1. Physical description of the Baltic Sea

The Baltic Sea is one of the largest brackish water areas in the world, with a surface area of 420,000 km^2. The drainage area of the Baltic Sea is about four times larger than its surface area and is inhabited by around 85 million people (Figure 1.1). More than one third of the Baltic Sea is shallower than 30 meters, giving it a small total water volume in comparison to its surface area.

The Baltic Sea is relatively isolated from other seas, and has only a narrow connection to the North Sea through the Sound and the Belt Seas. Hence, it takes approximately 30 years for the Baltic Sea waters to be fully exchanged (Stigebrandt 2001). Marine water enters the Baltic Sea predominantly during winter storms. These inflow events bring in water of higher salinity, and also improve oxygen conditions in the deep waters (See Box 1.1). Freshwater reaches the Baltic Sea from numerous rivers, corresponding to about one fortieth of the total water volume per year (Bergström *et al.* 2001).

Together, these hydrological conditions give rise to the characteristic brackish water gradient of the Baltic Sea, where there is gradual change from a surface water salinity of 15–18 (psu) at the entrance (the Sound), 7–8 in the Baltic Proper and 0–2 in the northeast parts (HELCOM 2016a; Figure 1.2). Salinity can also vary depending on the depth, because the density of water increases with salinity. Many sub-basins of the Baltic Sea are stratified, with more saline water near the bottom and water masses with lower salinity above.

Geologically, the Baltic Sea is very young. After the last glaciation (the Weichselian Glaciation ending around 12,000 years ago) when the Scandinavian ice sheet retreated, the Baltic Sea area has gone through a series of differing salinity phases, including both freshwater and marine/brackish water phases (Harff *et al.* 2011). The recent configuration

Figure 1.1.
The Baltic Sea is surrounded by nine countries, covers an area of around 420,000 km^2, and has a drainage area around four times its surface area. Due to its strong salinity gradient, and hence biological features, the area is sub-divided into 17 sub-basins based on topography and hydrology. These sub-basins are also referred to in the assessments made in this report.

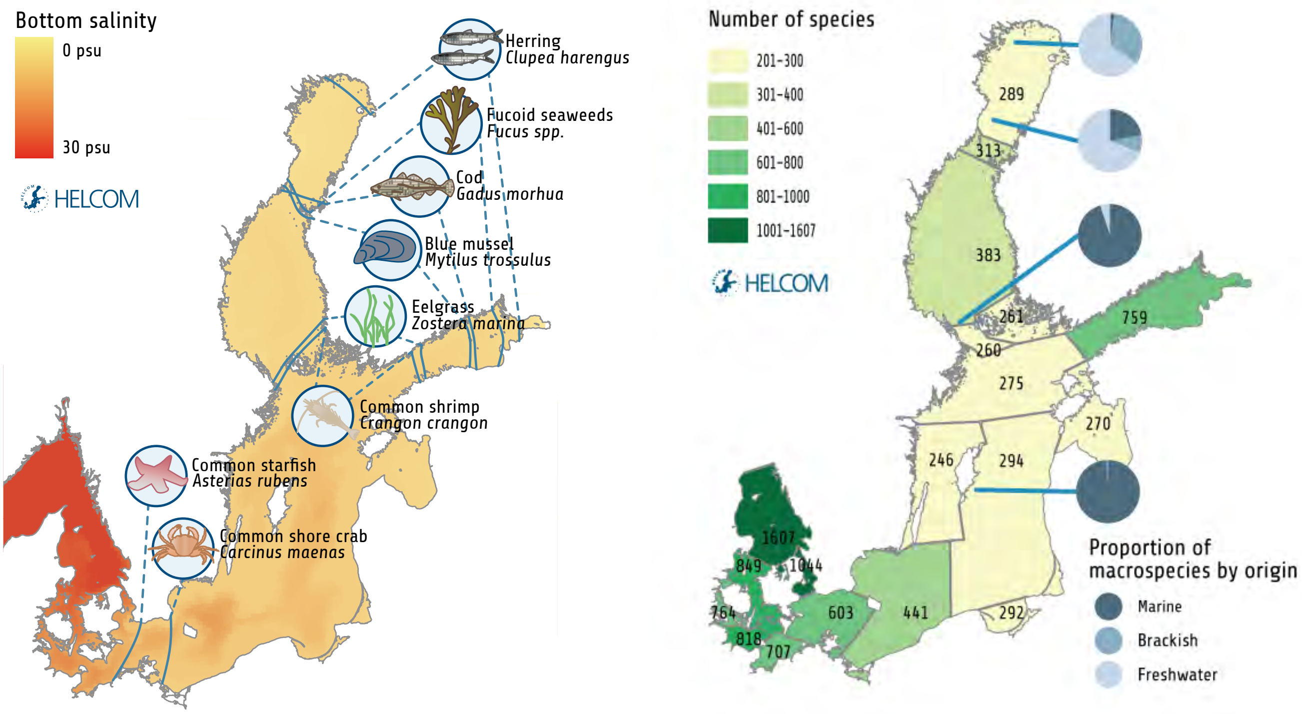


Figure 1.2.
The Baltic Sea is characterised by brackish water, and by gradually decreasing salinity from its entrance in the southwest to the inner parts. These conditions also affect the distribution of species. The left figure shows the salinity in different areas of the Baltic Sea and the inner distribution limits of some species of marine origin (cod and herring: according to Natural Resources Institute Finland (2017); other species: Furman *et al.* (2014) and Finnish Environment Institute (2017)). The right figure shows the total number of macrospecies in the sub-basins, including invertebrates, fish, mammals, birds and macrophytes (HELCOM 2012a). The blue pie charts illustrate how the proportions of freshwater, brackish and marine species shift along the salinity gradient, based on the number of macrospecies in each of these categories at different locations (Furman *et al.* 2014).

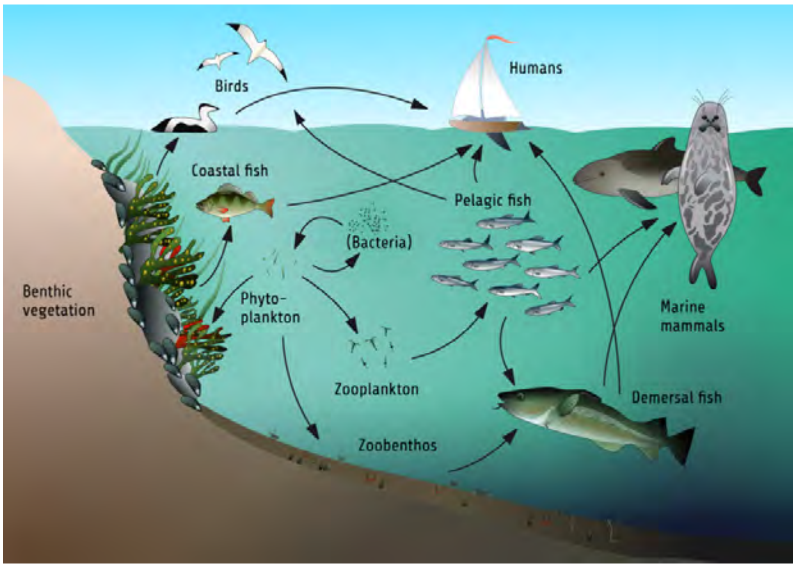


Figure 1.3.
A schematic, simplified illustration of the food web structure in the Baltic Sea.
Illustration: Sebastian Dahlström

of the Baltic Sea, with a connection to the North Sea, was established during the Littorina transgression between 7,500 and 4,000 years before present. The entrance to the North Sea was previously wider, but narrowed due to land upheaval (Leppäranta and Myrberg 2009). The current brackish water form of the Baltic Sea was initiated only around 2,000 years ago (Emeis *et al.* 2003).

Most of the species of marine origin in the Baltic Sea originate from a time when the sea was saltier, and since then they have had limited genetic exchange with their counterparts in fully marine waters. On a Baltic-wide scale, marine species live side by side with freshwater species that reproduce in freshwater tributaries or which can tolerate the brackish conditions. The brackish water imposes physiological stress on both marine and freshwater organisms, but there are also several examples of genetic adaptation and diversification (Johannesson and André 2006). Although marine species are generally more common in the southern parts, and freshwater species dominate in the inner and less saline areas, the two groups of species create a unique food web where marine and freshwater species coexist and interact (Figure 1.3).

1.2. Climate and hydrology

The whole Baltic Sea region is situated in a temperate climate zone. The middle and northern areas have longer winters with stronger frosts, whilst the southwestern and southern areas have relatively moist and mild winters.

Global climate change is also seen in the Baltic Sea region. The maximum extent of ice cover is lower today than the historical average, with a sharp decline in recent years, and a decrease in the mean number of ice days (Figure 1.4).

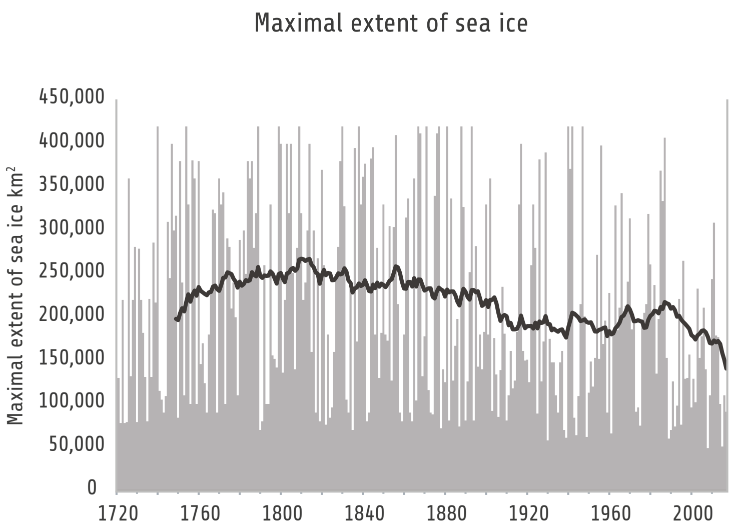
The changing climate affects the long term trend in water temperature (Figure 1.5). Salinity is affected due to increased input of freshwater to the Baltic Sea. The large scale variability over time in temperature and salinity is, however, also influenced by hydrodynamic factors (Figure 1.6). The increase in carbon dioxide along with global climate change is expected to cause acidification, with a decreasing pH in the long term (Figure 1.7).

Inflows of marine water to the Baltic Sea have been rare since the 1980s, although they have had a slightly higher frequency in recent years (Figure 1.8).

The scarcity of high intensity inflows has been an important contributing factor to the extension of areas with poor oxygen conditions in the deeper waters of the Baltic Sea (Figures 1.9-1.10). In particular, there is a clear increase in the occurrence of anoxic areas since 1999 (Hansson *et al.* 2011). Oxygen depletion occurs when the level of oxygen in the water is lower than the level needed by most species to persist. Anoxia occurs when all oxygen in the water has been consumed by biological processes. Hydrogen sulphide is formed if there is anoxia for a longer period. Most life forms cannot sustain anoxic conditions, and habitats with hydrogen sulphide only support some bacteria and fungi (Hansson *et al.* 2017).

In the deeper areas of the Baltic Sea, conditions of low oxygen or even anoxia are an intrinsically natural phenomena, although enhanced by nutrient loading. The recent improvements in the oxygen conditions in the deeper southern and central Baltic basins are related to the saline water inflows in 2013-2016 (Box 1.1). By contrast, the brackish surface and sub-surface waters above the halocline are oxygenated by vertical mixing and thermohaline circulation. Seasonal oxygen deficiency occurring in shallow areas and coastal waters is mainly driven by eutrophication, where weather developments have an impact. Warm, windless summers increase the probability of low oxygen conditions in these shallower regions during late summer (August-September).

The impact of the saline water inflows on the deeper, north-eastern areas of the Baltic Sea is not as straightforward as in the central Baltic. The oxygen conditions in the near-bottom layer of the Gulf of Finland, for example, depend on both the saline water inflows and wind-driven alterations of estuarine circulation (Lips *et al.* 2017). Furthermore, the oxygen conditions have worsened after the December 2014 inflow in the northern Baltic Proper (see Fig. 1.10) and the Gulf of Finland. This was caused by the propagation of former anoxic and hypoxic sub-halocline waters from the eastern Gotland Basin to the northern Baltic Proper and from the northern Baltic Proper to the Gulf of Finland (Liblik *et al.* 2018).



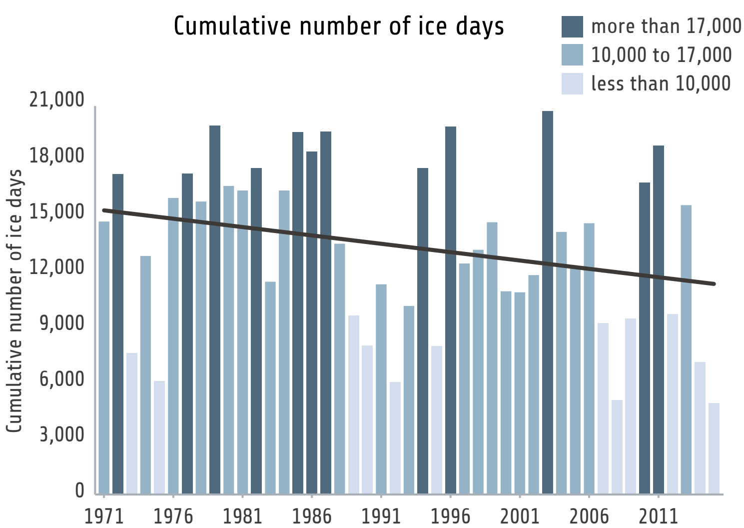


Figure 1.4.
Temporal development in ice cover. The upper graph shows the maximum extent of sea ice during winter (km2) over the past 300 years, with the black line giving the 30-year moving average. The lower graph shows the cumulative number of ice days per winter since 1971. Years with a low number of ice days are more common in recent years (light blue bars), and there is a decreasing trend. Source: Finnish Meteorological Institute.

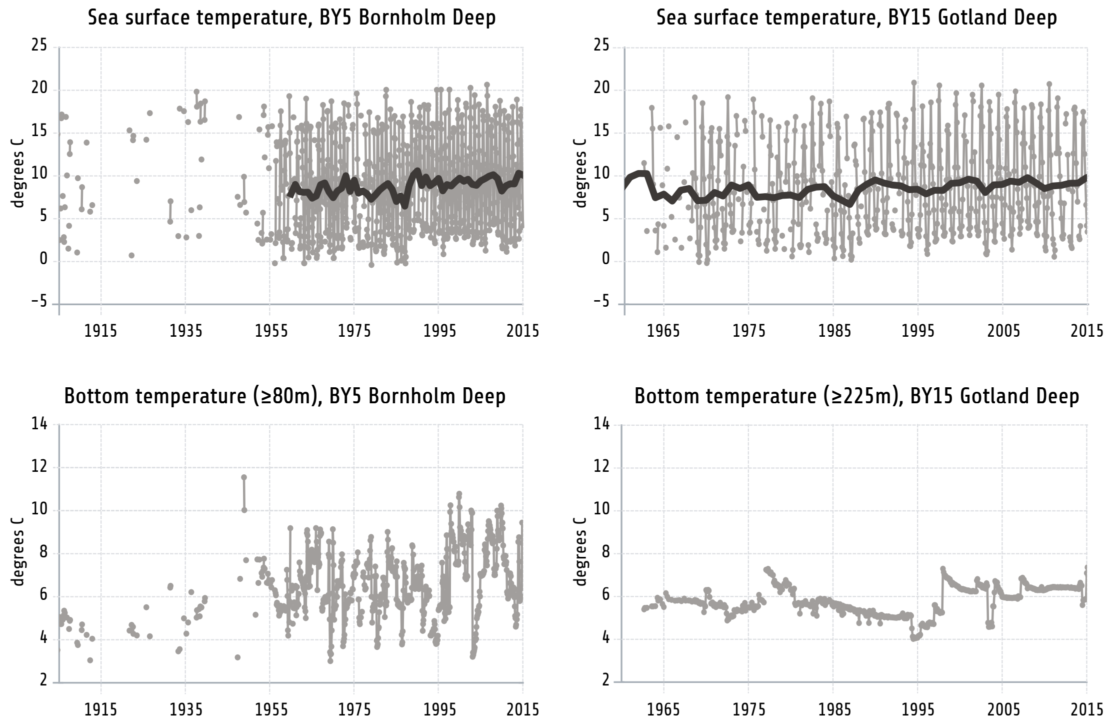


Figure 1.5.
Changes over time in the seawater temperature in the Bornholm Deep and the Gotland Deep. Upper panel: The sea surface temperature oscillates over the year, approaching zero degrees in the winter and reaching 16–19 degrees in the summer. The lines show changes in the annual averages. Lower panel: In the deep water, the highest temperature recordings have been observed in recent decades in both basins. The variation in temperature in the deep water reflects the inflow of marine water from the North Sea. Based on data from the HELCOM COMBINE database.

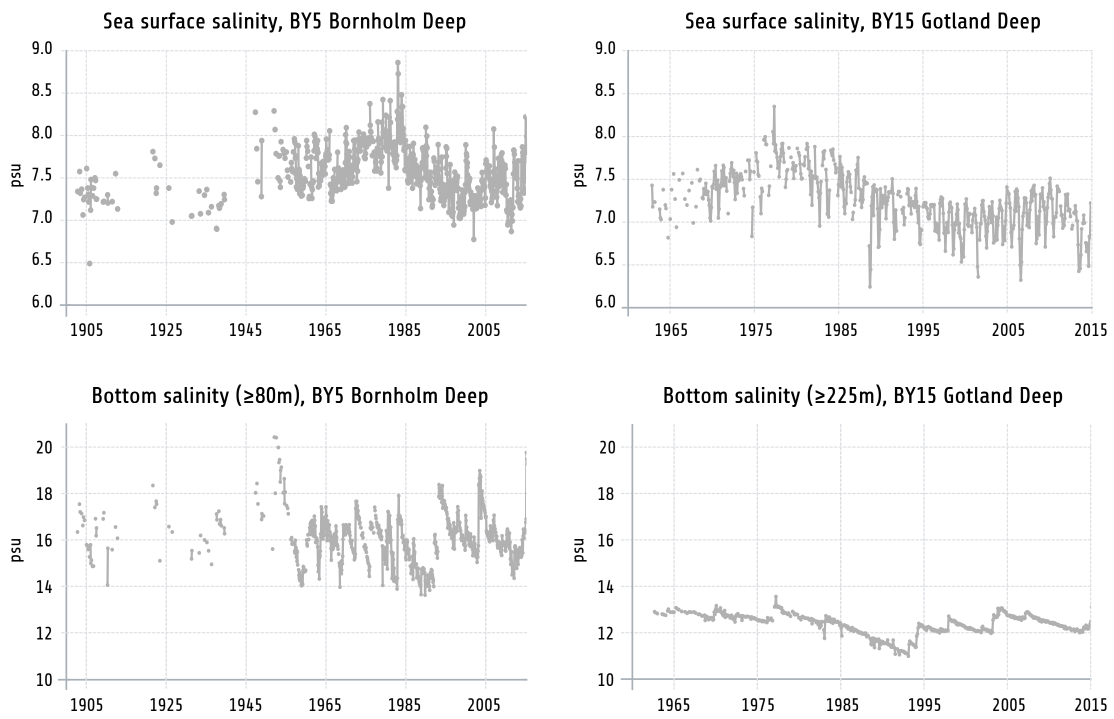


Figure 1.6.
Changes over time in surface water and deep water salinity. The surface water salinity in the Bornholm Deep and the Gotland Deep, upper panel, are clearly lower now than in the 1970s. The lower panel shows the salinity in the deep water. The effects of marine water inflow are seen as oscillations, which are more pronounced in the Bornholm Deep which is closer to the Baltic Sea entrance. Based on data from the HELCOM COMBINE database.

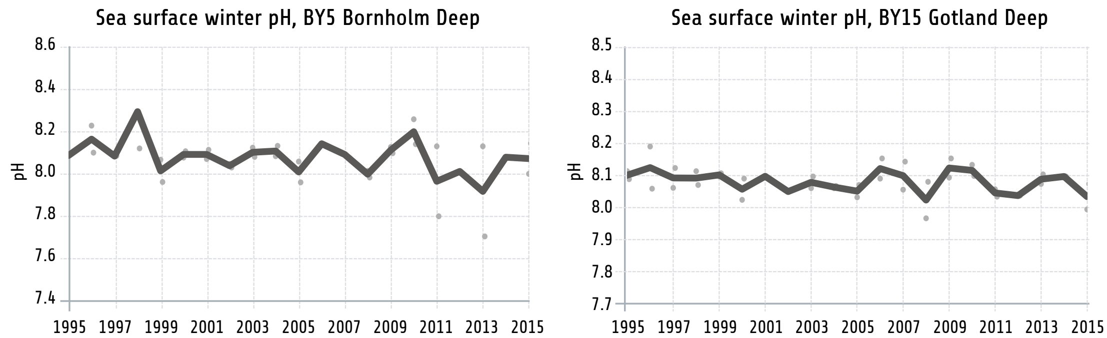


Figure 1.7.
Changes in pH over time in the surface water of the Bornholm Deep and the Gotland Deep during 1995–2015, measured during winter. The line shows changes in the winter averages (January and February). Based on data from the HELCOM COMBINE database. Baltic Sea water is influenced by the outer North Sea, as pulses of marine water enter intermittently. These inflows to the Baltic Sea lead to temporary increases in salinity in the deeper water of the Baltic Sea and fluctuations in temperature (Figures 1.5–1.6), and are highly important for oxygenating the deep water areas and supporting the physical environment of marine species.

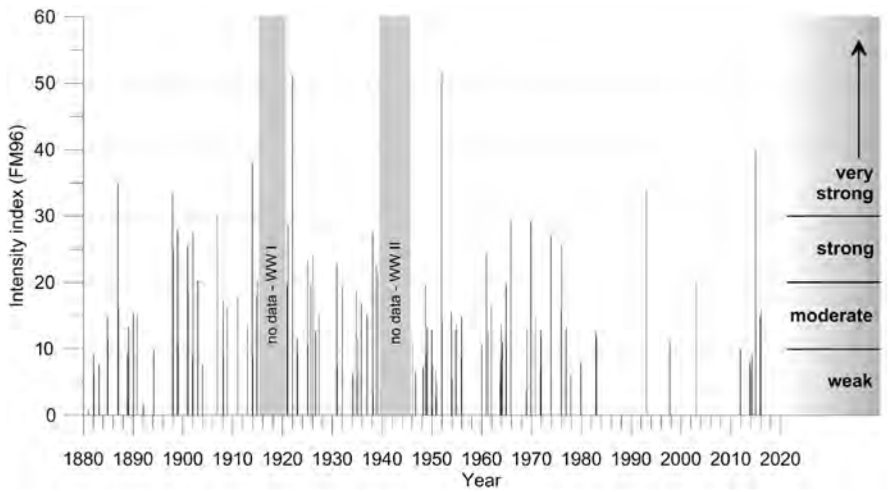


Figure 1.8.
Intensity of inflow events to the Baltic Sea between 1880 and 2015. Inflows of saline water occurred regularly with six to seven events per decade until the 1980s, but their frequency has been low in recent decades. Since 2014, an intensified inflow period of several smaller events and three stronger events (so called Major Baltic Inflows) started again. The Major Baltic Inflow of December 2014 is the third largest in the history of measurements and the largest one since 1951. Source: Feistel *et al*. (2016), Mohrholz *et al*. (2015).

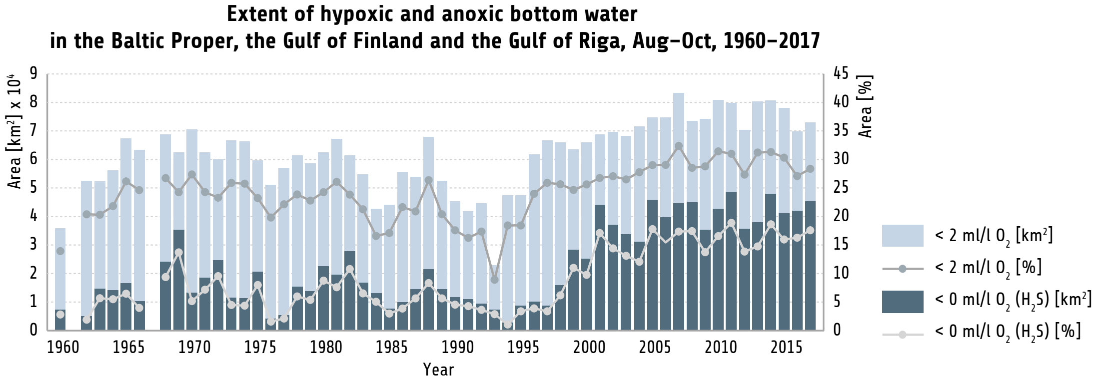


Figure 1.9.
The total area with poor oxygen conditions (<2 ml/l, light blue and dark blue bars), and no oxygen (dark blue bars, identified by the presence of hydrogen sulphide) have increased over past decades. In particular, the area with no oxygen was around three times larger during 1999–2016, compared to 1960–1998, based on data from the Baltic Proper, Gulf of Finland and the Gulf of Riga. Source: Hansson *et al.* (2017).

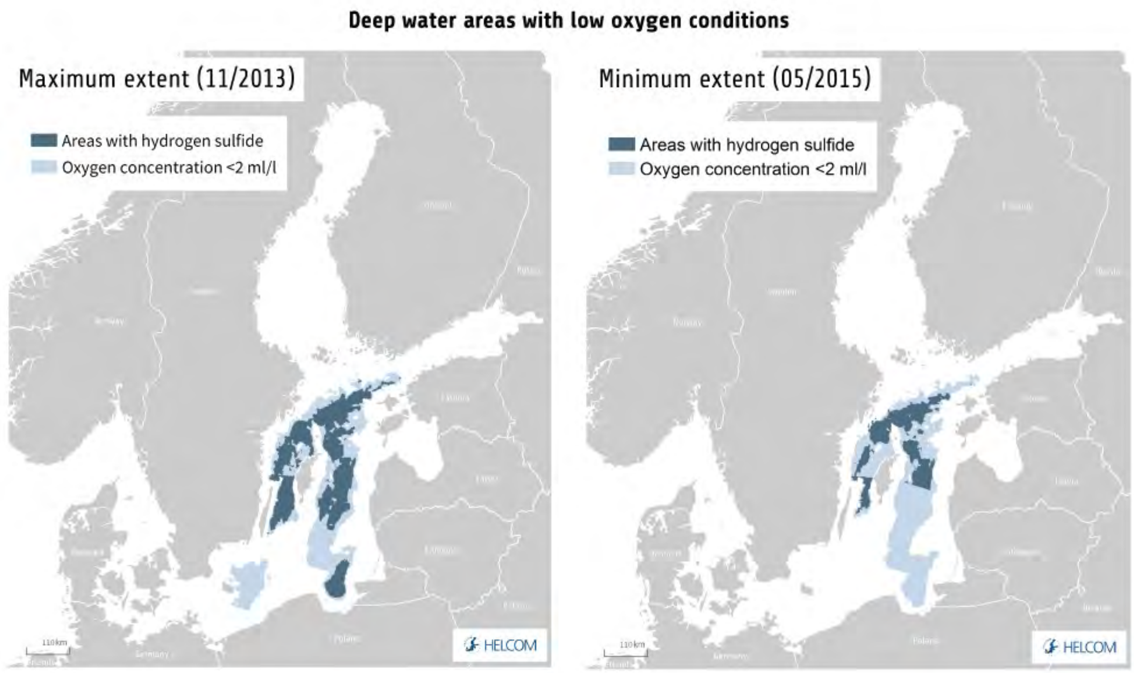


Figure 1.10.
Poor oxygen conditions at the seafloor restrict productivity and biodiversity in the Baltic Sea. The maps show the minimum and maximum distribution of anoxic areas in the deep-water (where hydrogen sulphide is present) and areas with less than 2 ml/l oxygen during 2011–2016, based on point measurements and modelling. Data from Leibniz Institute for Baltic Sea Research Warnemünde. See also Feistel *et al.* (2016). Due to the range of input data used, the map may not correctly reflect the situation in the Gulf of Finland.

Box 1.1

Deeper Baltic Sea oxygen conditions during the assessment period

Oxygen conditions in the deep water have been improved by a series of inflow events since the end of 2013. A series of smaller inflow events occurred in November 2013, December 2013, and March 2014. These interacted positively and reached the deep water of the central Baltic Sea for the first time since 2003 (Naumann and Nausch 2015). In December 2014, a very strong inflow occurred, which transported 198 km^3 of saline water into the Baltic Sea (Mohrholz *et al.* 2015), and was followed by smaller events. A Major Baltic Inflow of moderate intensity also occurred between 14 and 22 November 2015, followed by a third moderate Major Baltic Inflow between 31 January and 6 February 2016 (Feistel *et al.* 2016). These events caused intensified oxygen dynamics in the Arkona Basin, Bornholm Basin, and Eastern Gotland Basin, and the northern Baltic Proper was affected up to the end of 2016.

As a result, the near bottom oxygen concentrations in the Bornholm deep ranged from 0.08 ml/l (in November 2015) to 5.4 ml/l (in February 2015), measured at 95 m water depth. In the Gotland deep, where hydrogen sulphide was present in concentrations corresponding to a negative oxygen content of -8.75 ml/l (in November 2013), oxygen concentration increased to 2.9 ml/l in April 2015 at 235 m depth (Nausch *et al.* 2016).

Maximum ventilation occurred in May 2016. The major Baltic inflow of December 2014 caused the Bornholm Basin to become fully ventilated. Hydrogen sulphide was absent in the Gdansk Basin and Eastern Gotland Basin, and the former anoxic bottom water was replaced (see Figure 1.10).

The recent inflows have reduced the large pool of hydrogen sulphide that was present in the Eastern and Northern Gotland Basin. However, oxygen concentrations in the deep water are near zero below the permanent stratification and conditions near the bottom have become increasingly anoxic during 2017. There are signs of increasing amounts of hydrogen sulphide in the Eastern and Northern Gotland Basins close to the bottom. In order to prevent further deterioration of the oxygen situation, with the formation of hydrogen sulphide concentrations, new major inflows are needed (Hansson *et al.* 2017).

Baltic Sea. Oxygen conditions in the deep water have been slightly improved by a series of recent inflow events.
© Jack Keene (CC BY-NC-ND 2.0)

1.3. Environmental management and the ecosystem approach

Due to its enclosed nature and relatively low biodiversity, the Baltic Sea is especially vulnerable to environmental pressures. The long winter season limits its productivity, and the brackish water creates challenging conditions for both marine and freshwater organisms. Due to the limited water exchange with other seas, inputs of nutrients and other substances from the drainage area accumulate in the Baltic Sea and are only slowly diluted. The land-based inputs, together with pressures arising from human activities at sea, influence the status of habitats and species, and eventually also impact on human well-being.

Typical pressures occurring in the Baltic Sea include eutrophication, contamination, marine litter, the introduction and spread of non-indigenous species, underwater sound, fishing and hunting, as well as habitat loss and disturbance.

The ecosystem approach to management builds on an incremental understanding of the effects of human-induced pressures on the environment, impacts on marine life and consequences for human well-being. In some cases the mechanisms of how species and habitats are impacted are relatively well known, but in other cases management has to be based on limited knowledge, with the aim being to increase the common level of knowledge over time. The ecosystem approach is fundamental in all HELCOM work, and is used as the basis for achieving good environmental status and sustainable use of Baltic Sea resources as stated in the Baltic Sea Action Plan (HELCOM 2007). This approach recognizes the complexity of ecosystems. It accepts that pressures do not act in isolation and thus that management inevitably needs to consider the impacts of all relevant pressures on the marine ecosystem when managing human activities (Box 1.2). This is a challenge since management of resources, as well as regulation of human activities, tends to be localised and limited within sectors.

Swimming in the sea off Tjurkö, Sweden.

Salmon eggs hatch in rivers with outflows into the Baltic Sea and spend the first parts of their lifecycle there, feeding on invertebrates and being dependent on the river water environment. After one or two years they grow into so called smolt and migrate to the Baltic Sea, where they mature into adult salmon and remain for a few years. During this time, a salmon may migrate hundreds of kilometres and encounter many different environments before returning to the river to spawn. Its health and survival is influenced by food availability, fishing pressures, and potentially also underwater sound, marine litter and the quality of available food, and it is dependent as well on the environmental quality of their spawning rivers.

Photo: Esa Lehtinen

Bladderwrack is an important habitat-forming seaweed which colonises hard substrates in the Baltic Sea. In other seas it lives in the intertidal zone, but in the Baltic Sea it lives continuously submerged. Many small animals thrive among the structures formed by the seaweed, and it is a productive environment for small fish and benthic species. These small animals are also important for keeping the seaweed clean. The bladderwrack lives attached to the rock or other hard substrate all its life. It is sensitive to the quality of the surrounding water and hence eutrophication or changes in the food web can be damaging. When food webs are disturbed, due to a decrease of big predatory fish for example, this may also affect the number of small animals among the seaweed and the quality of this habitat.

Photo: Nicklas Wijkmark

Box 1.2

Cumulative effects on species

One person or activity alone does not exert much pressure on the environment, but when scaled up the impact of many humans and their activities may have a considerable impact on marine species, and the different impacts act together on the environment. Additionally, single or cumulative impacts might trigger changes in the food web, with potential cascading effects further up or down in the food web.

Some species migrate far and encounter several different environments and different types of pressures during their life. Other species are local and cannot move, even if the local environment changes, and the water masses around them have travelled long distances and may include harmful substances from sources far away. The status of pressures, species and habitats is influenced by multiple connections to human activities. The linkages between human activities and pressures are outlined in Chapter 3, and the impacts of current pressures in the Baltic Sea on species and habitats are assessed using the Baltic Sea Impact index in Chapter 6. Understanding these linkages also helps reveal important knowledge gaps for setting management targets and helps us to better understand how human activities depend upon, and benefit from, marine ecosystem services.

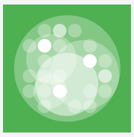
1.4. Regional Cooperation

The Helsinki Convention encompasses the protection of the Baltic Sea from all sources of pollution from land, air, and sea based activities. It also commits the signatories to take measures to conserve habitats and biological diversity and to ensure sustainable use of marine resources. Contracting Parties to the Convention are the nine countries that border the Baltic Sea and the European Union. Regional monitoring and assessments have been a core task of the inter-governmental Helsinki Commission (HELCOM), established to oversee the implementation of the Convention and to share knowledge in support of regional environmental policy.

The HELCOM Baltic Sea Action Plan (BSAP; HELCOM 2007) is a joint programme for HELCOM countries and the EU to restore the good environmental status of the Baltic marine environment by 2021. It is structured around four segments for which specific goals and objectives have been formulated: eutrophication, hazardous substances, biodiversity, and maritime activities (Figure 1.11). The initial HELCOM holistic assessment (HELCOM 2010a) was the first integrated assessment made by HELCOM and provided a baseline for the implementation of the Baltic Sea Action Plan.

HELCOM also acts as the coordination platform for the regional implementation of the EU Marine Strategy Framework Directive (MSFD) that aims to achieve a good environmental status in European marine environments by 2020 (EC 2017a,b). Eight of the nine countries around the Baltic Sea are EU Members States. Through HELCOM as the coordinating hub, the regional follow-up of the two policy frameworks can thus be met simultaneously and be carried out coherently by the countries bordering the Baltic Sea (Box 1.3). For Russia, being the only country bordering the Baltic Sea that is not an EU Member State, the Russian Maritime Doctrine defines the policy of Russia up to 2020 in the field of maritime activities. The Doctrine includes the protection and conservation of the marine environment where sustainable economic and social development, along with international cooperation, are important elements.

Other European policy frameworks, such as the Habitats Directive, Water Framework Directive and the Birds Directive (EC 1992, 2000, 2009), also share important objectives with the Baltic Sea Action Plan, for example the aim of achieving a favourable conservation status of species and habitats and good ecological quality and chemical status of coastal waters. HELCOM work is complementary to these directives and also the ecosystem based management ambitions of the Common Fisheries Policy. When relevant, and for a more complete understanding, results from assessments carried out to follow-up these policies are also used and referred to in this report. Further, the report can support follow up and implementation of other policies both on regional and global levels. It will for instance serve as a baseline scenario for implementation of the ocean-related UN Sustainable Development Goals in the Baltic Sea.



Eutrophication

Baltic Sea unaffected by eutrophication

- Clear water
- Natural level of algal blooms
- Natural distribution and occurrence of plants and animals
- Natural oxygen levels

Biodiversity

Favourable status of Baltic Sea biodiversity

- Natural marine and coastal landscapes
- Thriving and balanced communities of plants and animals
- Viable populations of species

Hazardous substances

Baltic Sea undisturbed by hazardous substances

- Concentrations of hazardous substances close to natural levels
- All fish are safe to eat
- Healthy wildlife
- Radioactivity at the pre-Chernobyl level

Maritime activities

Enviromentally friendly maritime activities

- Enforcement of international regulations – no illegal discharges
- Safe maritime traffic without accidental pollution
- Efficient emergency and response capabilities
- Minimum sewage pollution from ships
- No introductions of alien species from ships
- Minimum air pollution from ships
- Zero discharges from offshore platforms
- Minimum threats from offshore installations

Figure 1.11.
The environmental objectives for the Baltic Sea Action Plan are structured around the segments eutrophication, hazardous substances, biodiversity, and maritime activities.

Box 1.3.

Baltic Sea main policies driving the assessment

The Baltic Sea Action Plan and the Marine Strategy Framework Directive have similar goals and objectives, and thus, progress towards achieving the same regional aim, which can be assessed using the same indicators and tools. The 'State of the Baltic Sea' report covers the topics addressed by the four segments of the Baltic Sea Action Plan and its follow-up Ministerial Declarations, as well as the descriptors of the Marine Strategy Framework Directive. The assessment is organised according to Pressures on the environment (Chapter 4) and the status of Biodiversity and food webs (Chapter 5). The indicators used in the respective sub-chapters are listed in Table B.1.3.1 and Table B.1.3.2.

Marine litter and underwater sound are new components of the Baltic Sea Action Plan, taken up by HELCOM in the Ministerial Declarations (Moscow, 2010 and Copenhagen, 2013). The EU Marine Strategy Framework descriptor related to the removal of commercial fish and shellfish can be associated with the provisions of 2013 HELCOM Declaration on ecosystem-based fisheries, while hydrological conditions cannot be directly assigned to any segment of the Baltic Sea Action Plan. Maritime activities, which is a focal area of HELCOM and one of the four BSAP segments, is linked to several of the descriptors, including eutrophication, contaminants, and non-indigenous species.

Table B.1.3.1.
Indicators used in Chapter 4 of this report ('Pressures'), and their relation to the segments of the Baltic Sea Action Plan (BSAP) and the descriptors of the Marine Strategy Framework Directive (MSFD). An asterisk (*) denotes that the indicator or threshold values have not been fully adopted in HELCOM yet and are currently tested. Indicators in italics are under development in HELCOM and at this time are only included descriptively in the report. The indicators are presented by the segments of the Baltic Sea Action Plan: Eutrophication (green), Hazardous substances (purple) and Maritime activities (orange), and the follow-up declarations (burgundy). All indicators on eutrophication and hazardous substances are also relevant for the maritime segment of the Baltic Sea Action Plan.

BSAP segment	**Baltic Sea unaffected by eutrophication**
MSFD descriptor	**5 – Eutrophication**
Sub-chapter in this report	**4.1. Eutrophication**
Indicators	— Dissolved inorganic nitrogen — Dissolved inorganic phosphorus — Total nitrogen — Total phosphorus — Chlorophyll-a — Cyanobacterial bloom index* — Secchi depth during summer — Oxygen debt — State of the soft-bottom macrofauna community — Coastal waters: indicators developed under the Water Framework Directive

BSAP segment	**Baltic Sea undisturbed by hazardous substances**
MSFD descriptor	**8 – Contaminants** **9 – Contaminants in fish and seafood**
Sub-chapter in this report	**4.2. Hazardous substances**
Indicators	— Hexabromocyclododecane (HBCDD) — Metals (Cadmium, Lead, Mercury) — Polybrominated biphenyl ethers (PBDEs) — Perfluorooctane sulphonate (PFOS) — Polyaromatic hydrocarbons (PAHs) and their metabolites — Polychlorinated biphenyls (PCBs), dioxins and furans — TBT and imposex* — *Diclofenac* — Radioactive substances — White-tailed sea eagle productivity (coastal waters only)

Box 1.3. (continued)

Table B.1.3.1. (continued)

BSAP segment	Environmentally friendly maritime activities	
MSFD descriptor	8. Contaminants	2. Non-indigenous species
Sub-chapter in this report	**4.2. Hazardous substances**	**4.5. Non-indigenous species**
Indicators	— Operational oil spills from ships	— Trends in arrival of new non-indigenous species

Baltic Sea Action Plan follow-up declarations (2010, 2013):	Prevent and reduce marine litter from land and sea-based sources	No negative impact on marine life	Maintain or restore fish stocks above levels capable of producing Maximum Sustainable Yield (MSY)	Assess impacts on the seabed
MSFD descriptor	10 – Marine litter	11 – Introduction of energy	3 – Commercially exploited fish and shellfish	6 – Seafloor integrity
Sub-chapter in this report	**4.3. Marine litter**	**4.4. Underwater sound**	**4.6. Species removal by fishing and hunting**	**4.7. Seabed loss and disturbance**
Indicators	— *Beach litter* — *Litter on the seafloor* — *Microlitter*	— *Continuous low frequency anthropogenic sound* — *Distribution in time and space of loud low- and mid-frequency impulsive sound*	— Fishing mortality — Spawning stock biomass (of cod, dab, sole, herring, sprat)	— *No indicator. Descriptive approach*

Box 1.3. (continued)

Table B.1.3.2
Indicators used in Chapter 5 of this report ('Biodiversity'), relating to the biodiversity segment of the Baltic Sea Action Plan (BSAP) and descriptor 1 of the Marine Strategy Framework Directive (MSFD). An asterisk (*) denotes that the indicator or threshold values have not been fully adopted in HELCOM yet and are currently being tested. Indicators in italics are under development in HELCOM and at this time are only included descriptively in the report.

BSAP segment	**Favorable status of Baltic Sea biodiversity**
MSFD descriptor	**1 – Biodiversity**
Sub-chapter in this report	**5.1 Benthic habitats**
Indicators	— State of the soft-bottom macrofauna community (some areas) — Oxygen debt
Sub-chapter in this report	**5.2 Pelagic habitats**
	— Zooplankton mean size and total stock — Chlorophyll-a — Cyanobacterial bloom index* — Diatom/Dinoflagellate index* — Seasonal succession of dominating phytoplankton groups*
Sub-chapter in this report	**5.3 Fish**
	— Abundance of key coastal fish species — Abundance of coastal fish key functional groups — Abundance of seatrout spawners and parr — Abundance of salmon spawners and smolt **Commercial fish — indicators from ICES:** — Spawning stock biomass (for cod, dab, sole, herring, sprat) — Fishing mortality (for cod, dab, sole, herring, sprat)
Sub-chapter in this report	**5.4 Marine mammals**
	— Population trends and abundance of seals — Nutritional status of seals — Reproductive status of seals — Distribution of Baltic seals — *Number of drowned mammals and waterbirds in fishing gear*
Sub-chapter in this report	**5.5 Waterbirds**
	— Abundance of waterbirds in the breeding season — Abundance of waterbirds in the wintering season — *Number of drowned mammals and waterbirds in fishing gear*

2. Overview of the holistic assessment

The HELCOM State Of The Baltic Sea Report builds upon experience gained from the HELCOM initial holistic assessment in 2010. This initial assessment provided for the first time a coherent assessment of the Baltic Sea ecosystem and its pressures from a holistic perspective, based on available data and prevailing knowledge. The regional development of indicators and assessment methods has continued since then and made the improvements in the current report possible. Through the HELCOM coordinated work of hundreds of experts, thirty regionally agreed core indicators have been made operational and are included in this assessment to reflect the status of the Baltic Sea environment, together with five indicators included as test. Several additional aspects are evaluated descriptively in order to arrive at a comprehensive assessment of the status of the Baltic Sea in 2011–2016.

The HELCOM holistic assessment is a multi-layered product; this summary report is supported by supplementary reports, several supporting HELCOM assessment reports, core indicator reports and spatial data fact sheets (Figure 2.1). Ninety-six spatial data sets at regional scale have been collated using regular HELCOM processes or dedicated data calls, to evaluate the geographical distribution of human activities, pressures, species and habitats.

The foundation of the assessment is the core indicators, which are based on the HELCOM coordinated monitoring programme and regionally agreed threshold values. The core indicators were assessed according to defined assessment units representing different levels of detail, in a regionally agreed nested system. Four assessment unit levels were used, from coastal water bodies to the entire region, to enable assessing each core indicator at its most relevant spatial scale and making comparisons across indicators and geographical areas. Assessment tools with the core indicators were used to produce thematic integrated assessment results on hazardous substances (CHASE), eutrophication (HEAT) and biodiversity (BEAT; see Box 2.1).

The current assessment focuses on the time period 2011–2016. In addition, data showing temporal development have been provided in order to understand long-term trends and evaluate the direction of ongoing changes. The focus of the assessment has been to show results of relevance at the regional scale, and large-scale patterns between geographic areas.

More detailed descriptions of the assessments applied are found in the supplementary reports, and references in relation to the integrated assessments of eutrophication hazardous substances and biodiversity, as well as of the assessment of cumulative impacts and the economic and social analyses (Figure 2.1).

Summary report with complete overview and key messages

STATE OF THE BALTIC SEA REPORT

Method descriptions and more detailed results

HOLAS II Supplementary material
- Thematic sssessment of eutrophication
- Thematic assessment of hazardous substances
- Thematic assessment of biodiversity
- Thematic assessment of cumulative impacts
- Thematic assessment – Economic and social analyses

Other supporting HELCOM assessments
- Maritime assessment
- Pollution load compilation
- Thematic assessment of coastal fish
- Ecological coherence of MPA network
- Red List of Baltic Sea species
- Checklist of Baltic Sea macrospecies

Indicator approaches and assessments, data sources

Core indicator reports

Spatial data fact sheets on
- human activities
- pressures
- ecosystem components

HELCOM

Figure 2.1.
Overview of key publications supplementing or supporting the State of the Baltic Sea report. The thematic assessments listed as HOLAS II supplementary material reflect the same results as in the State of the Baltic Sea report, and additionally include more detailed results and method descriptions (HELCOM 2018A–E). The core indicator reports give the assessment details and technical background to the applied core indicators, and are identified where referred to in the text. Other HELCOM assessments supporting the State of the Baltic Sea report: Maritime activities (HELCOM 2018f), Pollution load compilation (HELCOM 2015a); Thematic assessment of coastal fish (HELCOM 2018g), Ecological coherence of MPA network (Marine protected areas; HELCOM 2016b), Red List of Baltic Sea species (HELCOM 2013b), Checklist of Baltic Sea macrospecies (HELCOM 2012a).

Box 2.1.

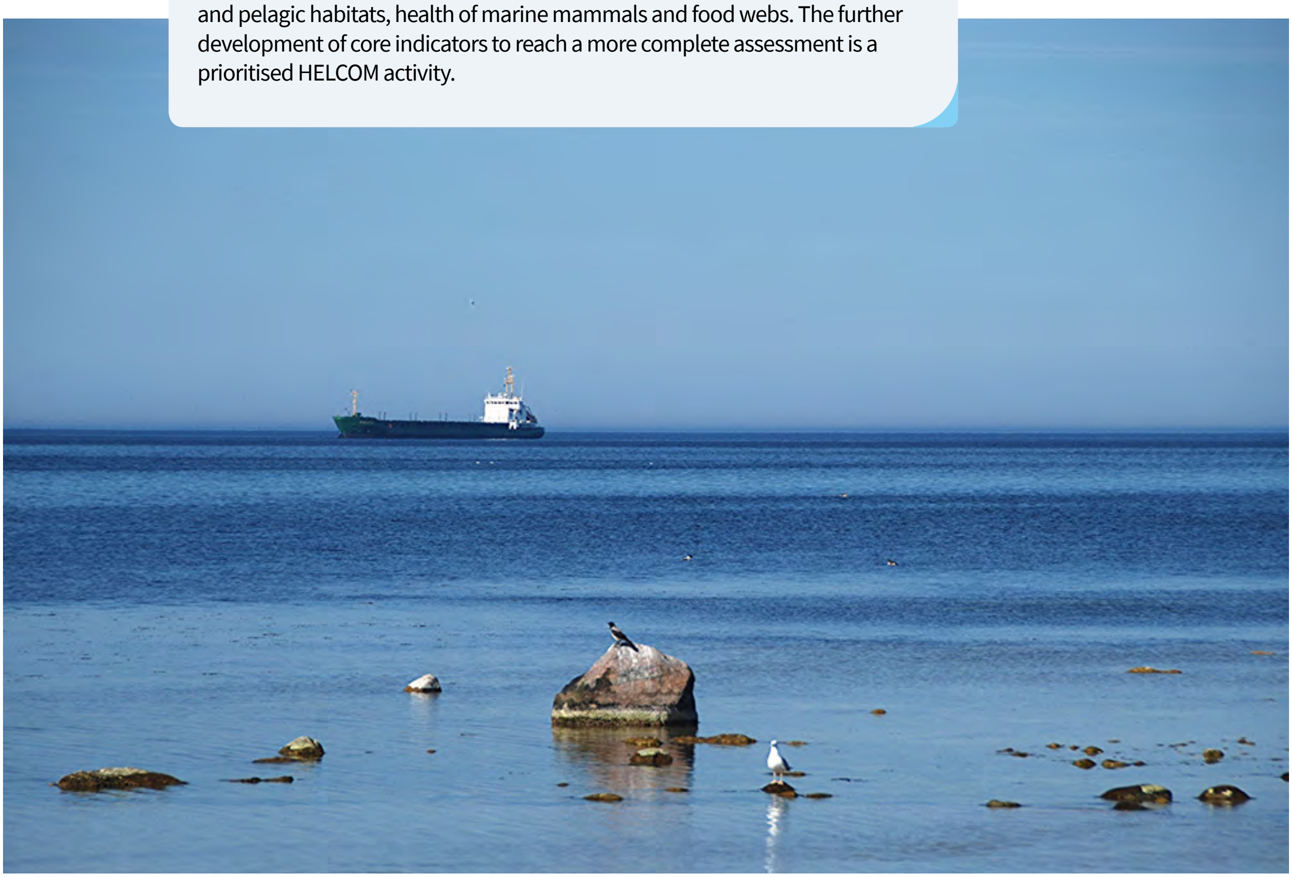
The core indicator based assessment

This assessment uses core indicators to measure the status of the Baltic Sea marine environment on the basis of selected and representative elements. The HELCOM core indicators cover both biodiversity and human induced pressures and impacts on the Baltic Sea ecosystem. The core indicators were selected according to a set of principles including ecological and policy relevance, measurability with the monitoring data and linkage to anthropogenic pressures (HELCOM 2013c). The HELCOM core indicators evaluate the observed status in relation to a regionally agreed threshold value, in many cases using data from regionally coordinated monitoring. Hence, the results indicate whether status is good or not according to each of the core indicators.

Furthermore, integrated assessments of biodiversity, eutrophication and hazardous substances, are made based on the core indicators using the BEAT, HEAT and CHASE assessment tools. The integrated tools were also used in the initial holistic assessment (HELCOM 2010a) and have been developed further in the second holistic assessment. The integrated assessments do not only show whether status is good or not, but also indicate the distance to good status by use of five categories; two representing good status and three representing not good status.

The assessments are performed at the spatial scale of HELCOM assessment units, which have four different levels; each core indicator being assessed at its most relevant scale. For example, birds are assessed at level 1 which is the whole region, salmon and sea trout, as well as zooplankton are assessed at level 2 which further subdivides the Baltic Sea into sub-basins. Level 3 separates the sub-basins also into coastal and offshore areas, and level 4 uses a finer subdivision of coastal areas, in line with national management practices such as water bodies as designated under the EU Water Framework Directive.

The assessment is based on currently available core indicators. For some elements, operational indicators are still lacking or limited, such as for benthic and pelagic habitats, health of marine mammals and food webs. The further development of core indicators to reach a more complete assessment is a prioritised HELCOM activity.



Cargo near Fårö, off the east side of Fårö, Sweden.

Every one of us has a personal relationship with the Baltic Sea marine environment. We gain benefits when we use the sea for recreation and transportation, we harvest its resources, and some of us obtain direct employment and income from marine activities. These uses influence the state of the environment in many cases, reducing the ability of the marine ecosystem to provide goods and services for human well-being. The importance of the Baltic Sea marine environment to society, to national and regional economies and for the well-being of current and future generations is shown by economic and social analyses, illustrating that protection and use of marine waters brings significant contributions to economies and the welfare of citizens.

Hundreds of years ago, fishing was vital for the survival of people around the Baltic Sea, often combined with farming and hunting. Shipping played an essential role in the transportation of people and goods. These activities are still of key importance today, although hunting is no longer a source of livelihood. Additionally, more advanced technology is available and traditional ways of using the sea are accompanied by new ones, such as offshore energy production, extraction of sand and gravel, aquaculture, as well as tourism and recreation. Overall, the presence of human activities has increased, and more parts of the sea are accessed.

3.1. Links between activities and environment

Human activities in the Baltic Sea and its surroundings are responsible for pressures on the environment. The size of the catchment area of the Baltic Sea is four times the size of its surface area, and is currently inhabited by around 85 million people. Inputs from human activities in the catchment area, such as nutrient loading and hazardous substances, add to pressures from human activities at sea, causing cumulative impacts to the status of the marine environment. Important current pressures acting on the Baltic Sea environment are shown in Figure 3.1, together with links to the many human activities that may contribute to them. Examples of human activities of importance in the Baltic Sea and their spatial distribution are shown in Figure 3.2.

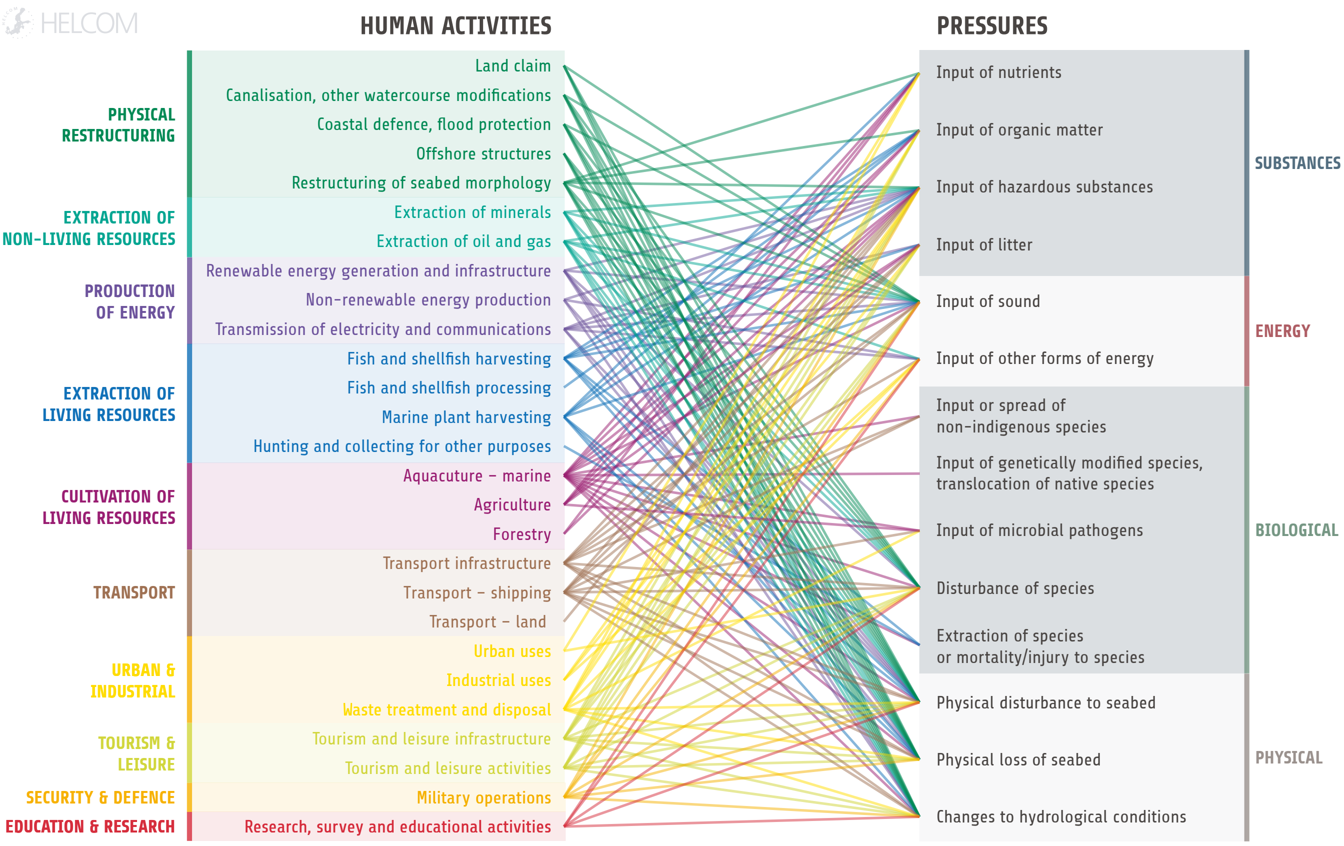


Figure 3.1.
Human activities in the Baltic Sea and their connection to pressure types. The lines show which pressures are potentially connected to a certain human activity, without inferring the pressure intensity nor potential impacts in each case. The figure illustrates the level of complexity involved in the management of environmental pressures.

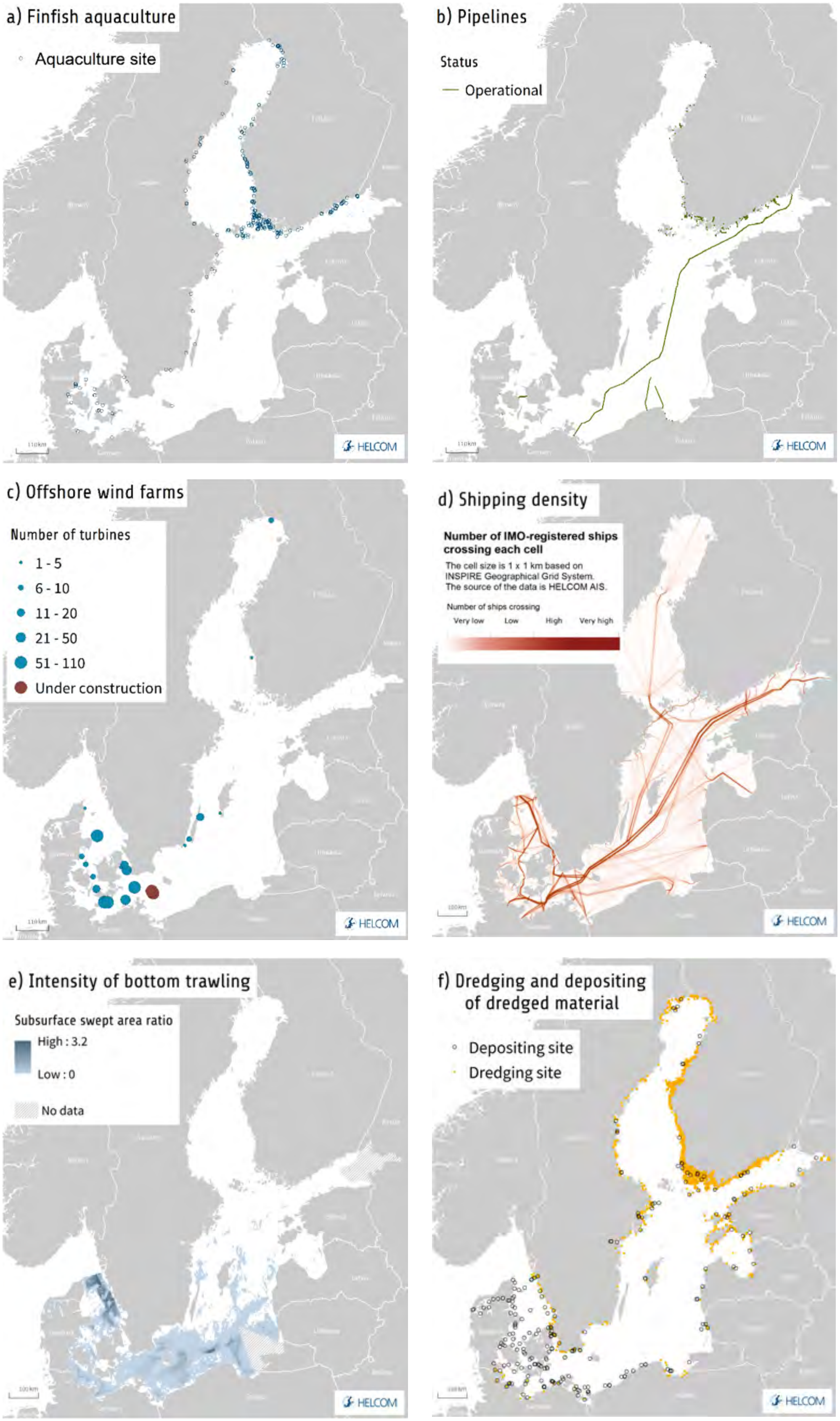


Figure 3.2.

Examples of human activities of importance in the Baltic Sea and their spatial distribution: a) finfish aquaculture sites, b) location of pipelines, c) location of offshore wind farms, d) shipping density, e) intensity of bottom trawling, and f) dredging sites and dredging material deposit sites. The spatial distribution of the activities are dependent, for example, on the distribution of underlying resources and topography. Fishing activities have the highest intensity in areas where the target species are most abundant; depth and seabed properties determine suitable locations for sand extraction or wind farms; and shipping routes need to be planned in relation to travel distances and safety. However, the distribution of certain activities, such as aquaculture, is a result of regulatory and cultural differences. Marine spatial planning has an emerging role in using these different aspects to manage human activities at sea, as well as mitigating negative effects on the environment.

Activities in the Baltic Sea and its coastal areas bring employment and economic benefits to national economies, and also affect people's welfare directly; for example, by providing recreational space. The first holistic assessment included some case study results of the costs and benefits of improving the state of the Baltic Sea (HELCOM 2010a). The present assessment deepens our understanding of the connection between the marine environment and human welfare. On the one hand, the regional economic and social analyses consider the economic benefits foregone if the marine environment deteriorates. But on the other hand, they illustrate economic benefits arising from the use of the marine environment.

Figure 3.3 outlines the regional economic and social analyses and their role in their holistic assessment. More detailed descriptions on methods and additional data are presented in HELCOM (2018A; Thematic assessment).

The Baltic Sea has always been a source of employment and economic activity.

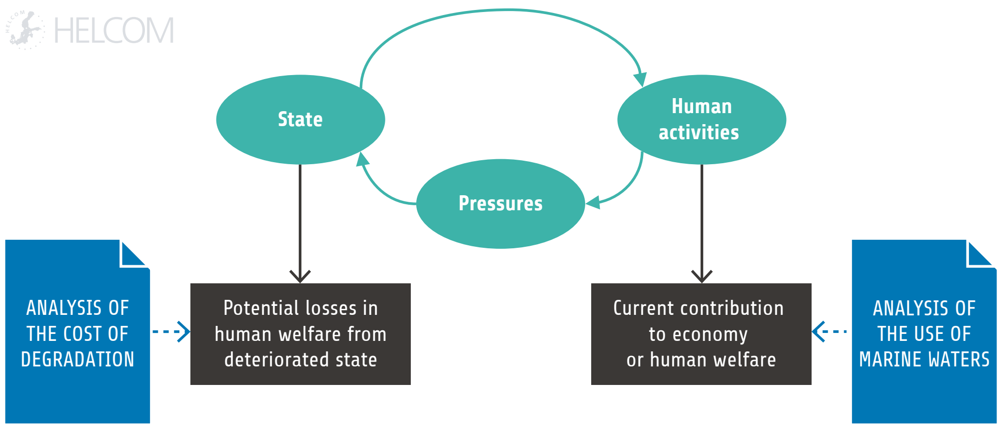


Figure 3.3.
Roles of economic and social analyses in the holistic assessment. The human activities contribute to the national and regional economies and human welfare, which is measured by the economic and social analysis of the use of marine waters (Box 3.1). The state of the marine environment affects human welfare. The welfare losses from not being in a good environmental status are estimated in the cost of degradation analysis (Box 3.2). The status also affects the economic contribution from many activities, such as recreation and fish and shellfish harvesting, as shown by the link back from 'state' to 'activity'.

Fishing on Kråkö Island, Finland.
© Sara Estlander

3.2. Economic benefits from the protection and use of the Baltic Sea

The 'use of marine waters analysis' assesses the contribution that human activities make to the economies in the Baltic Sea region (Box 3.1). Meanwhile, the 'cost of degradation analysis' measures the economic benefits that are lost when the sea does not reach a good environmental status (Box 3.2). Data to assess the economic impact of marine environment deterioration on the human activities dependent on the sea is scarce. An example of connecting the human activities, their economic performance and the marine environment is given in Box 3.3

From the human welfare perspective, deterioration of the marine environment reduces the value that people place on it. An example of simultaneous use of marine waters and costs of degradation analysis for marine and coastal recreation is provided in Box 3.4. The results show that the annual economic value of recreation is 15 billion euros and the annual economic loss in recreational values from marine deterioration is 1-2 billion euros. The results are estimated using a travel cost approach, based on data from a standardized survey of households in all Baltic Sea countries (Czajkowski *et al.* 2015).

Regionally representative use of marine waters analysis considers fish and shellfish harvesting, marine aquaculture, tourism and leisure, renewable energy generation, and marine transport and infrastructure, and are presented here. Additional information on economic and social indicators for human activities, for which regionally comparable data is not yet available is provided in the Thematic assessment on economic and social analyses (HELCOM 2018A). More information on human activities in the Baltic Sea can be found in HELCOM (2018f).

Box 3.1.

Use of marine waters: Economic benefits from the use of the sea

Economic and social analysis of the use of marine waters examines the economic contribution to regional and national economies from using marine waters in their current state. This contribution is measured with economic and social indicators. These indicators describe the importance of the marine activities to the economy, for example by estimating 'value added' or 'employment', or the direct economic value from the use of the marine environment to the citizens' living in the coastal countries. In this report, the information is derived mainly from existing statistics, except for marine and coastal recreation, where statistics are complemented with data on economic value to citizens.

The indicators do not capture the negative economic impacts that marine uses may have on the quality of the marine environment and thus potentially on other uses of the marine environment, but are a piece of the overall picture of how society and the marine environment are linked.

Further improving our understanding of the economic contribution from marine activities will require harmonised data across all coastal countries, reporting data separately for different sea areas (Baltic and North Seas), and differentiating between land activities, freshwater activities and marine activities, particularly for tourism.

Box 3.2.

Losses in human well-being from the degradation of the marine environment

Degradation of the environment causes multiple adverse effects that reduce the economic benefits (or welfare) that people obtain from the marine environment, including increased water turbidity and more frequent cyanobacterial blooms, reduction and changes in fish stocks, contamination of fish and seafood, increased litter on the beaches and in the sea, and loss of marine biodiversity. The economic benefits that are lost if the sea does not reach a good environmental status are called the cost of degradation (see Figure B3.2.1).

The losses in human welfare can be assessed in monetary terms based on economic valuation studies that estimate the effect on citizens' benefits from changes in the quality of the marine environment. It is important to acknowledge the related uncertainties when using such value estimates. For example, a citizen's perceptions of changes in the quality of the marine environment can be unclear, nevertheless, the value estimates can be used as a proxy for the cost of degradation. When estimating, the focus can be either on degradation themes, such as eutrophication, or ecosystem services, such as recreation.

Various methodological approaches and assessment results are available for estimating losses in human welfare. When no such data are available for a certain country or region, value transfer is an example of how to relate existing individual evaluation to entire marine region. Results from currently available analyses are presented in this chapter for recreation (Box 3.4), eutrophication (chapter 4, section 4.1, Box 4.1.2) selected biodiversity aspects (chapter 5, section 5.6, Box 5.6.1; see also HELCOM 2018A).

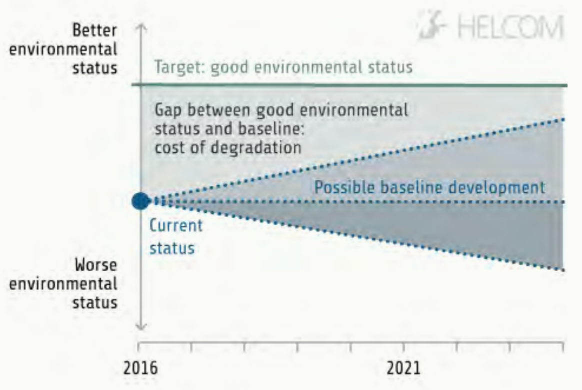


Figure B3.2.1.
Illustration of the cost of degradation concept. Cost of degradation results from the difference between the current/baseline environmental status and the good environmental status.

Box 3.3.

Example of ecosystem services approach in the use of marine waters analysis

The ecosystem services approach allows for a holistic analysis of the links between the status of the ecosystem and human well-being, and is not limited to market based information. Linking economic indicators, for example 'value added', with the ecosystem services approach, we can explore how human activities benefit from and impact on the environment in a more comprehensive way. The graph shows the results of this method applied in Sweden (Fig. B3.3.1).

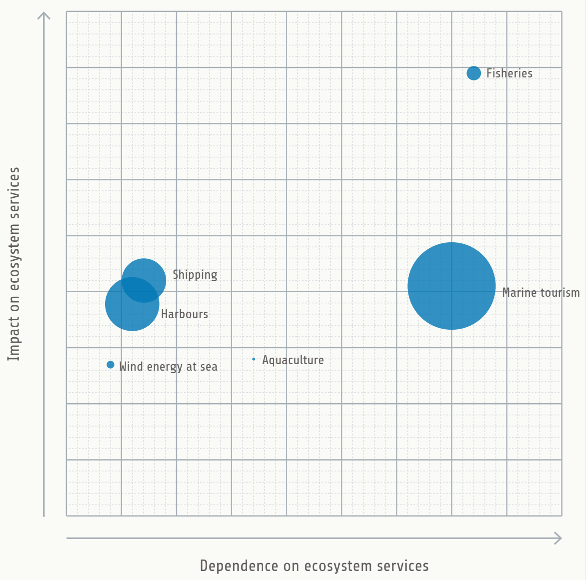


Figure B.3.3.1.
Example on how human activities benefit from an impact on the environment. The bubble sizes represent the value added of each activity. The vertical axis represent the total environmental impact of human activities on the ecosystem services, and the horizontal axis represent the activities dependency on the state of ecosystem services. Economically and ecologically sound marine management would shift the location of the bubbles downward and increase the size of the bubbles. The result of this method is expected to vary from country to country.

Box 3.4

Simultaneous analysis of the economic value of marine use and cost of degradation – an example

Marine and coastal recreation is an activity which is dependent on the state of the Baltic Sea environment. Thus, it is possible to assess both the current economic value of recreation, and the losses in recreation values due to the deterioration of the marine environment. Results are available from a recent extensive study on Baltic Sea recreation that covers all coastal countries (Czajkowski *et al.* 2015).

The value of current Baltic Sea recreational visits represents the economic benefit from the activity. The estimates are based on information about travel costs and the number of recreational visits people make to the Baltic Sea and its coast. They measure the total value of Baltic Sea recreation visits during a year. The total recreational benefits of the Baltic Sea are around 15 billion euros annually (Figure B3.4.1).

The losses in value of Baltic Sea recreation, due to deterioration of the marine environment, are measured based on a change in citizens' recreation values from a one-step change in the perceived status of the Baltic Sea marine environment. The perceived environmental status was measured on a 5-step scale from 'very bad' to 'very good', with the average being 'neither bad nor good', and thus, a one-step change means an improvement from 'neither bad nor good' to 'rather good'. The change in recreation values stems from the predicted change in the expected number of trips to the Baltic Sea when the perceived environmental conditions change, based on econometric modelling. The losses of recreation values due to the deterioration of the marine environment are estimated to be 1–2 billion euros annually (Figure B3.4.2).

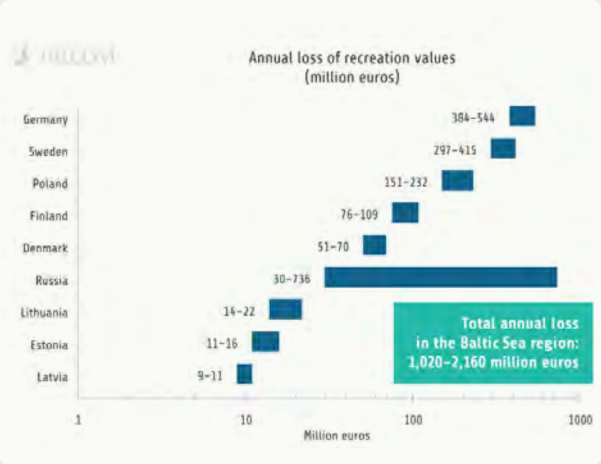


Figure B3.4.2.
Lost recreation benefits due to deterioration of the marine environment. The total losses of recreation values are 1–2 billion euros annually for the Baltic Sea region. Value estimates are in purchasing power parity adjusted 2015 euros. Source: Czajkowski *et al.* (2015). This extensive study is an example of the necessity and importance of economic valuation studies that cover all coastal countries, but further studies are needed across all countries before the results of the assessment can form a basis for the socioeconomic value of recreation in the Baltic Sea region.

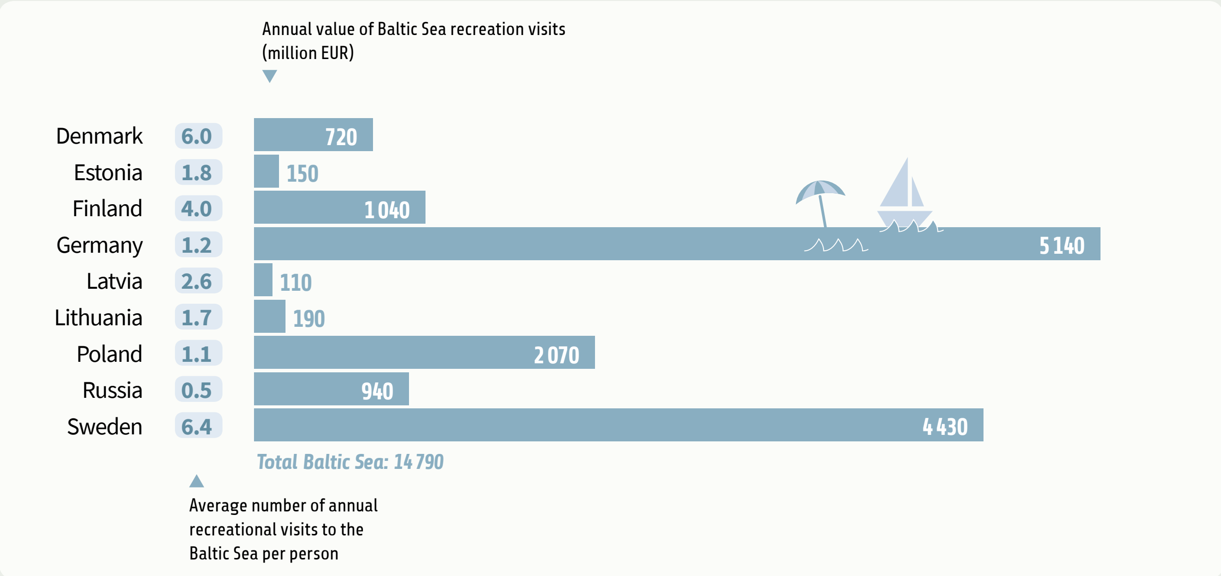
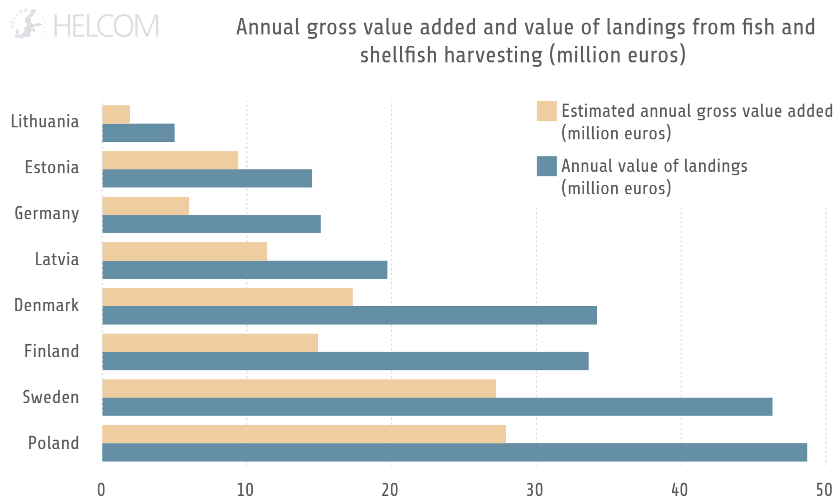


Figure B3.4.1.
Annual value of marine and coastal recreation and average number of annual recreational trips to the Baltic Sea.
Data from the year 2010. Source: Czajkowksi *et al.* (2015).



	Poland	Sweden	Finland	Denmark	Latvia	Germany	Estonia	Lithuania
Estimated annual gross value added (million euros)	27.90	27.20	14.90	17.30	11.40	6.00	9.40	1.90
Annual value of landings (million euros)	48.7	46.3	33.6	34.2	19.7	15.1	14.5	5

Figure 3.4.
Economic indicators related to fish and shellfish harvesting. Data from the year 2015. Source: Scientific, Technical and Economic Committee for Fisheries (STECF 2017). All monetary values have been adjusted for inflation; constant prices (2015). STECF does not report on Russia.

Fish and shellfish harvesting

Fish and shellfish harvesting is a sector involved in the extraction of living resources. The 'use of marine waters analysis' describes commercial small-scale and large-scale fleet fishing which takes place within the Baltic Sea waters. The small-scale fishing fleet uses vessels shorter than twelve metres, while the large-scale fleet includes vessels larger than twelve metres. The data originates from the annual report on the EU fishing fleet published by the Scientific, Technical and Economic Committee for Fisheries (STECF 2017), for all countries except Russia. Due to the reduced number of vessels and/or enterprises in Germany and the Baltic States, data which were considered sensitive (on distant-water fleets) were not delivered to the STECF. This has an impact on the regional level analysis.

The number of active vessels in the Baltic Sea was estimated at 6,192 in 2015 (STECF 2017), and 6,500 in 2014 (STECF 2016a). The Finnish fleet was the largest (1,577 vessels). Among the EU Member States, Estonian, Finnish and Latvian marine fisheries are fully dependent on the Baltic Sea region, while other EU Member States vessels operate also in other marine fishing regions. Only vessels operational in the Baltic Sea are included in the statistics (Figures 3.4 and 3.5). The value of landings in the Baltic Sea region totalled 217 million euros in 2015, compared to 218 million euros in 2014. The highest total values for fish and shellfish landed by national fleets from the Baltic Sea waters were by the Polish, Swedish and Finnish fleets, and the lowest total values by the Estonian and Lithuanian fleets. The value of landings is similar in size to the value of estimated revenue.

The gross value added for the Baltic Sea area was 116 million euros in 2015 compared to 95 million euros in 2014. The highest values were for Sweden and Poland, and the lowest values for Lithuania and Germany. In terms of employment, the commercial fishing sector related to Baltic Sea waters employs an estimated 9040 people. It should be noted that the full-time equivalent employment is near half of this number (4704). Poland, Estonia and Finland have a clearly higher number of persons employed in their fleets operating in the Baltic Sea region, compared to the other countries. There is employment also in related sectors, such as fish and shellfish processing (see HELCOM 2018A). The spatial distribution

Figure 3.5.
Employment in fish and shellfish harvesting. Data from the year 2015. Source: Scientific, Technical and Economic Committee for Fisheries (STECF 2017). All monetary values have been adjusted for inflation; constant prices (2015). STECF does not report on Russia.

of fish harvesting in the Baltic Sea is illustrated in Figure 3.6 by the spatial distribution of commercial landings of cod, herring and sprat.

Marine aquaculture

The marine aquaculture sector involves the cultivation of living resources in the marine environment. Economic impacts from aquaculture are presented only for Finland, Denmark and Sweden (STECF 2016b, Statistics Sweden 2017). There is one finfish and one shellfish farm in the German waters of the Baltic Sea, but the production volumes and other types of economic data are confidential, and thus there is information only on the location of the farms. For all the other countries, the production is assumed to be zero (and thus the turnover, gross value added and employment), based on the national production and sales data reported to the European Scientific, Technical and Economic Committee for Fisheries. Shellfish aquaculture is not included in the figures. Of the Baltic Sea countries, Denmark, Germany and Sweden are involved in shellfish aquaculture, but it has a lower significance in the Baltic Sea than finfish aquaculture. For example, Denmark

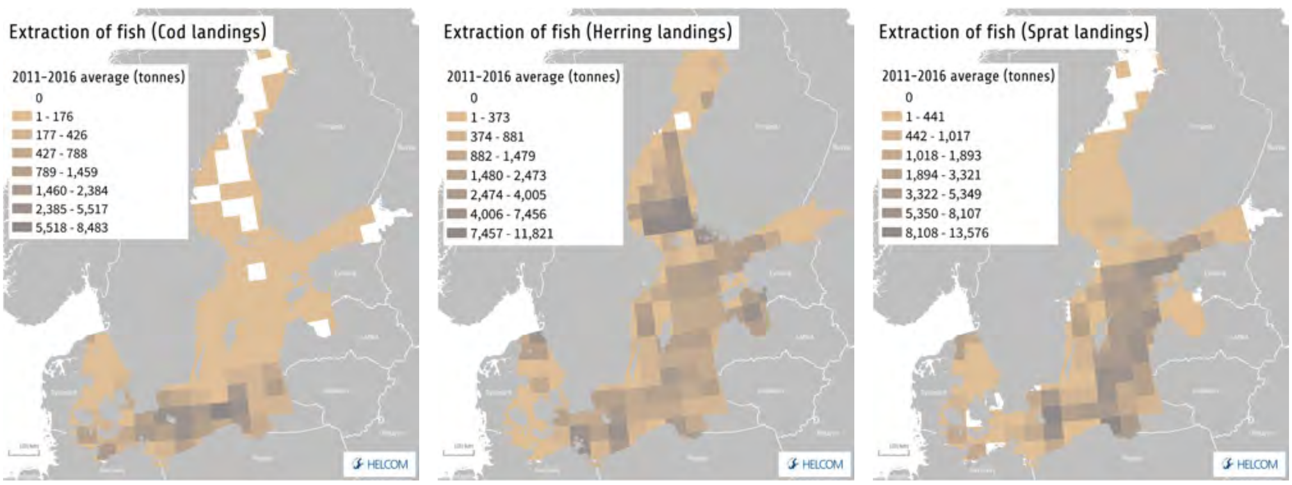
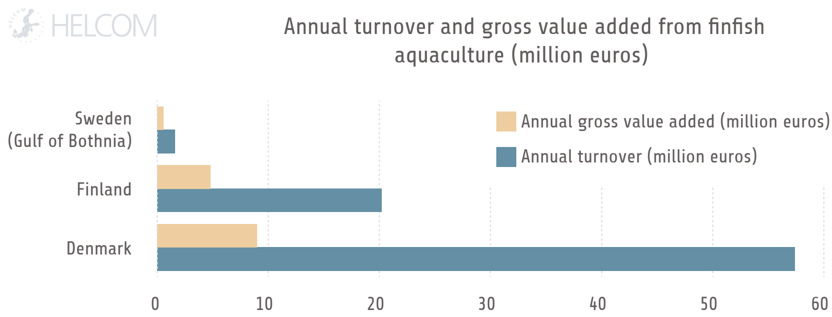


Figure 3.6.
Spatial distribution of commercial landings of cod, herring and sprat in the Baltic Sea.



	Denmark	Finland	Sweden (Gulf of Bothnia)
Annual gross value added (million euros)	9	4.8	0.535
Annual turnover (million euros)	57.4	20.2	1.6

Figure 3.7.
Economic indicators related to finfish aquaculture. Data from the year 2014. Sources: for Finland and Denmark: STECF (2016b), for Sweden: SwAM (2017)

produces blue mussels in the Baltic Sea with an annual turnover of 1.3 million euros.

Marine finfish aquaculture had a total turnover of 79 million euros in 2014, divided mainly between Finland and Denmark (Figure 3.7). The whole value for Denmark, Finland and Sweden can be attributed to the Baltic Sea. In Denmark, marine production of rainbow trout and trout eggs in sea cage farms is the second most important type of aquaculture after land based production of trout. The Danish marine production of rainbow trout is located in the Baltic Sea along the southern coast of Jutland and a few production sites along the coast of Zealand. In Finland, marine aquaculture consists of rainbow trout production in cages.

The Middelgrunden off shore wind farm in the Baltic Sea.
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Tourism and leisure

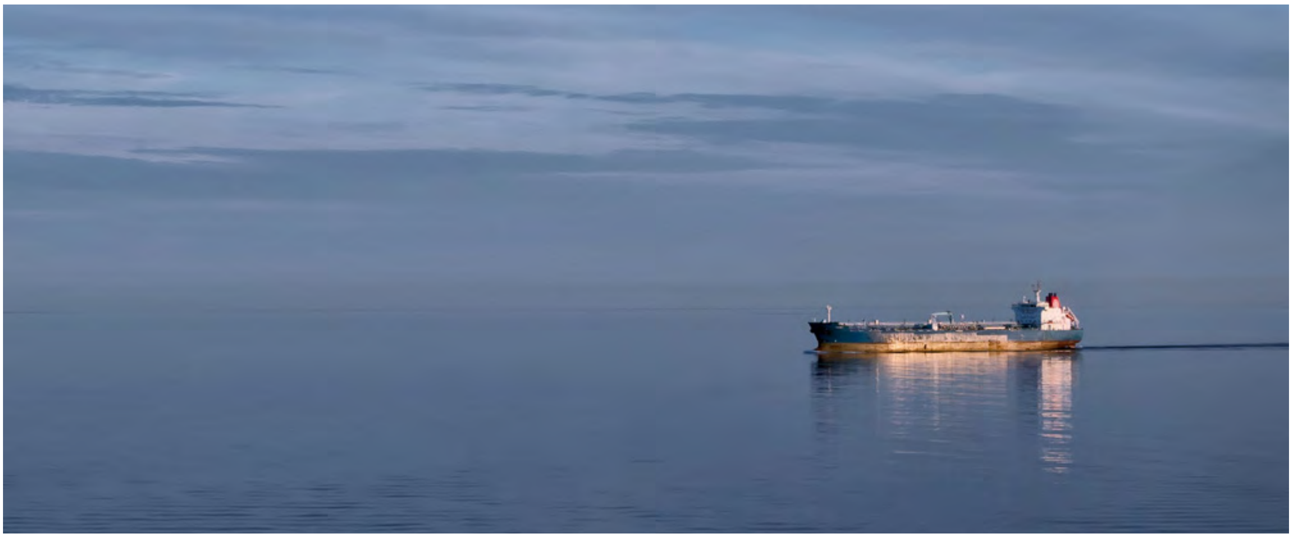
The coastal and marine tourism sector covers a wide range of sub-sectors including accommodation, food and drink, and leisure activities, such as boating and fishing. In many cases, it is difficult to separate the extent of the Baltic Sea tourism from tourism that is not dependent on the marine and coastal environment, as the activities are not limited to those which take place in the sea, but also includes those at the coast (See HELCOM 2018A). However, marine tourism and recreation are dependent on the state of the sea, which is not true for all tourism activities taking place along the coast.

The tourism sector is an important employer, providing employment to almost 160,000 people in coastal areas (Eurostat defines coastal areas as 'municipalities bordering the sea or having half of their territory within 10 km from the coastline' (Eurostat 2017a). However, all of this employment cannot be attributed to the Baltic Sea, as only a portion of tourism in coastal areas is dependent on the marine environment. Information about the economic importance of Baltic Sea recreation is presented in Box 3.4. The total recreational benefits of the Baltic Sea are around 15 billion euros annually.

Renewable energy generation

Offshore wind energy is a sub-sector of the renewable energy production sector which takes place in the sea. Offshore wind energy refers to the development and construction of wind farms in marine waters and the conversion of wind energy into electricity (EC 2013a). It is a new industry that is considered to have significant growth potential.

For offshore wind energy, non-monetary figures are used to describe the sector as there are no other



Freighter in the Baltic Sea.
© Joe de Sousa

socio-economic indicators available. The number and capacity of existing offshore wind turbines show the current situation, while the offshore wind turbines approved or under construction illustrate future development (Figures 3.8 and 3.9). In addition to these, there are dozens of proposed wind-farm areas for the Baltic Sea. For example, according to the data, there are no existing offshore wind turbines in Poland, but 40 have been proposed.

While the data have been accepted by the countries, the year the data originates from is not clear in all cases. This makes the numerals on the planned wind turbines rather uncertain.

Marine transport and related infrastructure

Marine transport can be divided into transport infrastructure and shipping, which includes both shipping of passengers and freight. These two sectors are interrelated as shipping utilises transport infrastructure.

Transport infrastructure includes ports, as well as activities done in relation to ports, such as dredging, cargo handling, and construction projects. The shipping transport infrastructure can be seen to cover shipbuilding and repair industry. Some data are available for all coastal countries, and some for the EU Member States.

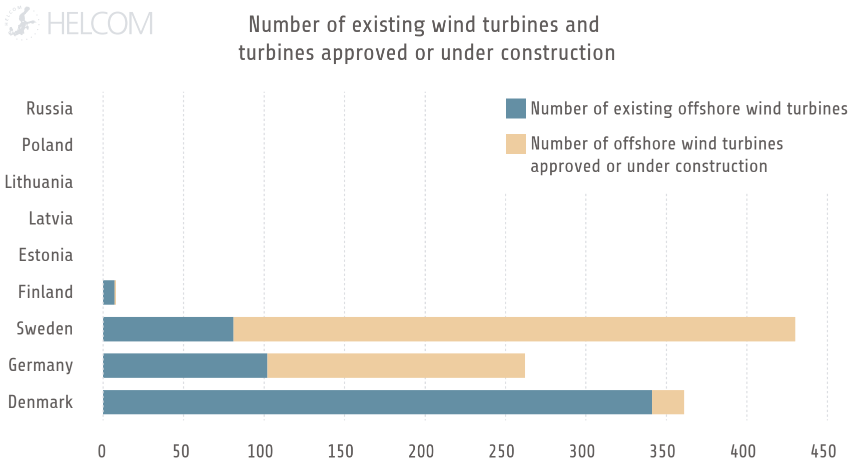
Transport infrastructure

There is no monetary data available for evaluating transport infrastructure (ports). In many countries, port authorities are public bodies and economic statistics are not available for this sector. Transport infrastructure is characterised with non-monetary data, including total port traffic, gross weight of goods handled in all ports and passengers embarking and disembarking in all ports (Figures 3.10-11).

Transport – shipping

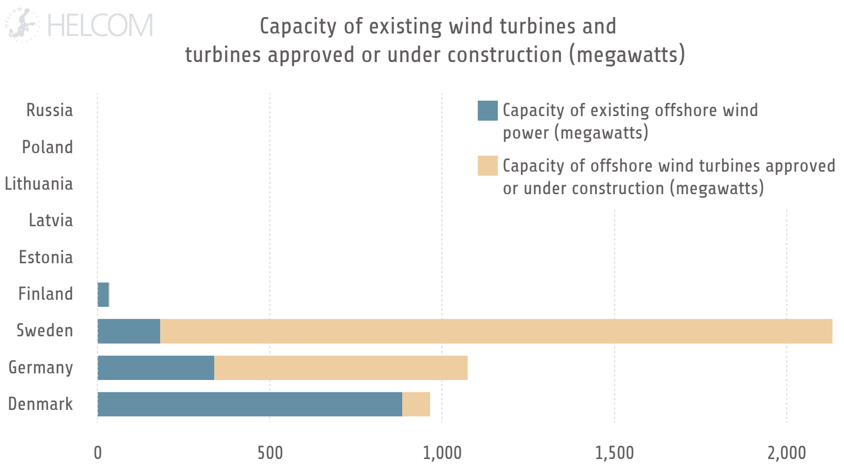
The socio-economic indicators for the shipping transport sector include both the value added from and the number of people employed by the sea and coastal freight and passenger transport (Figures 3.12 and 3.13). Around 25 % of the shipping in the Baltic Sea takes place under the flag of one of the Baltic Sea coastal countries, according to HELCOM data from the automatic identification system for vessels (AIS). It should be noted, however, that the numbers for Germany and Denmark relate to all shipping transport, not just the Baltic Sea. No data for Russia are available for the indicators based on Eurostat. Also, many countries do not report shipping statistics when the data ‘allow for statistical units to be identified’ (EU 2009); for example when there are too few actors to ensure anonymity of the data. In this case, data have been marked as confidential by countries. Together, these issues affect the regional totals.

The total value added for the region from freight transport is 5.1 billion euros and from passenger transport 2.5 billion euros. For value added from sea and coastal freight water transport, Germany has the highest value added with 4.1 billion euros, but this includes all marine shipping and is not specific to the Baltic Sea. Finland has the next highest at 426 million euros. Latvia and Lithuania have the lowest values. For value added from sea and coastal passenger water transport, the numbers are more evenly spread, with Sweden having the highest value added followed by Finland and Denmark. The total number of people employed is 22 300 for freight transport and 24 500 for passenger transport. In 2011, there were an estimated 42 million international ferry passengers in the Baltic Sea (HELCOM 2015b).



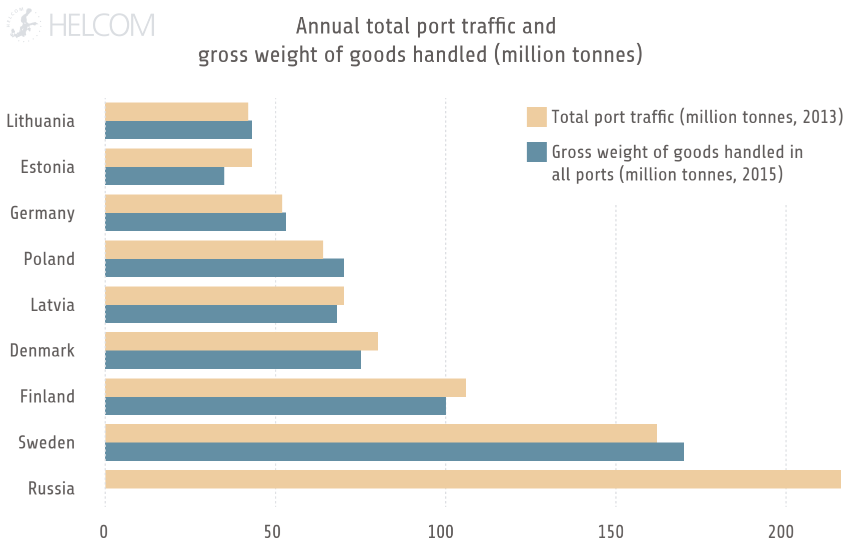
	Denmark	Germany	Sweden	Finland	Estonia	Latvia	Lithuania	Poland	Russia
	341	102	81	7	0	0	0	0	
	20	160	349	1					

Figure 3.8.
Number of existing offshore wind turbines and turbines approved or under construction by 2015. Source: HELCOM Maps and Data services. Empty data cells indicate missing information.



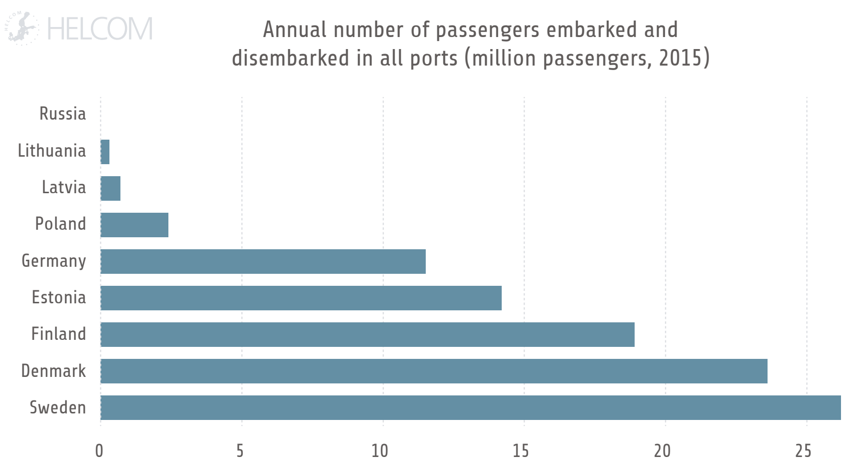
	Denmark	Germany	Sweden	Finland	Estonia	Latvia	Lithuania	Poland	Russia
	885	339	182	32	0	0	0	0	
	80	735	1,951	3					

Figure 3.9.
Capacity of existing offshore wind turbines and turbines approved or under construction in megawatts. Source: HELCOM Maps and Data services. Empty data cells indicate missing information.



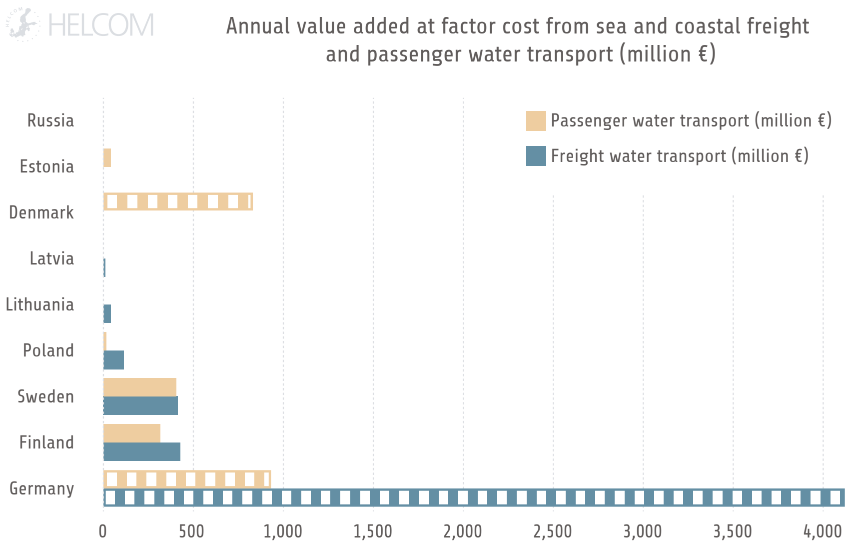
Russia	Sweden	Finland	Denmark	Latvia	Poland	Germany	Estonia	Lithuania
216	162	106	80	70	64	52	43	42
	170	100	75	68	70	53	35	43

Figure 3.10.
Annual total port traffic and gross weight of goods handled in all ports (million tonnes). Sources: For 'Total port traffic': Wahlström *et al.* (2014), for 'Gross weight of goods handled in all ports': Eurostat (2017b), except for Denmark (Statistics Denmark 2017, data for 2014 including only the HELCOM area) and Germany (Federal Statistical Office of Germany 2017a). The figures for Germany include information for the North Sea, which are dominated by the port of Hamburg and manyfold exceed the goods handled in the Baltic Sea). Empty data cells indicate missing information.



Sweden	Denmark	Finland	Estonia	Germany	Poland	Latvia	Lithuania	Russia
26.2	23.6	18.9	14.2	11.5	2.4	0.7	0.3	

Figure 3.11.
Annual number of passengers embarked and disembarked in all ports (million passengers, 2015). Source: Eurostat (2017c), except Denmark (Statistics Denmark 2017; data for 2014 including only the HELCOM area) and Germany (Federal Statistical Office of Germany 2017b). Empty data cells indicate missing information.



	Germany	Finland	Sweden	Poland	Lithuania	Latvia	Denmark	Estonia	Russia
Passenger water transport (million €)	932	316	404	16			811	39	
Freight water transport (million €)	4,120	426	413	113	39	10			

Figure 3.12.
Annual value added at factor cost from sea and coastal freight and passenger water transport in 2015 (million euros). 'Value added at factor cost' is defined by Eurostat as the 'gross income from operating activities after adjusting for operating subsidies and indirect taxes'. Value adjustments (such as depreciation) are not subtracted. Source: Eurostat (2017c). Empty data cells indicate missing or confidential information. Danish and German numbers include both the North and Baltic Sea.

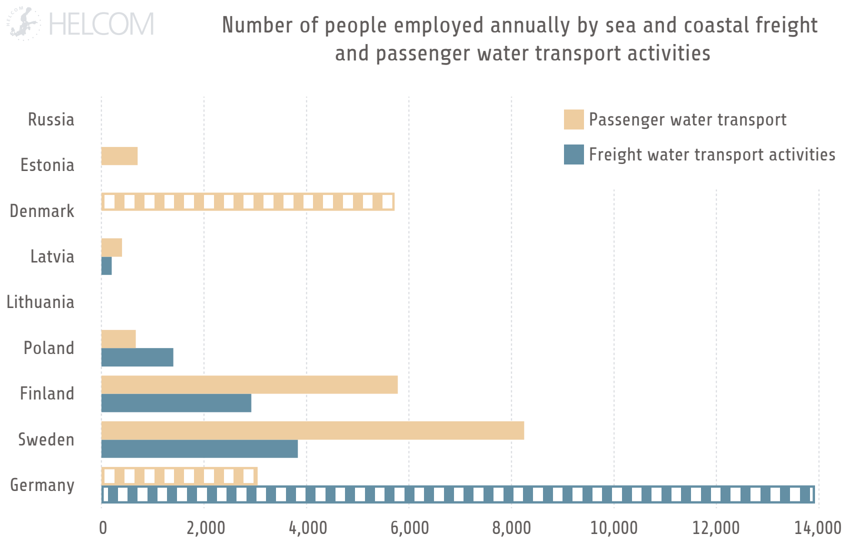


Figure 3.13.
Number of people employed annually by sea and coastal freight and passenger water transport in 2015 (million euros). Source: Eurostat (2017c). Empty data cells indicate missing or confidential information. Danish and German numbers include both the North and Baltic Sea.

Today 85 million people inhabit the drainage area of the Baltic Sea. The sea is one of the world's largest brackish water areas and is inhabited by both marine and freshwater species. A mix of land-based human activities, including agricultural, industrial, and urban activities, exert a wide variety of pressures on the sea. The sea itself experiences busy shipping between its surrounding countries and is an important or emerging resource for fishing, fish-farming, gravel extraction and wind energy, to name a few, as well as being used for leisure and tourism. Some of the pressures on the Baltic Sea are exacerbated by the limited level of water exchange, which means that nutrients and other substances from the drainage area accumulate in the Baltic Sea and are only diluted slowly. HELCOM has identified seven distinct pressures, which are assessed in this chapter.

Plastic oil bottle floating in the Baltic Sea. © Anssi Koskinen (CC BY 2.0)

The Baltic Sea still suffers from eutrophication. Excessive input of nutrients to the marine environment enhances the growth of phytoplankton, leading to reduced light conditions in the water, oxygen depletion at the seafloor (as excessive primary producers are degraded), and a cascade of other ecosystem changes. At least 97 percent of the region was assessed as eutrophied in 2011–2016 according to the integrated status assessment. Nutrient inputs from land have decreased as a result of regionally reduced nutrient loading, but the effect of these measures has not yet been detected by the integrated status assessment. Although signs of improvement are seen in some areas, effects of past and current nutrient inputs still predominate the overall status.

Eutrophication, or an increase in the supply of organic matter to an ecosystem through nutrient enrichment, is induced by excessive availability of nitrogen and phosphorus for primary producers (algae, cyanobacteria and benthic macrovegetation). Its early symptoms are enhanced primary production, which is expressed through increased chlorophyll-*a* concentrations in the water column and/or the growth of opportunistic benthic algae, as well as changes in the metabolism of organisms. The increased primary production may lead to reduced water clarity and increased deposition of organic material, which in turn increases oxygen consumption at the seafloor and may lead to oxygen depletion. These changes may in turn affect species composition and food web interactions (as species that benefit from the eutrophied conditions are favoured directly or via effects on habitat quality and feeding conditions; Cloern 2001).

Inputs of nitrogen and phosphorus have been increasing for a long time in the Baltic Sea, mainly between the 1950s and the late 1980s (Figure 4.1.1, Gustafsson *et al.* 2012), causing eutrophication symptoms of increasing severity to the ecosystem (Larsson *et al.* 1985, Bonsdorff *et al.* 1997, Andersen *et al.* 2017). As a response to the deteriorating development, actions to reduce nutrient loading were agreed on by the 1988 HELCOM Ministerial Declaration, and reaching a Baltic Sea unaffected by eutrophication is included as one of the main goals of the Baltic Sea Action Plan (BSAP; HELCOM 2007). Maximum allowable inputs (MAI) for the whole Baltic Sea and each sub-basin, and Country-Allocated Reduction Targets (CART) were set in 2007, and updated in the 2013 HELCOM Ministerial Declaration (HELCOM 2013a).

Several HELCOM eutrophication assessments have been carried out since the agreement of the Baltic Sea Action Plan, to follow-up on the status of eutrophication of the Baltic Sea (HELCOM 2009, 2010a, 2014a; see also Box 4.1.1). The current assessment covers the situation during years 2011-2016. In comparison to previous HELCOM eutrophication assessments, some new indicators are included, enhancing the coverage of assessment criteria. For other indicators, threshold values for evaluating status have been refined, leading to an approach which increasingly enables evaluation of progress towards improved status. ▸

Box 4.1.1
HELCOM work on eutrophication

HELCOM has been a major driver in the regional approaches to reduce nutrient loads to the Baltic Sea. The management of Baltic Sea eutrophication has been advanced with the Baltic Sea Action Plan (HELCOM 2007), which includes a complete management cycle aiming for specified improved conditions in the Baltic Sea, based on the best available scientific information and a model-based decision support system.

Core indicators with associated threshold values representing good status with regard to eutrophication are established primarily from monitoring data, which are interpreted through statistical analysis. The threshold values applied in this assessment were in most cases established based on scientific proposals from the HELCOM TARGREV project (HELCOM 2013d), where statistical breakpoints were identified from historical datasets and hindcast model simulations extending back to the beginning of the 1900s. The scientific proposals were adjusted by HELCOM experts based on other relevant information, such as Water Framework Directive class boundaries in coastal waters, and adopted by the HELCOM Heads of Delegation (HELCOM 2012b and others; see also Thematic assessment: HELCOM 2018B).

In a following step, the relationships between changes in the inputs of nutrients to the Baltic Sea and the core indicators are established by physical-biogeochemical modelling. These relationships differ across sub-basins because of differences in water circulation, ecosystem characteristics, and inputs, for example. The model results give estimates of the maximum allowable input of nutrients to the different sub-basins in order for the core indicators to achieve their threshold values over time, recognizing that this might take many years.

The input reductions necessary to reach the basin-wise maximum inputs of nutrients are allocated to the HELCOM countries as country-wise reduction targets. In addition, certain reduction potential is indicated for upstream countries and distant sources (HELCOM 2013d). The allocation is done according to the 'polluter pays' principle of the Helsinki Convention. Progress in reaching nutrient reduction targets is evaluated based on annual compilations of the nutrient inputs to the Baltic Sea (HELCOM Pollution Load Compilation).

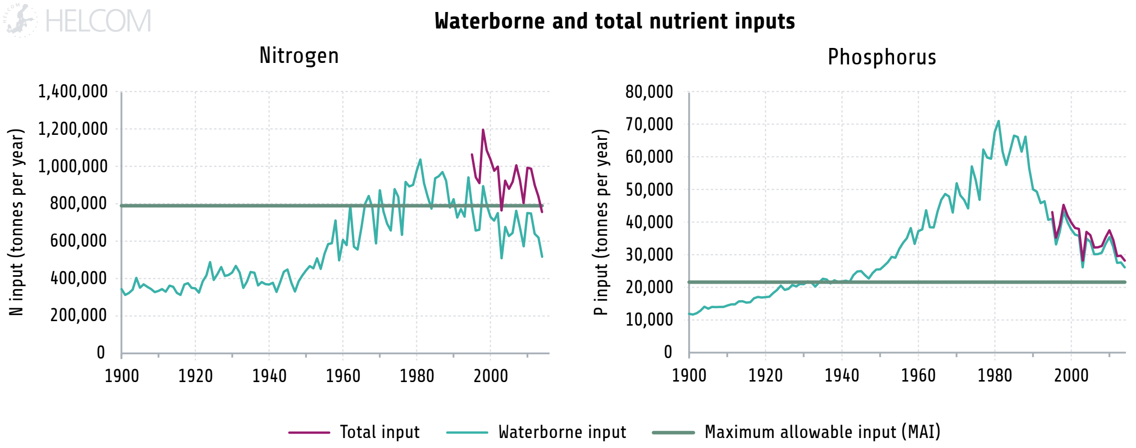


Figure 4.1.1.
Temporal development of waterborne and total nutrient inputs to the Baltic Sea from 1900 to 2014 with inputs of l nitrogen to the left and of phosphorus to the right. The green line shows the maximum allowable inputs (MAI). Sources: HELCOM (2015a), Gustafsson *et al.* (2012), Savchuk *et al.* (2012).

▸ Nutrient inputs to the Baltic Sea

Eutrophication was first recognized as a large-scale pressure of the Baltic Sea in the early 1980s, and in part attributed to anthropogenic nutrient loading (HELCOM 1987, 2009). Actions to reduce nutrient loading in the order of 50 % were agreed on by the 1988 HELCOM Ministerial Declaration, and reaching a Baltic Sea unaffected by eutrophication was identified as one of the goals of the Baltic Sea Action Plan in 2007 (HELCOM 2007, 1988).

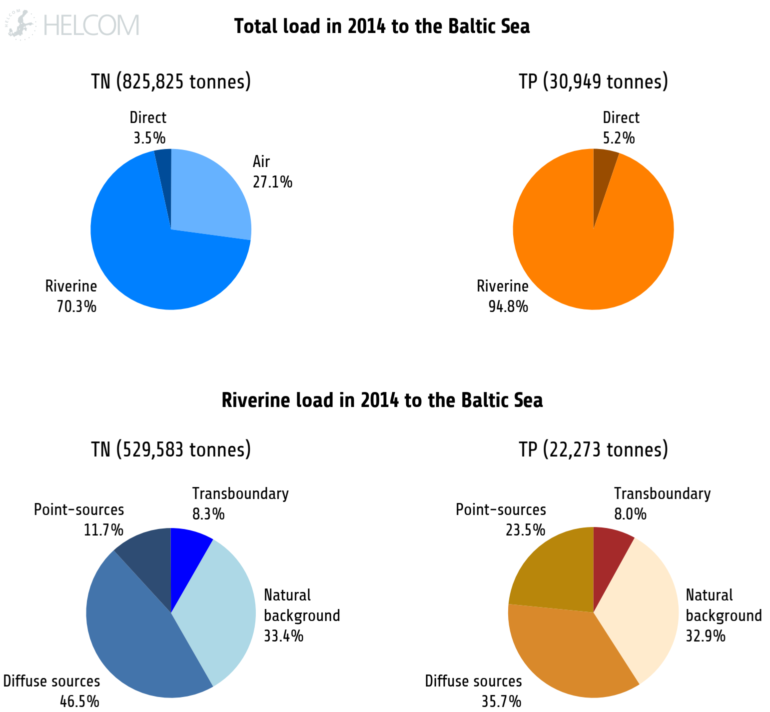


Figure 4.1.2.
Sources of nitrogen and phosphorus loads to the Baltic Sea in 2014. Source: HELCOM (2018h).

Trends in nutrient inputs

Since the 1980s, nutrient inputs to the Baltic Sea have decreased, and in some sub-basins strong reductions have taken place. For example, waterborne nitrogen inputs to the Baltic Sea are currently at the level that they were in the 1960s, and the phosphorus inputs at the level of 1950s (Figure 4.1.1). The total nitrogen input to the Baltic Sea was about 7 % larger than the maximum allowable input in 2015, whereas phosphorus input remained 44 % above this threshold value (HELCOM 2018i).

The current annual total input of nutrients to the Baltic Sea amounts to about 826,000 tonnes of nitrogen and 30,900 tonnes of phosphorus (HELCOM 2018h). Most of the input is riverine for both nitrogen and phosphorus (Figure 4.1.2). Atmospheric inputs account for about 30 % of the total nitrogen inputs, originating mainly from combustion processes related to shipping, road transportation, energy production, and agriculture. The largest relative decreases in inputs of nitrogen and phosphorus over recent decades have occurred in direct sources, which currently account for 4-5 % of the total loads (Figure 4.1.2). The atmospheric input of nitrogen has decreased by between 24 and 30 % during 1995-2015 for all sub-basins, while changes in waterborne nitrogen input are clearly more variable (HELCOM 2018i).

Natural sources constitute about one third of the riverine inputs of nitrogen and phosphorus to the Baltic Sea (Figure 4.1.2). A major part of the anthropogenic part originates from diffuse sources, mainly agriculture, while point sources, dominated by municipal waste water treatment plants, contribute with 12 % and 24 % of the riverine nitrogen and phosphorus loads, respectively.

▸ ***Nutrient reduction targets for sub-basins***

Based on the revised maximum allowable inputs (MAI) for the seven sub-basins of the Baltic Sea within the HELCOM nutrient reduction scheme, reductions of nitrogen input were needed in three sub-basins (HELCOM 2013a). Of these, the MAI has been fulfilled in the Kattegat, whereas reductions are still required for nitrogen input to the Gulf of Finland and Baltic Proper (HELCOM 2018i). In the remaining four sub-basins, the input of nitrogen has remained within or close to the maximum allowable input (Figure 4.1.3).

Reductions of phosphorus input were set for three sub-basins: the Baltic Proper, Gulf of Finland and Gulf of Riga (HELCOM 2013a). In all three cases, reductions are seen but notable further reductions are still needed in order to reach the allowable levels (Figure 4.1.3). So far, the most pronounced results are seen for the Gulf of Finland, where the phosphorus input has been cut with more than half compared to the reference period (Figure 4.1.4). This reduction has been attributed to improved waste water treatment in St. Petersburg and actions to prevent phosphorus release from a fertilizer factory in the catchment of river Luga (Raateoja and Setälä 2016).

Overall, the normalized input of nitrogen was reduced by 12 % and the normalized input of phosphorus by 25 % between the reference period (1997-2003) and 2015 (HELCOM 2018i). The strongest relative changes over the past decades are seen in the Kattegat and the Danish straits for nitrogen input and in the Gulf of Finland for phosphorus input (Figure 4.1.4). ▸

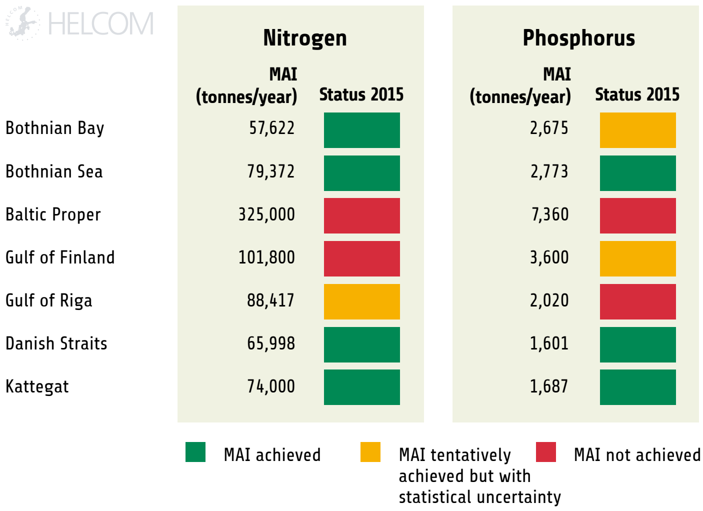


Figure 4.1.3.
Progress of nutrient reductions in the Baltic Sea in relation to maximum allowable inputs (MAI), based on the evaluation for year 2015 (HELCOM 2018i). The targets are set by sub-basin for nitrogen and phosphorus. The maximum allowable input differs between sub-basins, as shown by the numbers.

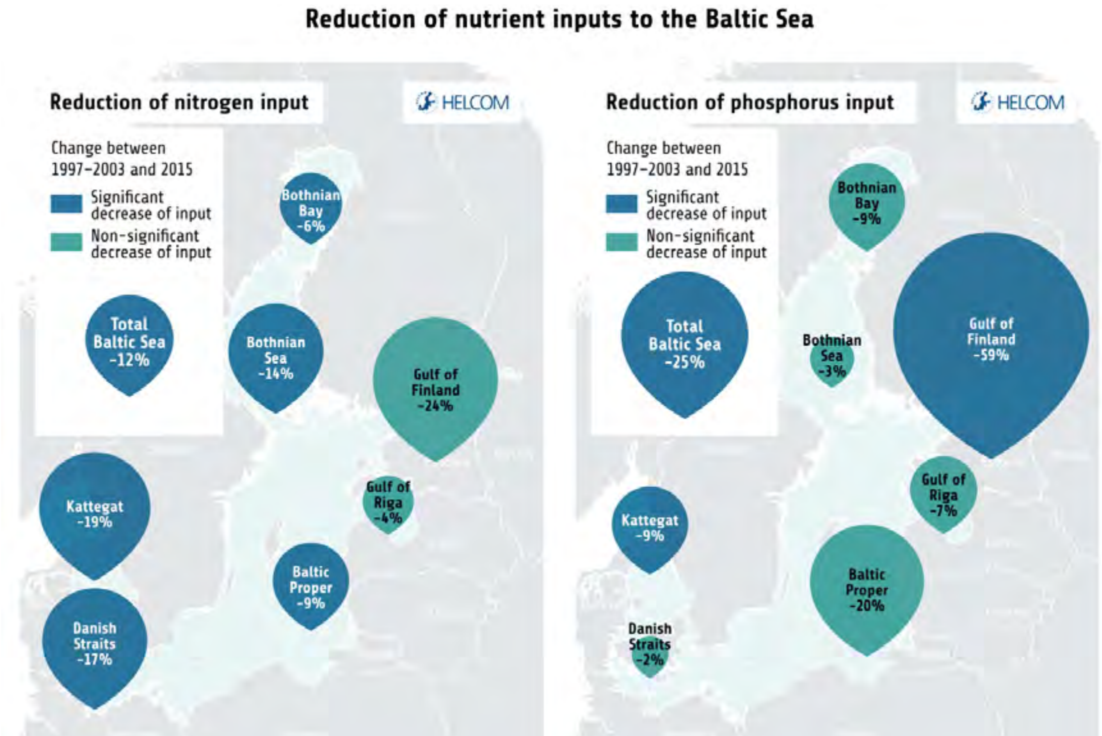


Figure 4.1.4.
The inputs of nitrogen and phosphorus to the Baltic Sea sub-basins have decreased significantly in recent years. The drop shapes show the relative change in annual average normalised net nutrient input to the sub-basins, including riverine, direct and airborne inputs comparing the year 2015 with the reference period 1997–2003. The size of each drop shape is proportional to the amount of change. Significance is determined based on trend analyses. Source: HELCOM (2018i).

Indicators included in the assessment

The integrated assessment of eutrophication was done using the HELCOM HEAT tool which aggregates the indicator results into a quantitative estimate of overall eutrophication status. Eutrophication status was evaluated by indicators within three criteria: nutrient levels, direct effects and indirect effects of eutrophication.

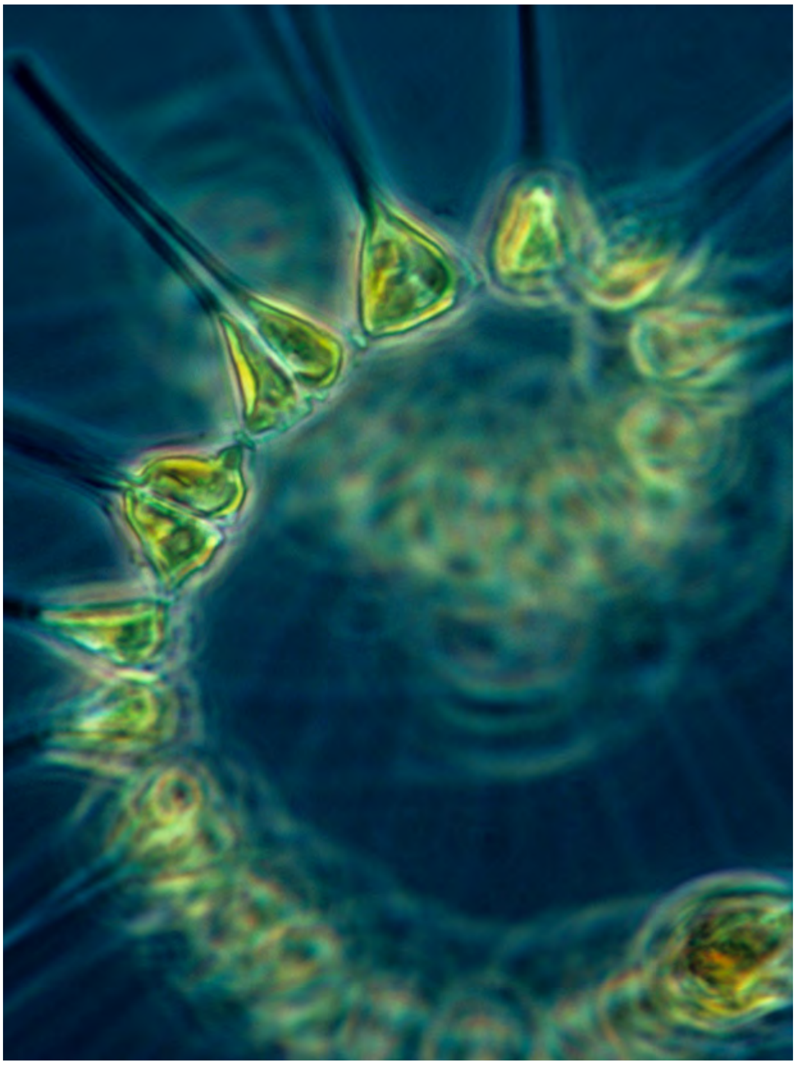
To assess nutrient levels in the surface water, eutrophication core indicators on the concentrations of nitrogen and phosphorus were used (Core indicator reports: HELCOM 2018j-m). Primary producers need both nitrogen and phosphorus for growth. Dissolved inorganic nitrogen and phosphorus, which are directly utilisable by primary producers, are assessed in the winter season when primary productivity is low and their concentrations are largely unaffected by uptake. Hence, these indicators represent the nutrient pool available for phytoplankton growth. Core indicators for total nitrogen and total phosphorus also include dissolved organic nutrients (such as proteins, urea and humic substances), as well as nutrients which are bound in particulate organic matter (such as phytoplankton and detritus). The inorganic nutrients which enter the sea are rapidly taken up by organisms and bound to their biomass. Via excretion and decay they are then transformed into dissolved organic nitrogen and phosphorus, which again re-mineralise (Markager *et al.* 2011, Knudsen-Leerbeck *et al.* 2017). Hence, the total nutrient indicators provide an estimate of the total level of nutrient enrichment in the sea[1,2].

To assess the direct effects of eutrophication, core indicators on chlorophyll-*a* concentrations in the surface water and water clarity were used (Core indicator reports: HELCOM 2018n-o). In addition, the 'Cyanobacterial bloom index', which is not yet an agreed core indicator, was included as test (HELCOM 2018p).

To assess indirect effects of eutrophication, the core indicator 'Oxygen debt' was used (Core indicator report: HELCOM 2018q). This indicator measures the volume-specific oxygen debt, which is the oxygen debt below the halocline divided by the volume of the water mass below the halocline. Hence, it estimates how much oxygen is 'missing' from the Baltic Sea deep water, primarily as a result of degradation of organic matter. In the open waters of the Bothnian Bay, Quark, Bothnian Sea, and Gulf of Riga, where the oxygen debt indicator was not applicable, the biodiversity core indicator 'State of the soft-bottom macrofauna community' was used in order to address indirect effects of eutrophication (Core indicator report: HELCOM 2018r). In these areas, this indicator was seen to be suitable for the eutrophication assessment, since it responds only or mainly to eutrophication-related pressures.

Coastal areas were assessed by national indicators mainly derived from the implementation of the Water Framework Directive (EC 2000). These indicators varied between different national coastal areas. They included indicators describing the level of phytoplankton (via biomass or chlorophyll-*a* -concentration), benthic invertebrate fauna, macrophytes (macroalgae and angiosperms), concentrations of nitrogen, concentrations of phosphorus, and water clarity (For more information, see Thematic assessment: HELCOM 2018B).

Magnification of phytoplankton.
© NOAA MESA Project (CC BY 2.0)



1 Please note that Danish measurements presented for total nitrogen and total phosphorus are underestimated. This might affect content and conclusions in this report in regard to the status assessment and assessment of nutrient input to Danish waters (See Box 2 in HELCOM 2018B).

2 The Finnish monitoring open sea estimates of phosphate and total phosphorus in 2011–2014 are in general 10 % lower than in 2015–2017 due to changes in instrumentation and accompanying methodology. This might affect the indicator values in assessment units SEA-012 to -017.

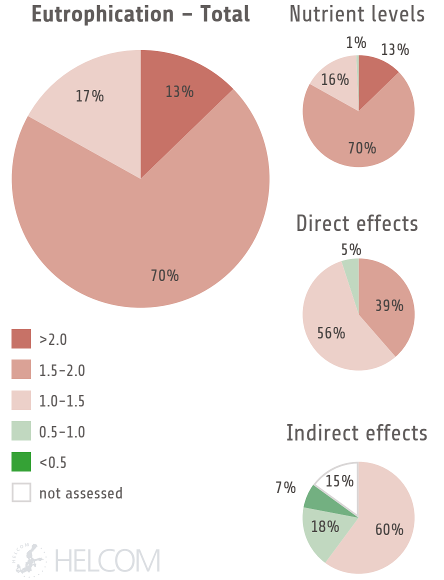
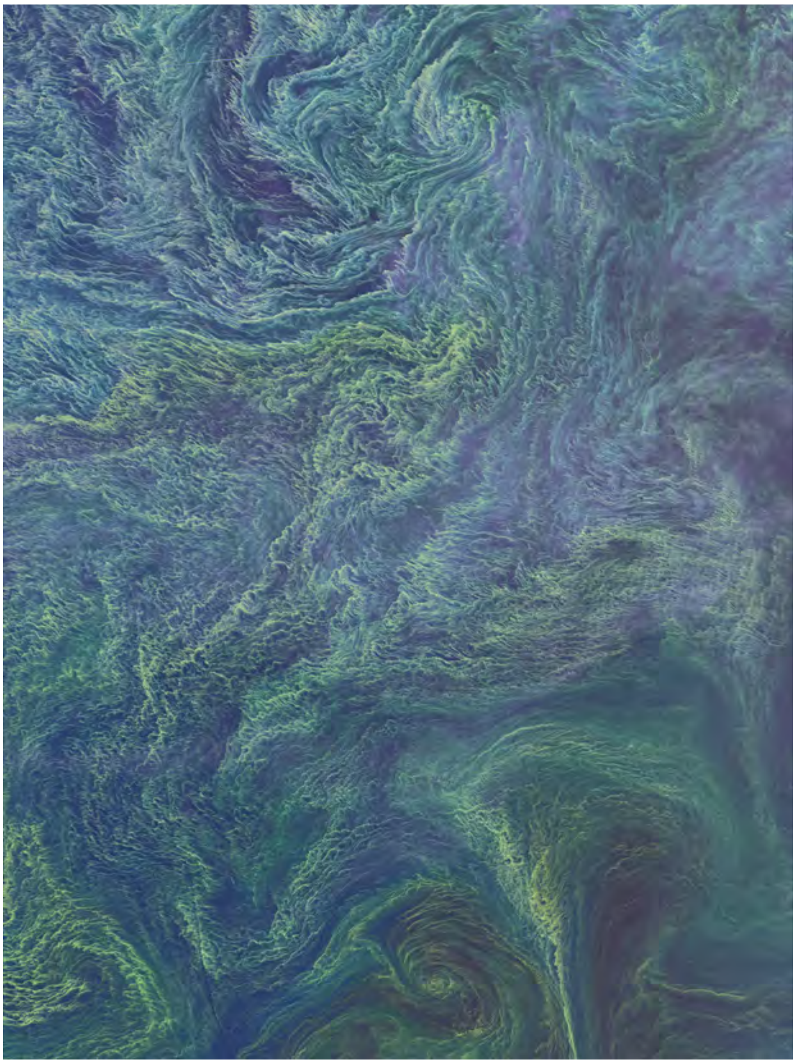


Figure 4.1.7.
Proportion of open sea area within each of the five status categories of the integrated assessment of eutrophication (based on km²). White denotes areas not assessed due to lack of indicators (see Figure 4.1.8).



Observed from space: algal bloom in the Baltic Sea. At least 97% of the surface area in the Baltic Sea, from the Kattegat to the inner bays, is below good status in regards to eutrophication.

Integrated status assessment

The integrated eutrophication status assessment for 2011–2016 shows that the Baltic Sea is still affected by eutrophication (Figure 4.1.5). Out of the 247 assessment units included in the HELCOM assessment of coastal and open water bodies, only 17 achieved good status.

In terms of areas covered, 96 % of the surface area in the Baltic Sea, from the Kattegat to the inner bays, is below good status in regards to eutrophication. The assessment results were in the category furthest away from good status in about 12 % of the area. Only a few coastal areas were not affected by eutrophication.

In many open-sea areas, good status was not achieved with respect to any of the assessed criteria; nutrient levels, direct or indirect effects of eutrophication (Figure 4.1.6, 4.1.7). Generally, indicators for nutrient levels were furthest away from good status, and thus had highest influence on the integrated assessment results. This was especially evident for the Bornholm Basin where shallow stations located in the Pomeranian Bay had significant impact on nutrient level results (Figure 4.1.8). Nutrient levels were in good status only in the Great Belt, being just below the limit for good status[3], and direct effects were in good status only in the Kattegat. For indirect effects of eutrophication, good status was seen north of and including the Åland Sea, covering 25 % of the total open-sea area.

Confidence in the assessment

The final confidence of the integrated assessment was moderate in most of the open sea. It was low in the Gulf of Riga, the Åland Sea and the Quark, and high in the Arkona Basin and Bornholm Basin (For more information, see the thematic assessment: HELCOM 2018B).

3 Eutrophication ratio 0.99

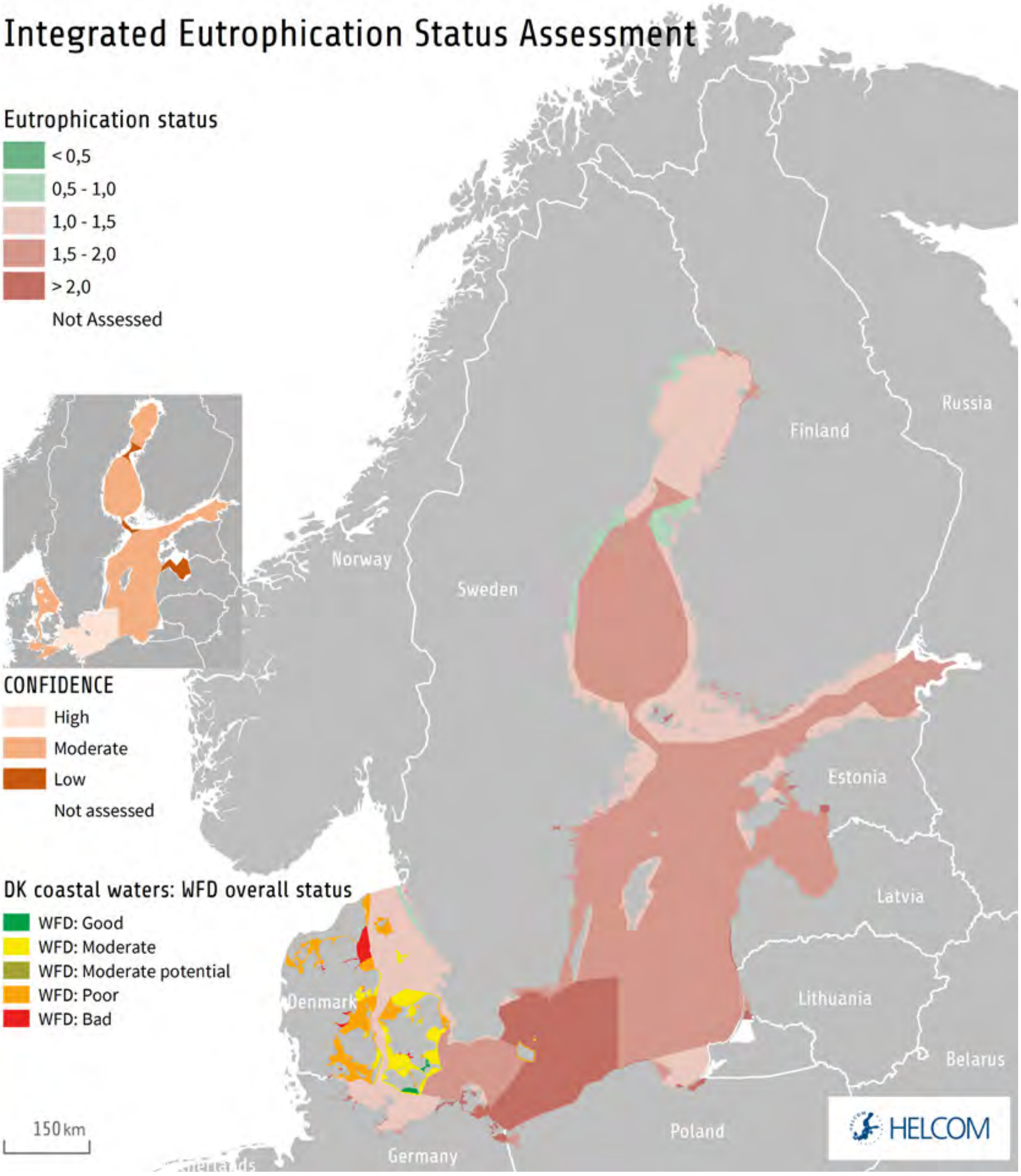


Figure 4.1.5.

Integrated status of eutrophication in the Baltic Sea 2011–2016. Each assessment unit shows the result for the criteria group furthest away from good status. For results by criteria, see Figure 4.1.6. Note that the integrated status of Swedish coastal areas in the Kattegat differs from corresponding results in the OSPAR intermediate assessment. In coastal areas HELCOM utilises national indicators used in the Water Framework Directive (WFD) to arrive at an assessment of eutrophication status in eight countries. Denmark refers to the assessments made under the WFD due to consideration of the national management of coastal waters. Danish coastal WFD-classification differs from the open sea classification and hence, the colours are not directly comparable. White areas denote that data has not been available for the integrated assessment. The map in the lower corner shows the confidence assessment result, with darker colors indicating lower confidence.

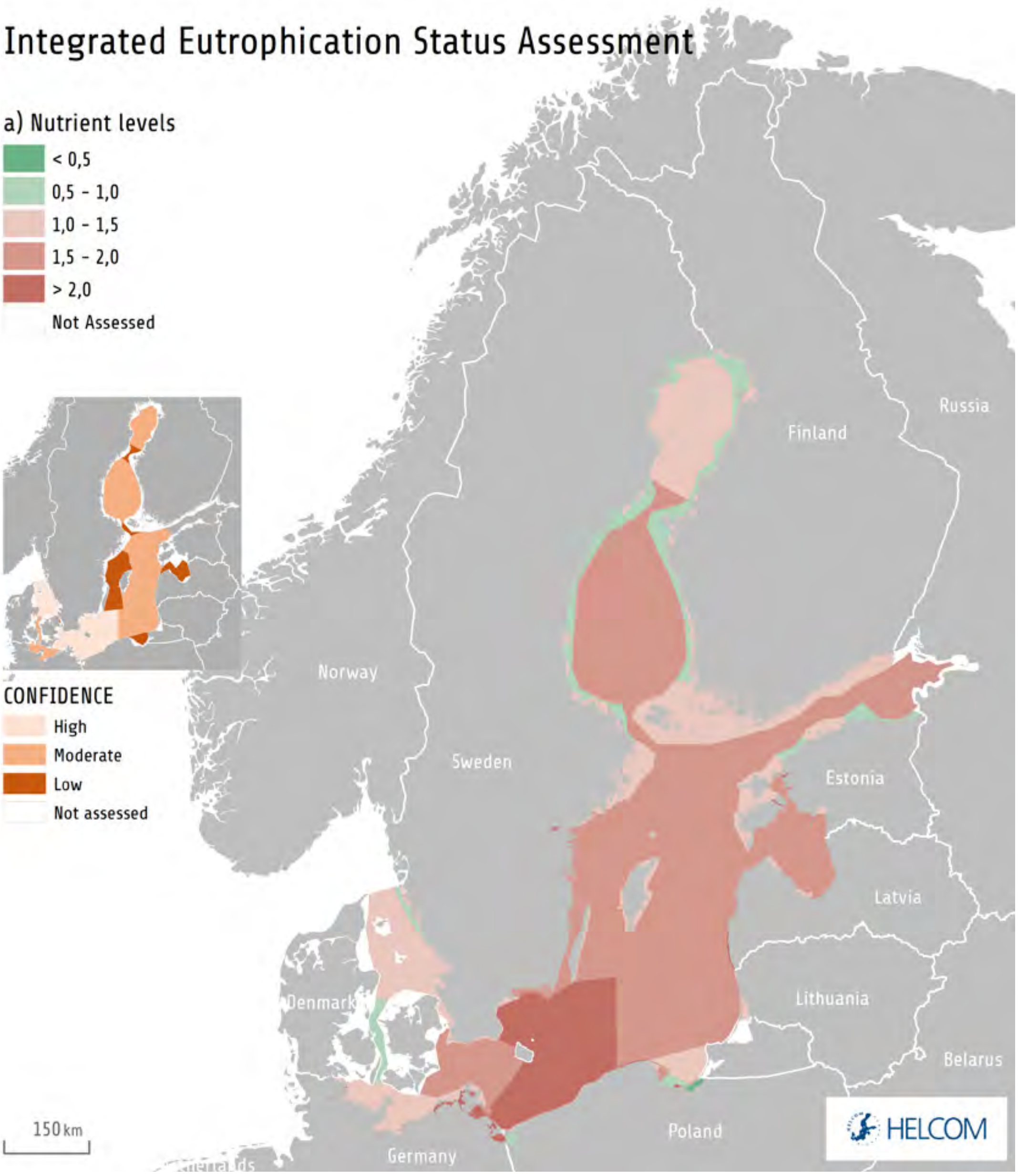


Figure 4.1.6a.
Integrated assessment results for eutrophication by criteria groups 2011–2016: Nutrient levels. In coastal areas HELCOM utilizes national indicators to assess the eutrophication status. White denote areas that were not assessed due to the lack of indicators. The inserted maps in each lower corner show the confidence assessment result, with darker colours indicating lower confidence. For indicators included, see Table 4.1.8.

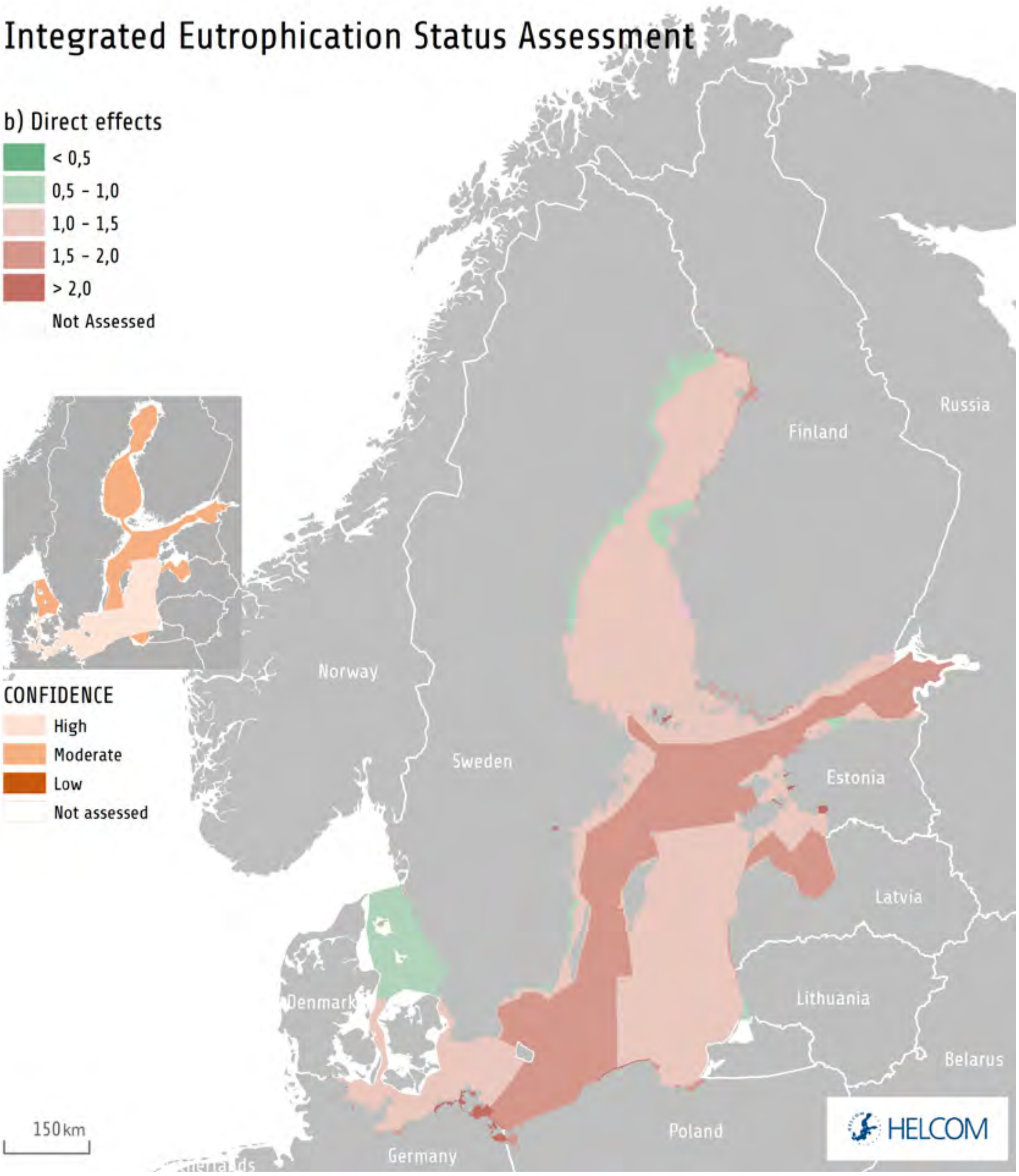


Figure 4.1.6b.
Integrated assessment results for eutrophication by criteria groups 2011–2016: Direct effects of eutrophication. In coastal areas HELCOM utilizes national indicators to assess the eutrophication status. White denote areas that were not assessed due to the lack of indicators. The inserted maps in each lower corner show the confidence assessment result, with darker colours indicating lower confidence. For indicators included, see Table 4.1.8.

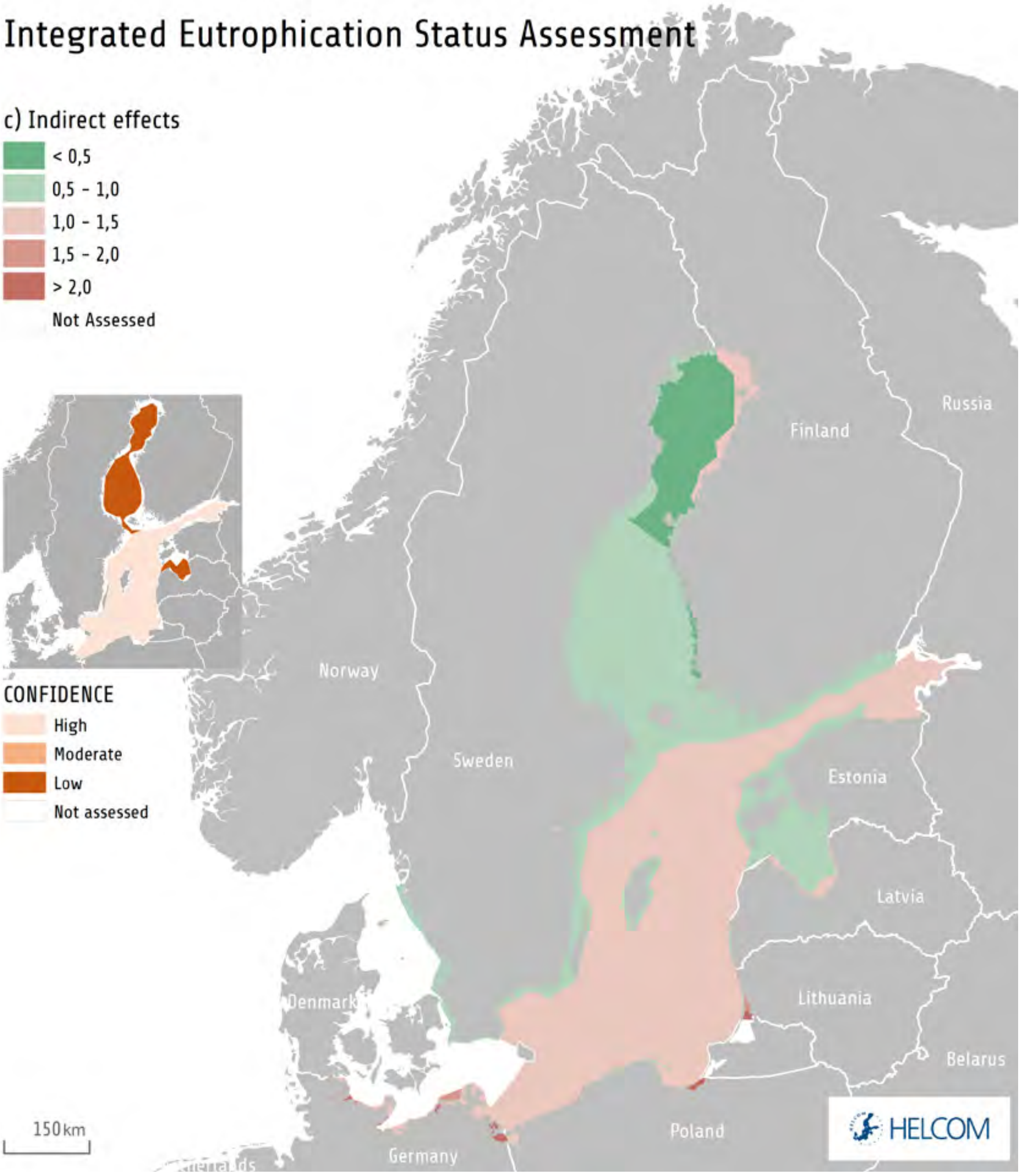


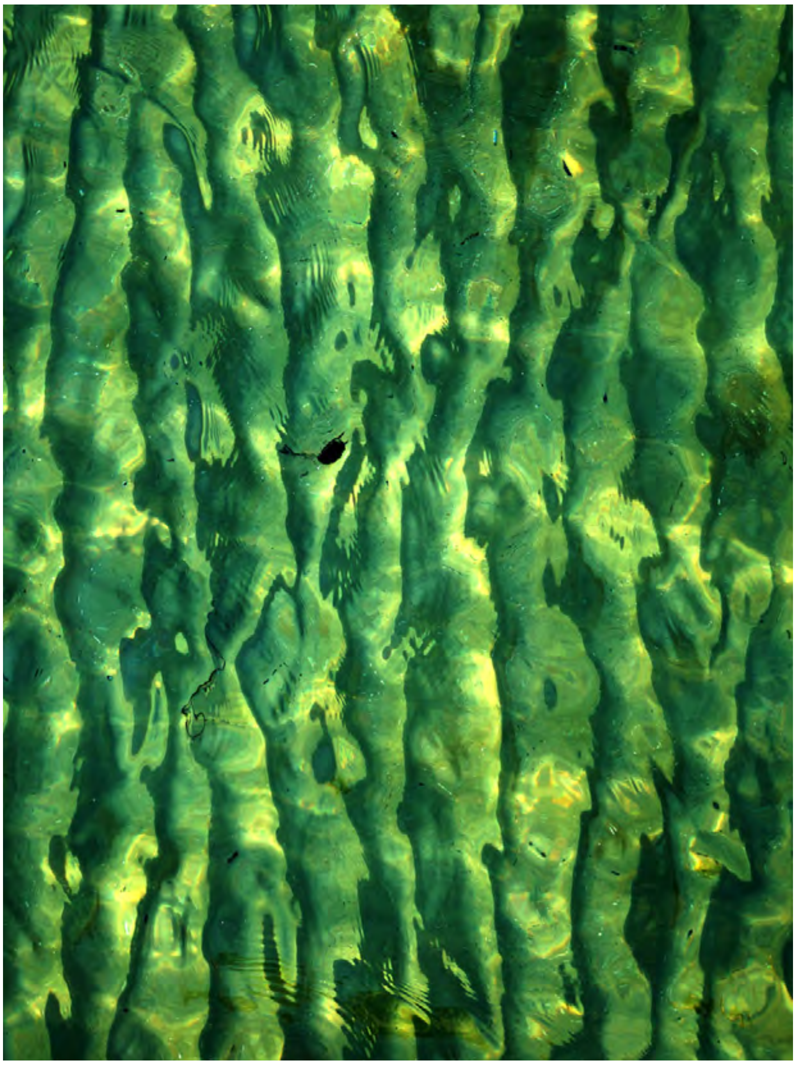
Figure 4.1.6c.
Integrated assessment results for eutrophication by criteria groups 2011–2016: Indirect effects of eutrophication. In coastal areas HELCOM utilizes national indicators to assess the eutrophication status. White denote areas that were not assessed due to the lack of indicators. The inserted maps in each lower corner show the confidence assessment result, with darker colours indicating lower confidence. For indicators included, see Table 4.1.8.

Changes in comparison to the previous assessment

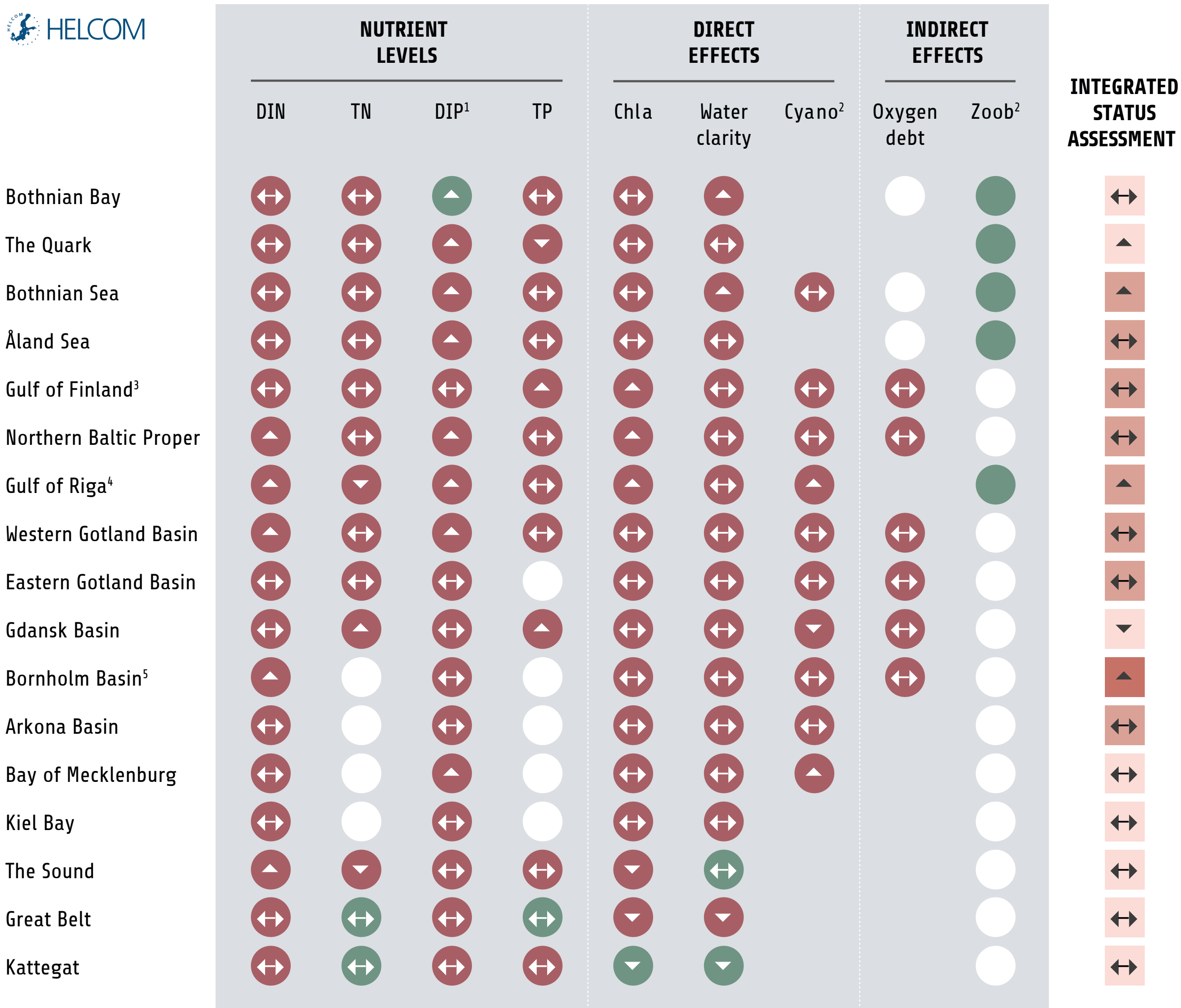
Compared to previous assessment results (2007-2011; HELCOM 2014a, 2015a) the integrated eutrophication status has improved in the Gdansk Basin, but deteriorated in four of the seventeen open-sea assessment units (Figure 4.1.8). However, a long-term analysis of integrated assessment results using HEAT 3.0 indicate an improving eutrophication status since the mid-1990s in the westernmost parts of the Baltic Sea: the Kattegat, Danish Straits and Arkona Basin (Andersen *et al.* 2017).

The limited improvement in comparison to the previous assessment could in part be attributed to natural variability acting on top of the human induced eutrophication effects. Past nutrient inputs have enhanced the occurrence of oxygen deficiency and led to an excess of nutrients in deep waters of the central Baltic Sea (Thematic assessment; HELCOM 2018B). Further, inflow events of marine water from the North Sea may have caused intrusions of nutrient-rich deep water from the Central Baltic Sea to adjacent areas leading to enhanced anoxia in the receiving areas and hence an enhanced release of phosphorus from the sediments.

Figure 4.1.8 shows the numerical integrated status assessment results for each of the open sea sub-basins, together with the corresponding core indicator results. More detailed results are presented in the thematic assessment: HELCOM (2018B).



Shallow water, Baltic Sea.



1 For all the northern areas, the increase is due to inflow of saline water which pushes up bottom water with high phosphorus concentrations. This negative development is therefore due to natural variability and temporarily counteracts the efforts to reduce the anthropogenic loadings (Eilola et al. 2014).
2 Included as test
3 The present comparison that shows unchanged conditions does not reflect the positive development in the eastern parts. Reduced phosphorus loading has improved conditions in the eastern part, but this is masked by the inflow of saline water that has increased phosphorus in the western parts of the gulf (Raateoja and Setälä 2016).
4 Lack of monitoring for part of the assessment years increases the uncertainty of the comparison between the two periods.
5 Nutrient concentrations in the Bornholm basin were high due to influence from shallow stations in the Pomeranian Bay and the influence from the plume of river Odra.

Figure 4.1.8.
Core indicator results for eutrophication 2011-2016, and changes in eutrophication ratios since 2007-2011 by open sea sub-basins. Green circles denote good status and red not good status. The corresponding integrated status assessment result is shown in the last column (See also Figure 4.1.5). The symbols indicate if the eutrophication ratio of the indicator (or integrated status), as estimated in HEAT, has changed since the last eutrophication assessment in 2007-2011. For the indicator results, a change equal to or more than 15 % was considered to be substantial and is indicated with ▲ for an increased eutrophication ratio (deteriorating condition) and with ▼ for a decreased ratio (improving condition). The symbol ↔ indicates a change of less than 15 % between the two compared time periods. For integrated status assessment results, the symbols reflect if there is a change in the overall status classification on the five-category scale. Empty circles denote no information due to the lack of agreed threshold value or commonly agreed indicator methodology. Absent circles denote that the indicator is not applicable. Abbreviations used: DIN = Dissolved inorganic nitrogen, TN= Total nitrogen, DIP= Dissolved inorganic phosphorus, TP = Total phosphorus, Chla= Chlorophyll-*a*, Cyano = Cyanobacterial bloom index, O2 = Oxygen debt, and Zoob = State of the soft bottom macrofauna community (Data for comparison was not available for this indicator). For more details, see core indicator reports: HELCOM 2018j-r.

Longer term changes in the core indicators

Assessments of longer term trends additionally show possible effects of nutrient reduction efforts over a larger time scale. When assessing a shorter time span, such as when comparing two assessment periods of six years each, as above, natural variability in climate and hydrography may result in temporarily worsened conditions even if the long term development shows a different pattern. A recent example is the major saline inflow which occurred in December 2014, which has caused intrusions of deep sea water with high phosphate concentration into surface waters (Finnish environment institute 2016). Further, the Baltic Sea has a long water residence time, lasting over decades. Hence, pools of nutrients and organic matter which have accumulated over decades with high nutrient inputs are very large and will delay the improvement in environmental conditions.

Analyses of developments since 1990 show an improving eutrophication status in the westernmost parts of the Baltic Sea (Thematic assessment; HELCOM 2018B). Levels of nitrogen are predominantly decreasing, with the exception of some sub-basins in the southern Baltic Sea. The results can be viewed as responses to substantial decreases in nitrogen loadings, proving that the nutrient reductions are effective. Phosphorus concentrations do not show the same improvement. For most areas the levels of phosphorus are constant or even increasing, with the exception of a decrease in total phosphorus concentrations in the Great Belt and Kiel Bay. This result reflects that phosphorus is stored in the sediment to a much higher degree than nitrogen, and the present conditions additionally encompass previous high inputs. In addition, the aforementioned major saline inflow has affected the situation in recent years. Ongoing reductions in phosphorus input are expected to lead to decreasing phosphorous concentrations over the coming years.

A summary of how selected indicators representing nutrient levels, direct and indirect effects have changed over the past decades is given below. More results are presented in HELCOM (2018B), and more details about each of the agreed HELCOM core indicators are given in the core indicator reports (HELCOM 2018j-r).

Core indicators on nutrient levels

The concentrations of dissolved inorganic nitrogen and total nitrogen did generally not achieve the threshold value with the exception of the Kattegat and Great Belt where the threshold values were achieved for total nitrogen (Figure 4.1.8)[4]. The highest eutrophication ratios occurred for dissolved inorganic nitrogen in the Gulf of Riga, the Gulf of Finland, and the Bornholm Basin. Average concentrations in the Bornholm Basin were high due to influence from shallow stations in the Pomeranian Bay under influence from the river Odra plume[5].

Winter concentrations of dissolved inorganic nitrogen have shown an increasing trend up until the early 1990s, but the increase has thereafter ceased throughout the Baltic Sea. They have decreased significantly in twelve of the seventeen sub-basins since the 1990s (Thematic assessment: HELCOM 2018B). Total nitrogen concentrations decreased significantly between 1990 and 2016 in ten of the sub-basins, but they increased in the Bornholm Basin, Gdansk Basin and the Eastern Gotland Basin (For examples, see Figure 4.1.9, see also HELCOM 2018B). Increasing variability is likely attributed to increased monitoring frequency in several sub-basins. In the Bornholm Basin, this also reflects influence from the river Odra.

In more recent times, comparing the last five year assessment period (2007–2011) to the current one (as presented in Figure 4.1.8 above), dissolved inorganic nitrogen concentrations have increased substantially in four out of fifteen addressed sub-basins. Concentrations of total nitrogen have decreased in the Sound and the Gulf of Riga and increased in the Gdansk Basin compared to the period 2007–2011.

The indicator for dissolved inorganic phosphorus achieved the threshold value only in the ▸

Beach on Ruhnu Island, Estonia.

4 This refers to the HELCOM threshold values, which are not identical to the OSPAR threshold values.

5 Reflecting a non-uniform distribution of samples, with more sampling in shallow than deeper stations.

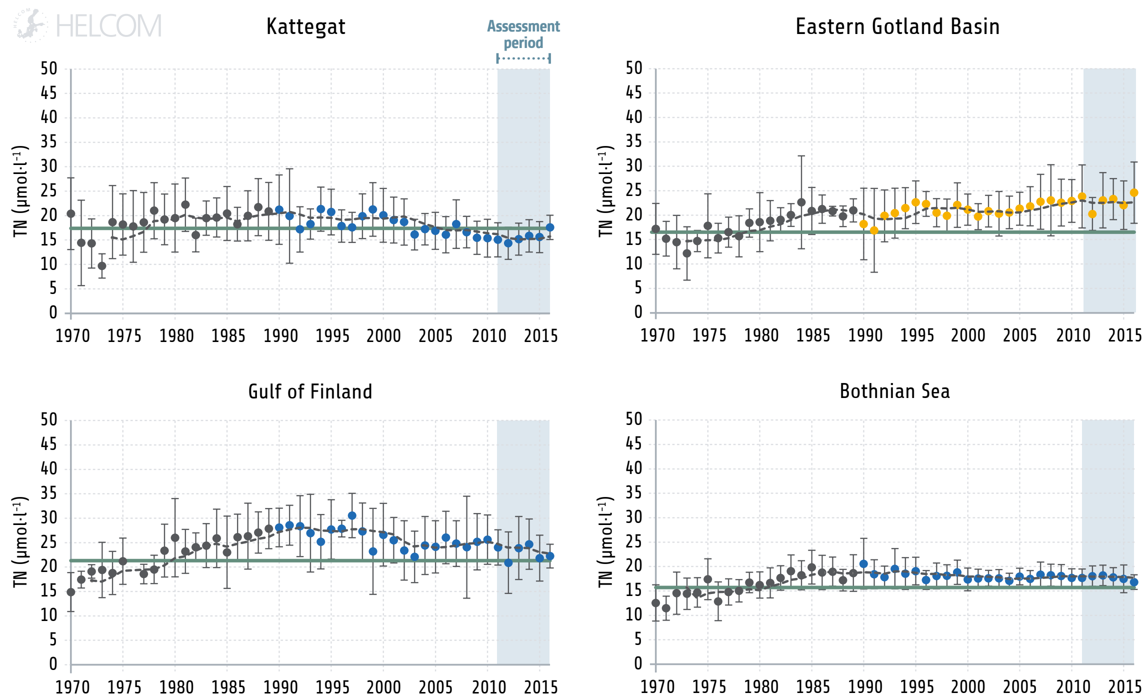


Figure 4.1.9.
Example of long term trends in nutrient levels in the Baltic Sea: Temporal development of total nitrogen concentrations in the Kattegat, Eastern Gotland Basin, Gulf of Finland and Bothnian Sea. Dashed lines show the five-year moving averages and error bars the standard deviation. Green lines indicate the indicator threshold values. Significance of the trends was assessed with the Mann-Kendall tests for the period 1990-2016. Significant ($p<0.05$) improving trends are indicated with blue and deteriorating trends with orange data points. Results for the other sub-basins are shown in HELCOM (2018B).

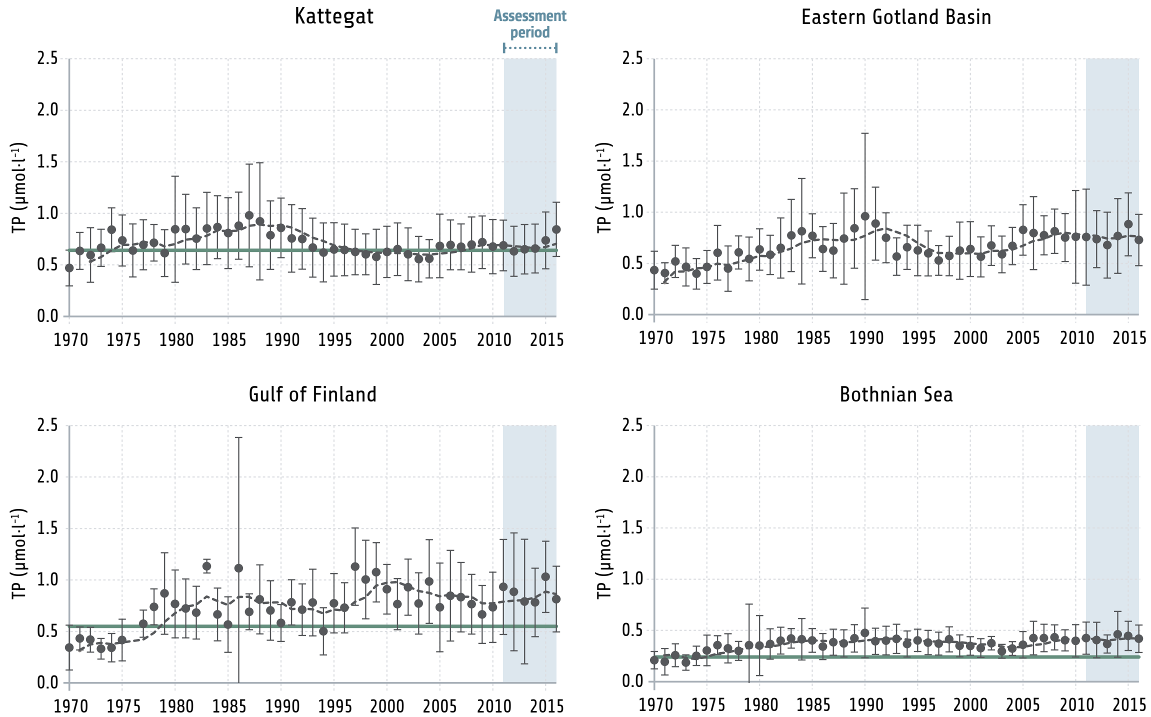


Figure 4.1.10.
Example of long term trends in nutrient levels in the Baltic Sea: Temporal development of total phosphorus concentrations in the Kattegat, the Eastern Gotland Basin, the Bothnian Sea and the Gulf of Finland. Dashed lines show the five-year moving averages and error bars are the standard deviations. Green lines indicate the indicator threshold values. Significance of the trends was assessed with the Mann-Kendall tests for the period 1990-2016. None of these examples showed a significant trend ($p> 0.05$). Results for the other sub-basins are shown in HELCOM (2018B).

Bothnian Bay, and total phosphorus achieved it only in the Great Belt. A notable increase in total phosphorus was seen in the 1960s and 1970s. This increase ceased around 1990, and relatively large fluctuations have occurred over time (For examples, see Figure 4.1.10; see also Thematic assessment: HELCOM 2018B). During the assessed time period 1990-2016, an increase in concentrations of dissolved inorganic phosphorus occurred in one sub-basin, the Åland Sea. Concentrations of total phosphorus increased significantly in the Northern Baltic Proper, the Bornholm Basin and the Western Gotland Basin, but decreased in the Great Belt and Kiel Bay (HELCOM 2018B).

In comparison to the latest assessment period (2007–2011) the current levels of dissolved inorganic phosphorus are higher (>15 %) in eight of the seventeen sub-basins (Figure 4.1.8). Total phosphorus concentrations have increased substantially in the Gdansk Bay and the Gulf of Riga and decreased in the Northern Baltic Proper and the Quark. In areas with deep water oxygen deficiency, increases in phosphorus concentrations can at least partly be attributed to release of phosphorus from sediments during transition to anoxic conditions (Conley *et al.* 2002, 2009, Lehtoranta *et al.* 2016).

Core indicators on direct effects

None of the core indicators for direct effects, namely 'Chlorophyll-a' and 'Water clarity', nor the pre-core indicator 'Cyanobacterial bloom index[6]' achieved the threshold value east of the Sound (Figure 4.1.5). The indicator for Chlorophyll-*a* achieved the threshold value in the Kattegat, as did water clarity in the Kattegat and the Sound.

The chlorophyll concentrations have remained essentially unchanged during the past few decades (1990-2016), with the exception of the most western parts of the Baltic Sea, where it shows decreasing trends (Figure 4.1.11; see also Thematic assessment: HELCOM 2018B). The result corresponds well with decreases in nitrogen inputs and concentrations in the western parts, where nitrogen is considered the most limiting nutrient for phytoplankton growth. In the central and eastern parts of the Baltic Sea, where summer chlorophyll-*a* concentration is mainly related to phosphorus concentrations the indicator shows no changes. A deteriorating trend was detected only in the Bornholm Basin, attributed to the influence from measurements at shallow stations in the Pomeranian Bay and outflow from the river Odra. Compared to the previous five year period (2007–2011), chlorophyll-*a* concentrations have decreased in the Kattegat, Great Belt and the Sound, but increased in the Northern Baltic Proper and the Gulf of Riga (Figure 4.1.8).

The long-term series for water clarity show a steadily deteriorating situation over several decades, most profoundly in the north-eastern sub-basins (Fleming-Lehtinen and Laamanen 2012). In more recent years, however, the decrease in water clarity has levelled off across most of the Baltic Sea (Figure 4.1.12; Thematic assessment: HELCOM 2018B). Looking over the time period 1990-2016, water clarity has decreased in four of the seventeen sub-basins, and has increased (improved) in the Kattegat and the Great Belt.

Water clarity is affected by the abundance of phytoplankton (which is related to eutrophication), but is also affected by the total amount of organic matter in the system. Particulate as well as dissolved organic matter affect the attenuation of light, and both of them have eutrophication and non-eutrophication related components. Eutrophication is attributed to the portion of organic matter produced within the sea, in the form of either phytoplankton or other organic matter.

As the total amount of organic matter in the system is still at a high level after many decades of elevated nutrient inputs, water clarity is not expected to decrease until the pools of organic matter are degraded or washed out of the Baltic Sea. Recovery is expected to take decades, although improvements in the most northern parts are promising.

In comparison to the period 2007–2011, water clarity has improved in three western sub-basins and decreased (deteriorated) in the Bothnian Bay and the Bothnian Sea under 2011-2016 (Figure 4.1.8).

The 'Cyanobacterial bloom index'[7] did not achieve the threshold value in any of the ten sub-basins where it was tested. The worst status was indicated for the Gulf of Riga, the Northern Baltic Proper and the Bothnian Sea. Long-term data was available for the Eastern Gotland Basin, the Northern Baltic Proper and the Gulf of Finland, showing a deteriorating trend in the Baltic Proper during 1990-2016 (Figure 4.1.13).

Compared to the previous five year period 2007–2011, the 'Cyanobacterial bloom index' has further deteriorated in the Gulf of Riga and the Bay of Mecklenburg and improved in the Gdansk Basin during the current assessment period 2011-2016 (Figure 4.1.8).

Core indicators on indirect effects

The core indicator 'Oxygen debt' did not achieve the threshold values in any assessed open sea sub-basin (Figure 4.1.5). The indicator has increased over the past century (Figure 4.1.14). It levelled off between the early 1980s and the early 1990s, but has subsequently increased again. In comparison with the most recent previous assessment period (2007–2011), oxygen debt during 2011-2016 has remained at the same level (Figure 4.1.8).

North of the Baltic Proper, the indicator 'State of the soft-bottom macrofauna community'[8] was included to evaluate the condition of the animal community at the seafloor. The indicator achieved the threshold value in these areas.

6 Included as test.

7, 8 Included as test

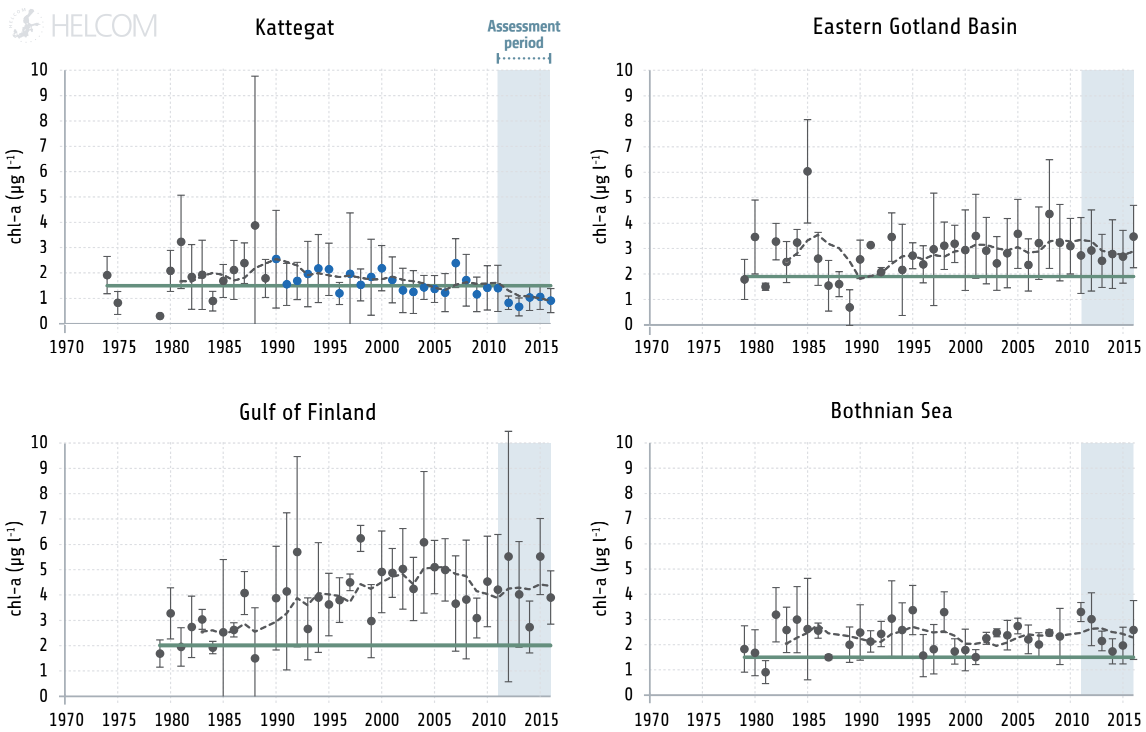


Figure 4.1.11.

Example of long term trends in direct effects of eutrophication in the Baltic Sea: Temporal development of chlorophyll-*a* concentrations in summer in the Kattegat, the Eastern Gotland Basin, the Bothnian Sea and the Gulf of Finland. Dashed lines show the five-year moving averages and error bars are the standard deviation. Green lines indicate the indicator threshold values. Significance of the trends was assessed with the Mann-Kendall tests for the period 1990-2016. Significant ($p<0.05$) improving trends are indicated with blue data points. None of these examples showed a significant deteriorating trend. Results for the other sub-basins are shown in HELCOM (2018B).

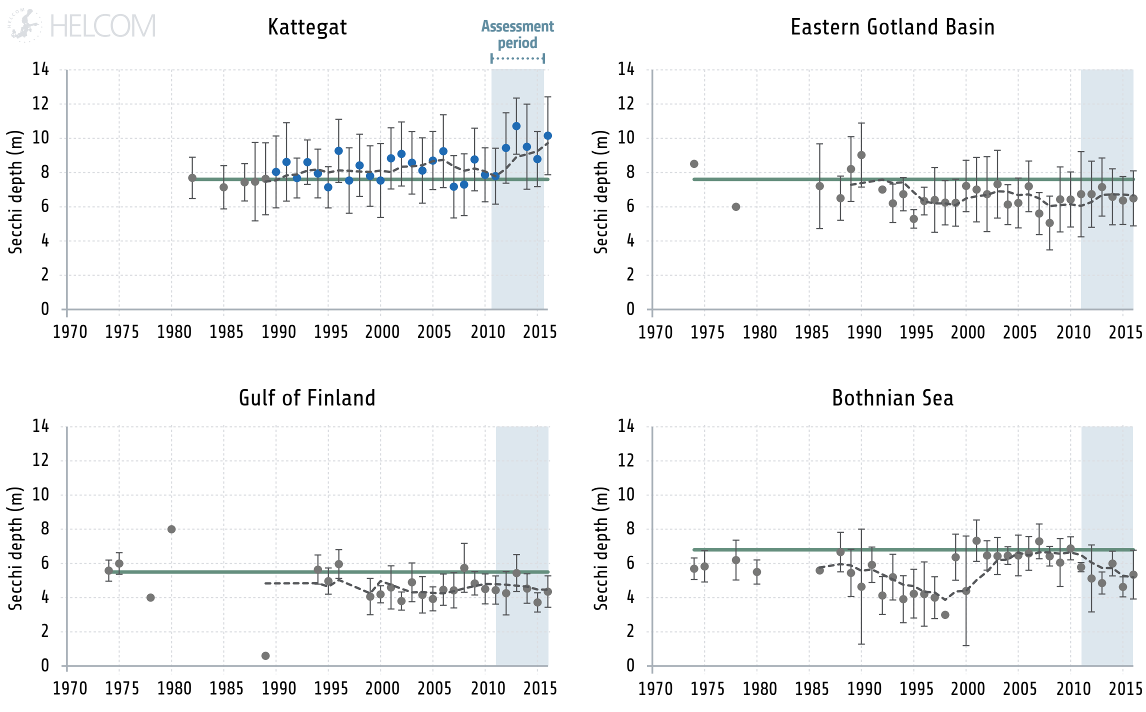


Figure 4.1.12.

Example of long term trends in direct effects of eutrophication in the Baltic Sea: Temporal development of water clarity in the Kattegat, the Eastern Gotland Basin, the Bothnian Sea and the Gulf of Finland. Dashed lines show the five-year moving averages and error bars the standard deviations. Green lines indicate the indicator threshold values. Significance of the trends was assessed with the Mann-Kendall tests for the period 1990-2016. Significant ($p<0.05$) improving trends are indicated with blue data points. None of these examples showed a significant deteriorating trend. Results for the other sub-basins are shown in HELCOM (2018B).

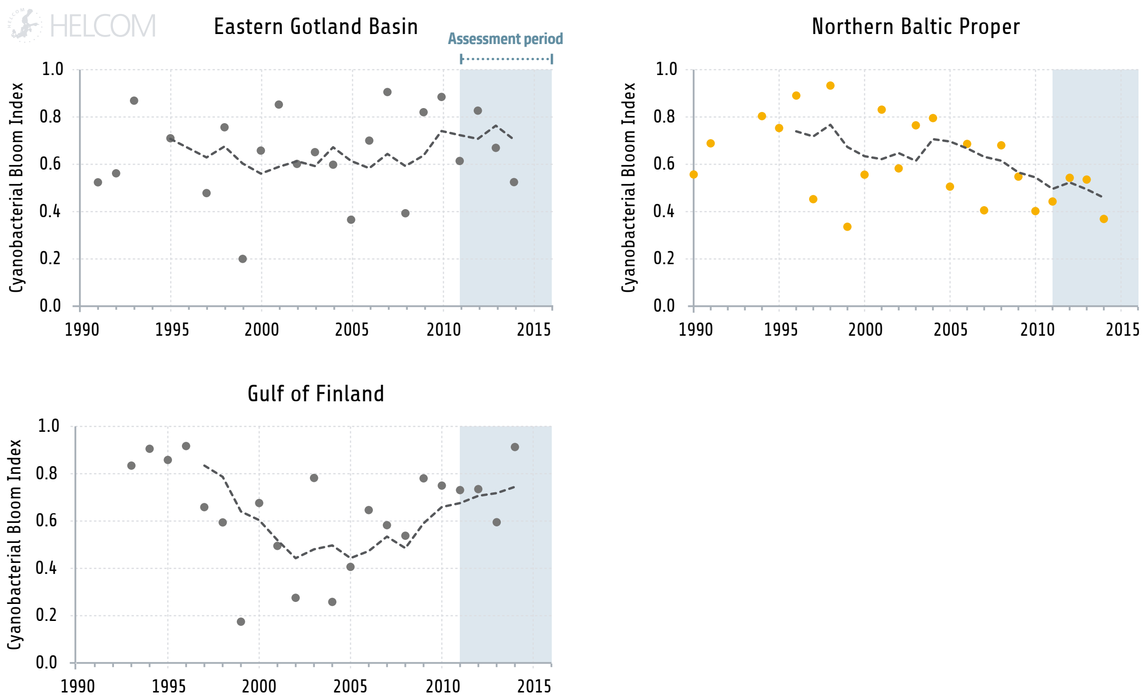


Figure 4.1.13.
Example of long term trends in the direct effects of eutrophication in the Baltic Sea: Temporal development of the 'Cyanobacterial bloom index'* in the Eastern Gotland Basin, the Northern Baltic Proper and the Gulf of Finland in 1990-2014. Dashed lines show the five-year moving averages. Significance of the trends was assessed with the Mann-Kendall test. A significant ($p<0.05$) deteriorating trend is indicated with orange data points. None of these examples showed a significant deteriorating trend in 1990-2014. The data represents the areal fraction with cyanobacteria accumulations and the sub-basin delineation of Kahru and Elmgren (2014), and the correlation between areal fraction and cyanobacterial surface accumulations presented by Anttila *et al.* (2018). *) Included as test

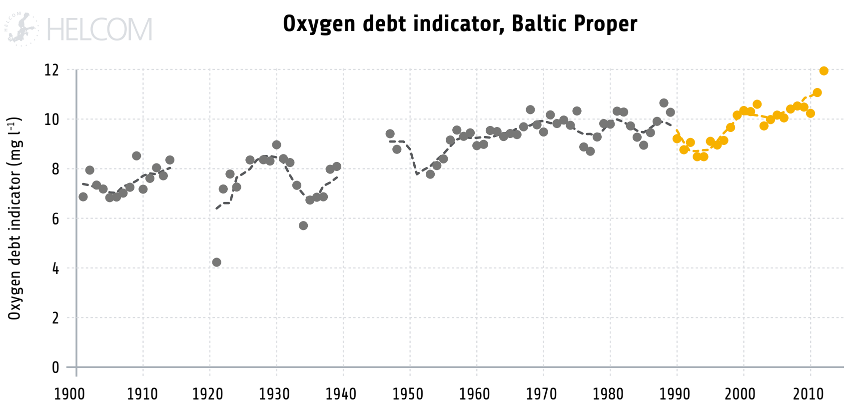


Figure 4.1.14
Example of long term trends in the indirect effects of eutrophication in the Baltic Sea: Temporal development in the core indicator 'Oxygen debt' in the Baltic Proper, showing the volume specific oxygen debt below the halocline based on the data and sub-basin division delineation of HELCOM (2013d). The dashed line shows the five-year moving average. The significance of the trend was tested for the period 1990-2012 by the Mann-Kendall test. Orange colour indicates significant ($p<0.05$) deteriorating trend: An increasing trend in oxygen debt signifies deteriorating oxygen conditions.

Box 4.1.2.
Costs of eutrophication

Eutrophication causes multiple adverse effects on the marine environment which also reduce the welfare of citizens. These include decreased water clarity, more frequent cyanobacterial blooms, oxygen deficiency in bottom waters, changes in fish stocks and loss of marine biodiversity. These effects decrease the environmental benefits from the Baltic Sea, both in terms of use-related values and non-use values.

Examples of use values are opportunities for and enjoyment from marine and coastal recreation. Non-use values stem from knowing that the marine environment is healthy and available to others in the same and future generations, for example.

Reaching a good eutrophication status for the Baltic Sea will bring about increased human welfare and economic benefits to citizens in the coastal countries. The benefits that are lost if the Baltic Sea does not reach a good environmental status are called the cost of degradation. The monetary benefits of reducing eutrophication have been assessed in a Baltic-wide stated preference contingent valuation study in 2011 (Ahtiainen *et al.* 2014). The results represent the value of reaching good eutrophication status in the Baltic Sea, based on citizens' stated willingness to pay, in a survey for achieving the target status. The study captured a variety of eutrophication effects, including water clarity, cyanobacterial blooms, underwater meadows, fish species composition and oxygen deficiency at the sea bottom. The change in eutrophication was described using all of these effects.

The study covers all nine coastal countries and considers a change in the condition of the entire Baltic Sea. The target state in the study corresponds closely to that of achieving a good environmental status of the sea, stating that all sub-basins except the Northern Baltic Proper have achieved good status. The time frame in the study is somewhat longer than in current policies, as it is set to the year 2050. Reaching a good status earlier than 2050 might bring about even greater benefits, as people generally place more value on goods and services that they obtain sooner.

Figure B4.1.2 presents the estimates of how benefits would be lost if eutrophication is not reduced in the Baltic Sea. The total losses are estimated at 3.8–4.4 billion euros annually for the Baltic Sea region. In other words, citizens' welfare would increase by this much each year if good eutrophication status was achieved. See also Thematic assessment on economic and social analyses: HELCOM 2018A.

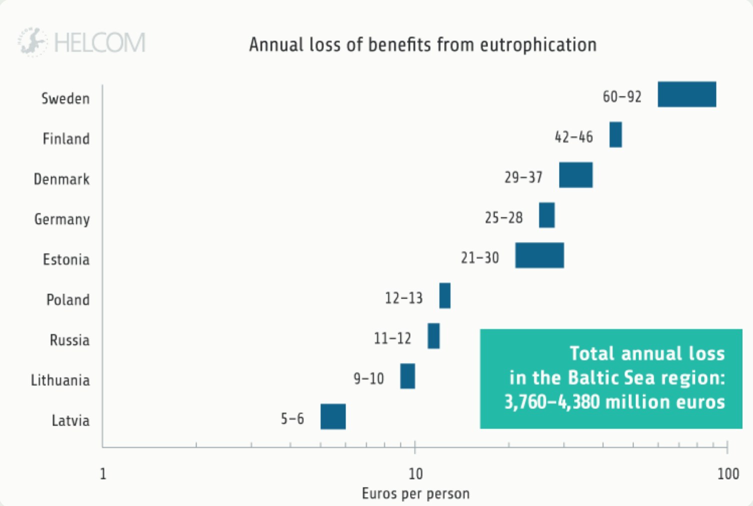


Figure B4.1.2.
Annual benefit losses from eutrophication (euros per person) and total in the Baltic Sea region (million euros). The ranges show the 95 % confidence intervals for the value estimates reported in the original study. Value estimates are in purchasing power parity adjusted 2015 euros. Source: Ahtiainen *et al.* (2014).

Impacts and future perspective

Primary production is a key process in the ecosystem as it provides energy for all organisms. On the other hand, excessive primary production leads to eutrophication symptoms and reduces the function of the food web in many cases, as well as socioeconomic effects (Box 4.1.2). An increased intensity and frequency of phytoplankton blooms typically leads to decreased water clarity and increased sedimentation. These conditions further limit the distribution of submerged vegetation, such as macroalgae and macrophytes, and reduce the habitat quality of coastal areas. Increased sedimentation and microbial degradation of organic matter increases oxygen consumption and depletes oxygen conditions in areas with poor water exchange, including deep water areas. The extent of oxygen-deficient waters has increased more than ten-fold over the past one-hundred and fifteen years (Carstensen *et al.* 2014). After a stagnation period, the oxygen deficiency has expanded again over the last two decades (Carstensen *et al.* 2014). Also in the coastal areas, hypoxia has steadily increased since the 1950s (Conley *et al.* 2011).

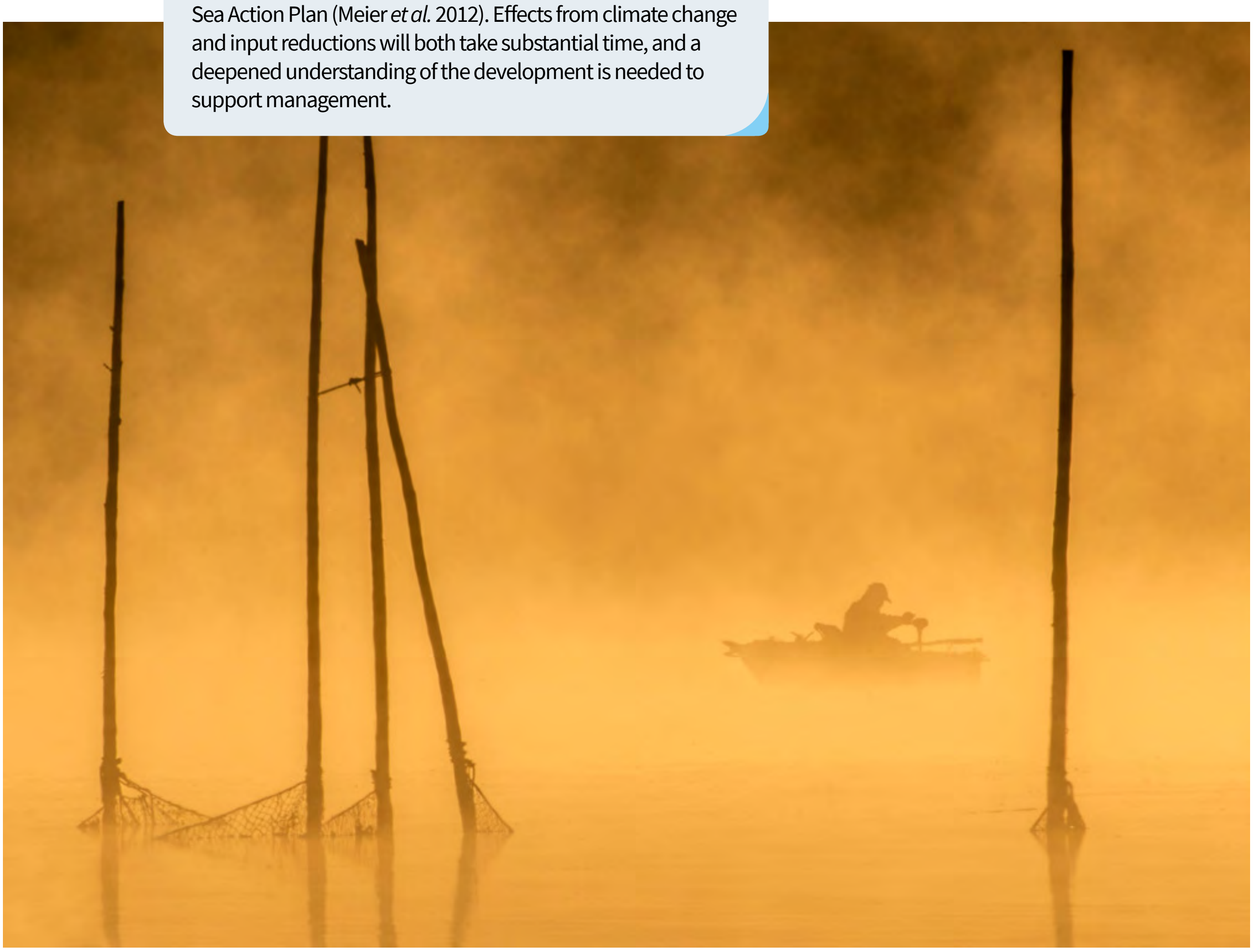
By the 1960s the soft bottom fauna was already disturbed in some parts of the Baltic Sea, attributed to eutrophication. Human induced nutrient inputs have contributed to the enhanced distribution of areas with poor oxygen conditions seen today, including deep waters. In areas with vertical stratification and low water exchange, eutrophication acts on top of naturally low oxygen levels, further enhancing these conditions. Life in deep water habitats is also highly dependent on aeration provided by inflows of marine water from the North Sea.

Some positive development in the eutrophication status is seen in the current assessment, such as a decrease in nitrogen concentrations in most of the Baltic Sea and improved water clarity and decreased chlorophyll-a concentrations in some western parts of the Baltic Sea. Moreover, the intensity of the spring blooms is seen to have been reduced from 2000 to 2014 due to reductions in nutrient loading (Groetsch *et al.* 2016). However, the results show that the Baltic Sea is still highly affected by eutrophication and that the impacts on organisms and human well-being will continue. Large scale responses to reduced loading are slow, and recently achieved reductions are not visible in the short time-frame of the assessments.

The recovery of the Baltic Sea from eutrophication depends on the continuing efforts to reduce nutrient loading. Ongoing and agreed reductions of nutrient inputs according to the HELCOM Baltic Sea Action Plan are foreseen to be effective in decreasing the eutrophication symptoms in the long term. Based on modelling simulations of the Baltic Sea biogeochemistry under different nutrient reduction schemes, implementation of the BSAP nutrient reductions will lead to significantly improved eutrophication state of the Baltic Sea within this century, including reduced primary productivity, nitrogen fixation and hypoxia (Saraiva *et al.* 2018). Climate change is foreseen to amplify eutrophication symptoms, with biogeochemical responses depending on the implemented nutrient reductions (Box 4.1.3), hence enhancing the importance of nutrient reductions (Saraiva *et al.* 2018). ■

Box 4.1.3
Effects of climate change on eutrophication

Adaptation to climate change is a central issue for the planning and implementation of measures to reduce nutrient inputs, as well as for adjusting the level of nutrient input reductions to ensure protection of the Baltic Sea marine environment in a changing climate. For example, the maximum allowable inputs are calculated under the assumption that Baltic Sea environmental conditions are in a biogeochemical and physical steady-state. This assumes that the environment will reach a new biogeochemical steady state under the currently prevailing physical steady state, after some time when the internal sinks and sources have adapted to the new input levels. This assumption is not likely to hold in a changing climate, as the physical environment is also changing and will feedback upon the biogeochemical cycling, for example by enhancing growth and mineralization rates. Simulations indicate that climate change may call for additional nutrient input reductions to reach the targets for good environmental status of the Baltic Sea Action Plan (Meier *et al.* 2012). Effects from climate change and input reductions will both take substantial time, and a deepened understanding of the development is needed to support management.



4.2. Hazardous substances

Man-made chemicals and heavy metals enter the Baltic Sea via numerous sources, including waste water treatment plants, leaching from household materials, leaching from waste deposits, and atmospheric deposition from industrial plant emissions, amongst others. Once in the Baltic Sea, they can cause various types of damage to the ecosystem. Some are highly visible in the form of oil-spills, others however can remain unnoticed or are only apparent when detrimental impacts on the ecosystem or biota are observed. Many contaminants degrade slowly and their impacts can magnify as they accumulate within the aquatic food web. The contamination status is elevated compared to natural conditions in all parts of the Baltic Sea.

Thousands of environmentally hazardous substances have been identified as potentially occurring in the Baltic Sea. The most harmful substances are persistent, toxic and accumulate in biota. Some hundreds of substances are regularly monitored. A subset of these are represented in the core indicators included in this assessment.

Indicators included in the assessment

The core indicators are assessed against regionally agreed threshold values (Box 4.2.1; for more details see Thematic assessment; HELCOM 2018C). These are derived from a number of sources to select values that have been scientifically tested and developed with the purpose of assessing environmental status or ensuring human safety. However, a risk can never be fully excluded even when the threshold value is achieved - especially for persistent or bio-accumulating substances - and the long-term goal is to reach zero concentrations of man-made chemicals.

Since the previous holistic assessment, HELCOM has further developed the assessment system for hazardous substances, and taken steps towards applying regionally harmonised methods. The integrated assessment was done using the HELCOM CHASE tool, which integrates individual results for indicator substances (or substances groups) into a quantitative estimate of overall contamination status.

Box 4.2.1

Threshold values for hazardous substances

Monitoring of hazardous substances takes place in three types of matrices, namely biota, water and sediment. Each of these has specific threshold values defined for each substance (or substance group). Primary threshold values identify the matrix deemed to be most appropriate for monitoring the specific substance or substance group, though secondary threshold values are commonly established and used where monitoring in the primary matrix is not available. If several threshold values are available, thresholds based on environmental quality standards (EQS) and the sampling matrix biota are preferred. Monitoring of biota reflects the accumulation of contaminants in the living environment.

— The environmental quality standard (EQS) values are used by HELCOM countries that are also EU Member States for the classification of chemical status of water bodies under the Water Framework Directive, at concentrations below this level it is assumed that no harm will be caused to the freshwater or marine environment.

— Background assessment criteria (BAC) have been developed to illustrate progress towards background concentrations of naturally occurring substances, and close to zero concentrations for man-made substances. Using background concentrations of naturally occurring substances as the threshold value may represent an even more precautionary approach than the use of other threshold values devised to indicate no environmental harm.

— Foodstuff threshold values stem from legislation of the European Union (EC 2006). The aim is to ensure human health is not detrimentally impacted. Foodstuff threshold values do not cover all combinations of matrices and contaminants relevant for an environmental assessment of the marine environment.

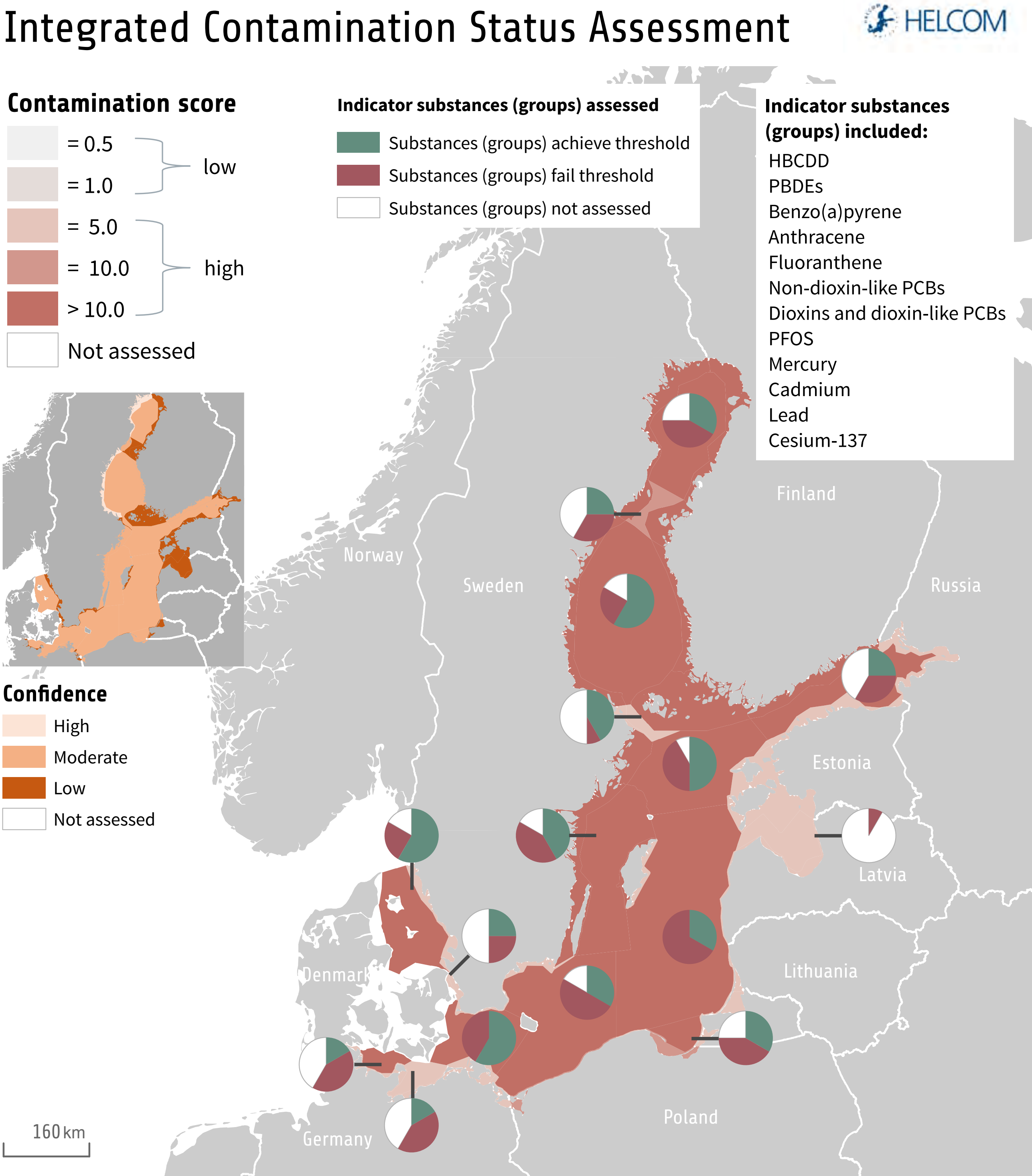


Figure 4.2.1.
The integrated contamination status of the Baltic Sea assessed using the CHASE tool. The assessment shows that hazardous substances give cause for concern in all assessed units. The integrated assessment is based on seven core indicators integrating concentrations-to-threshold derived values (Contamination ratios) for twelve individual hazardous substances (or substance groups). The pie charts indicate how many out of the twelve substances were assessed, defining those that achieved (green) or failed (red) their respective threshold value in each of the open sea assessment units. The overall assessment is moderated by a parallel assessment of confidence (see left inset map) and can be considered as an appraisal of the data coverage and quality in any given assessment unit. For Denmark the assessments of hazardous substances have been done in accordance with the Water Framework Directive due to consideration of the national management of the coastal and territorial waters. The assessment can be found in the Danish national River Basin Management Plans.

Integrated status assessment

Pressure on the marine environment from contaminants is high in all parts of the Baltic Sea (Figure 4.2.1). The ecosystem remains impacted by hazardous substances. Mercury, polybrominated diphenyl ethers, and the radioactive isotope cesium-137 show particularly high contamination scores in the integrated assessment.

Polybrominated diphenyl ethers (PBDEs) have mainly been used as flame retardants in plastic materials and polyurethane foams, and enter the Baltic Sea through waste water treatment plants and diffuse sources. The use of these flame retardants has been banned in most products since 2004 in Europe. The main source of heavy metals, such as mercury, is burning of fossil fuels, which enter the Baltic Sea through atmospheric deposition. Mercury is currently legally used in some applications such as low-energy light sources for example, but its use in several previous industries, including amalgams in dentistry, electrodes in paper bleaching, and thermometers, have been phased out.

Eleven of the assessed open sea areas are classified into the worst status category, with the Kiel Bay, Eastern Gotland Basin and Bothnian Bay being indicated as the most contaminated. Meanwhile, areas appearing to show better relative status are generally associated with low confidence in the assessment. The matrix 'biota' was commonly classified as having the worst status, and was thus a strong driver of the overall contamination status.

The total range of contamination ratios for the HELCOM core indicators, by substance or substance group is shown in Figure 4.2.2 for all coastal and open sea assessment units. Those substances most distant from their threshold values and failing the threshold value (based on the whole regional scale) are PBDEs, mercury, cesium-137, as well as tributyltin (TBT)[1] and imposex. Detailed results per core indicator and substance per open sea assessment unit are presented in Figure 4.2.3.

Confidence in the assessment

The integrated results for the geographical areas are regionally comparable, however the variation in confidence needs to be considered. Assessment units with lower confidence generally showed better status than those with high confidence, which can partly be attributed to the absence of monitoring of polybrominated diphenyl ethers or mercury, the two substances generally being the furthest from their respective threshold values, in these areas. Polybrominated diphenyl ethers and mercury were highly influential in areas being assessed as not achieving good status in all areas where they were monitored.

1 Included as test

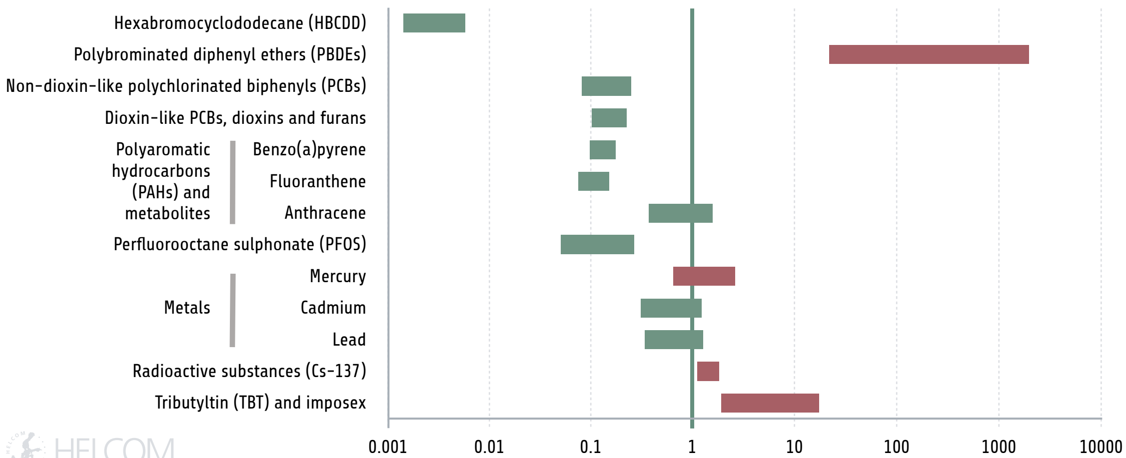
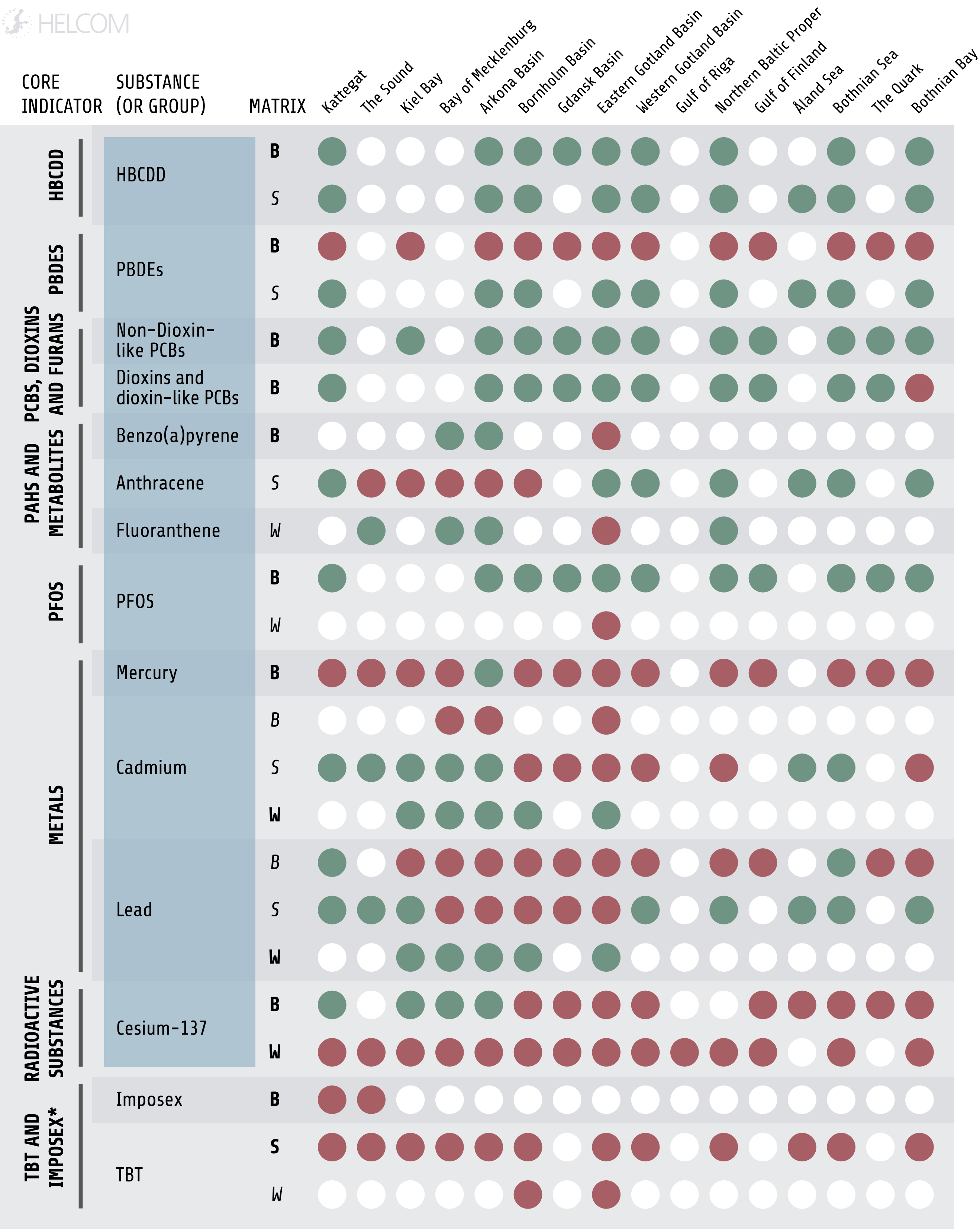


Figure 4.2.2.
Range of contamination ratios of the evaluated hazardous substances. The contaminant ratios are the observed concentration value divided by the threshold value, based on the mean concentrations for the assessment period 2011-2016. The horizontal bars show the range of contamination ratios from percentile 20 to 75 for each substance on a log-transformed scale. Red bars indicate that the median value fails the threshold value, as identified by the green line. The figure is based on the coastal and open sea data used in the integrated assessment. In addition, corresponding results for the core indicator on tributyltin* and imposex, which is not used in the integrated assessment, is presented. The core indicators are presented in more detail in the Core indicator reports (HELCOM 2018s-z). *) Included as test.



* Included as test

Figure 4.2.3.
Detailed results for the hazardous substances assessment in the open sea assessment units, by core indicators and substances. Red denotes that the substance fails the threshold value, and green denotes that threshold value is achieved. White cells are shown for units not assessed due to a lack of data. The core indicators have primary and secondary substances and threshold values. Primary substances and the matrix in which the primary threshold is set are shown in bold. Secondary substances and threshold values are shown in italics. Abbreviations used for matrices: B=biota; S=Sediment, W=Water, for substances (or groups): BCDD = hexabromocyclododecane, PBDE = polybrominated diphenyl ethers, PAHs = polyaromatic hydrocarbons, PCBs = polychlorinated biphenyls, PFOS = perfluorooctane sulphonate, TBT = tributyltin. The twelve substances (or groups) used in the integrated assessment are marked with pale blue shading.

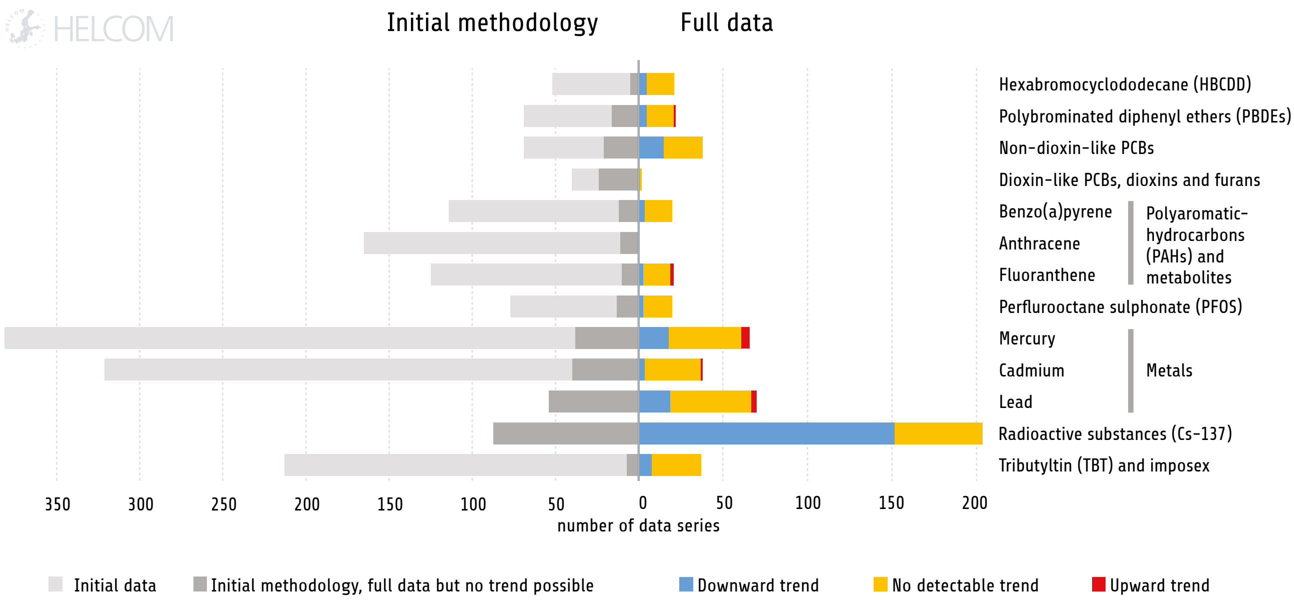


Figure 4.2.4.

Trends in indicator substances or substance groups shown as counts of data series based on the type of assessment methodology applied. The available data for which the trends are calculated differ between substances and stations, covering roughly the following years for each substance; polybrominated diphenyl ethers (PBDE): 1999–2016; mercury: 1979–2016; cadmium: 1985–2016; lead: 1979–2016; hexabromocyclododecane (HBCDD): 1999–2016; perfluorooctane sulphonate (PFOS): 2005–2016; benzo(a)pyrene: 1997–2016; anthracene: 1990–2016; non-dioxine-like polychlorinated biphenyls (PCB): 1978–2016; fluoranthene: 1997–2016, Cesium-137: 2011-2016, and for Tributyltin (TBT) and imposex: 1998–2016.

Changes in comparison to the previous assessment

The overall contamination status has not changed markedly since the previous holistic assessment (HELCOM 2010), showing that contamination from hazardous substances still gives cause for concern throughout the Baltic Sea area. Based on an analyses at core indicator level, the situation seems, however, not to be deteriorating. Out of 559 data series analysed with respect to trends over time, close to half (236) showed downward trends, 311 showed no detectable trend, and only 12 showed upward trends (Figure 4.2.4).

Due to the methodological differences between assessment periods, it is not possible to make a direct comparison between the current (2011-2016) and the previous holistic assessment. For example, there has been a development of regionally agreed threshold values, different substances or substance groups are sampled, and there is a substantial increase in the monitoring data included in the assessment. Changes can, however, be seen with respect to selected aspects. For example, polychlorinated biphenyls (commonly known as PCBs) and dioxins were identified amongst the substances having highest contamination ratios in the previous assessment (HELCOM 2010), but PCBs, dioxins and furans do to not appear to be a major driver of the integrated assessment status in 2011-2016.

In addition, a number of substances that were assessed in the initial holistic assessment (HELCOM 2010), such as hexachlorocyclohexane (HCH, lindane) and dichlorodiphenyltrichloroethane (DDT) and its metabolites are no longer considered as of significant concern. Substances that appear to have decreased in concern, however, still warrant careful future checking and monitoring, to ensure that concentrations remain low and that alternative or secondary sources do not result in degraded environmental status. For example, hexachlorobenzene has recently been recorded at increasing levels in air at some European monitoring stations and concentrations in sediment have been found to increase in at Swedish offshore sampling stations (EMEP 2017, Apler and Josefsson 2016).

An overview of results for selected hazardous substances indicators is provided below. A more comprehensive overview is provided in the Thematic assessment (HELCOM 2018C). ▸

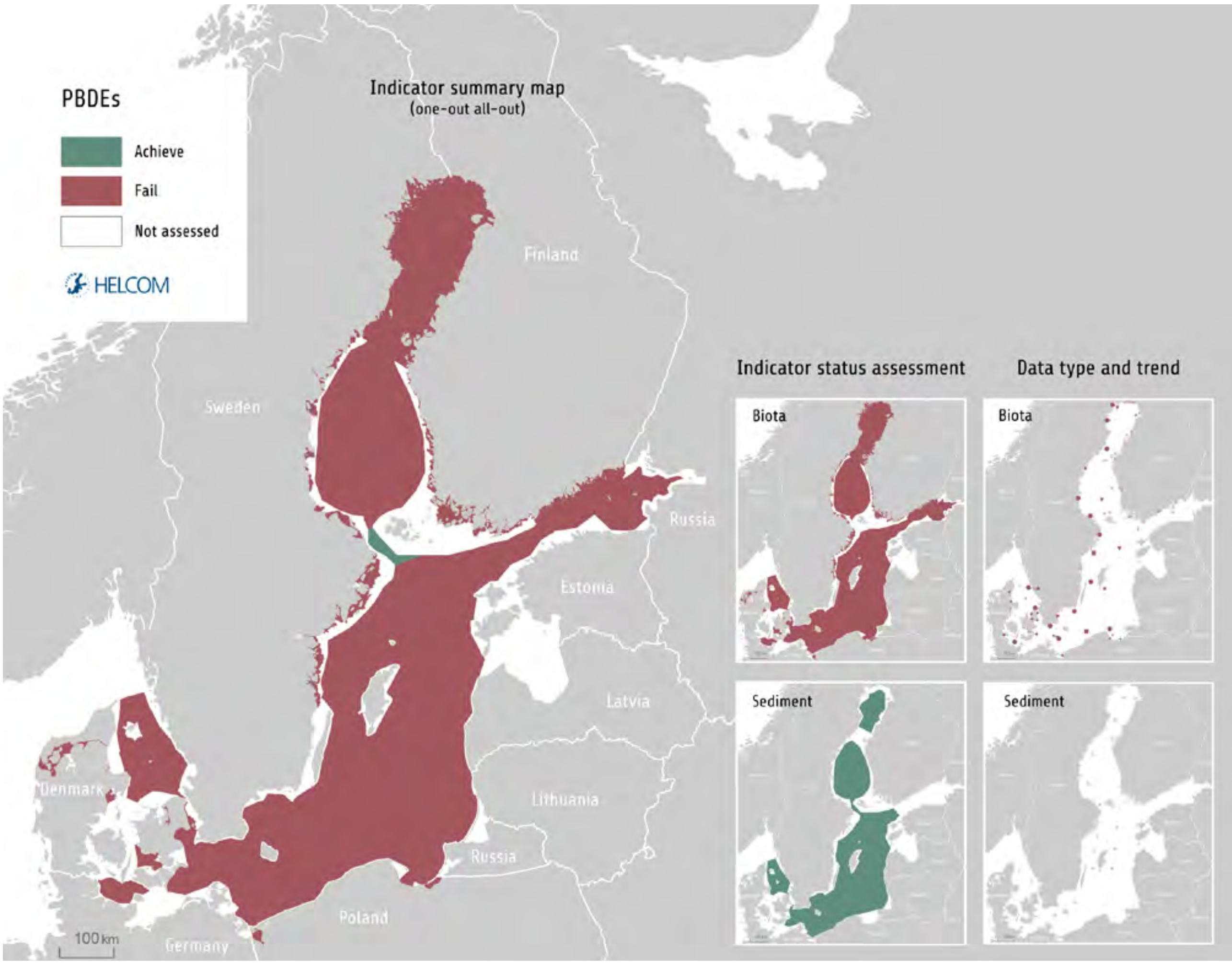


Figure 4.2.5.
Status assessment for polybrominated diphenyl ethers (PBDEs). The summary map (main map) shows the status assessed by the one-out-all-out approach, meaning that the matrix-threshold combination with the worst status is shown for each assessment unit. Status based on the primary threshold in biota (top inset row) and secondary threshold in sediment (bottom inset row) is also shown. Status in biota is evaluated in herring, cod, flounder, dab, eelpout and perch. Red colour indicates that PBDEs fail the threshold value and green colour indicates that the measured PBDEs concentrations are below the threshold value (achieve the threshold). Symbols on map define data type and trend with downward triangles indicating decreasing concentrations, upward triangles indicating increasing concentrations and circles indicating no detectible trends. For more details, see HELCOM (2018t).

▸ Core indicators from the integrated assessment

Polybrominated diphenyl ethers

Polybrominated diphenyl ethers (PBDEs) are toxic and persistent substances which bioaccumulate in the marine food web. The sum of six PBDE congeners are compared to the threshold value. The threshold value for biota is an environmental quality standard set to protect both the marine ecosystem, and humans consuming fish, from adverse effects. It is currently due for scientific re-assessment.

Polybrominated diphenyl ethers fail the threshold value for biota in all areas where they are monitored (Core indicator report: HELCOM 2018t, Figure 4.2.5). For sediments, the threshold value is achieved. For example the green area in the indicator summary map around the Åland Sea reflects an assessment based on the secondary threshold value in sediments, while there is a lack of data from biota in that area.

The use of polybrominated diphenyl ethers as flame retardant has been banned in most products in Europe since 2004. Therefore, decreasing concentrations are expected in the future. Out of the twenty-two stations where trends were assessed, downward trends were identified in five stations (both coastal and offshore). One station showed an upward trend.

In addition to polybrominated diphenyl ethers, several other man-made brominated substances have been found in the environment, but little is yet known on their effects on the environment and human health. To keep up with the developments and the emerging risks from such novel substances, it is important to continue and develop further collaborative monitoring and to map their occurrence and use in the Baltic Sea region (Kemikalieinspektionen 2017, Gustavsson *et al.* 2017).

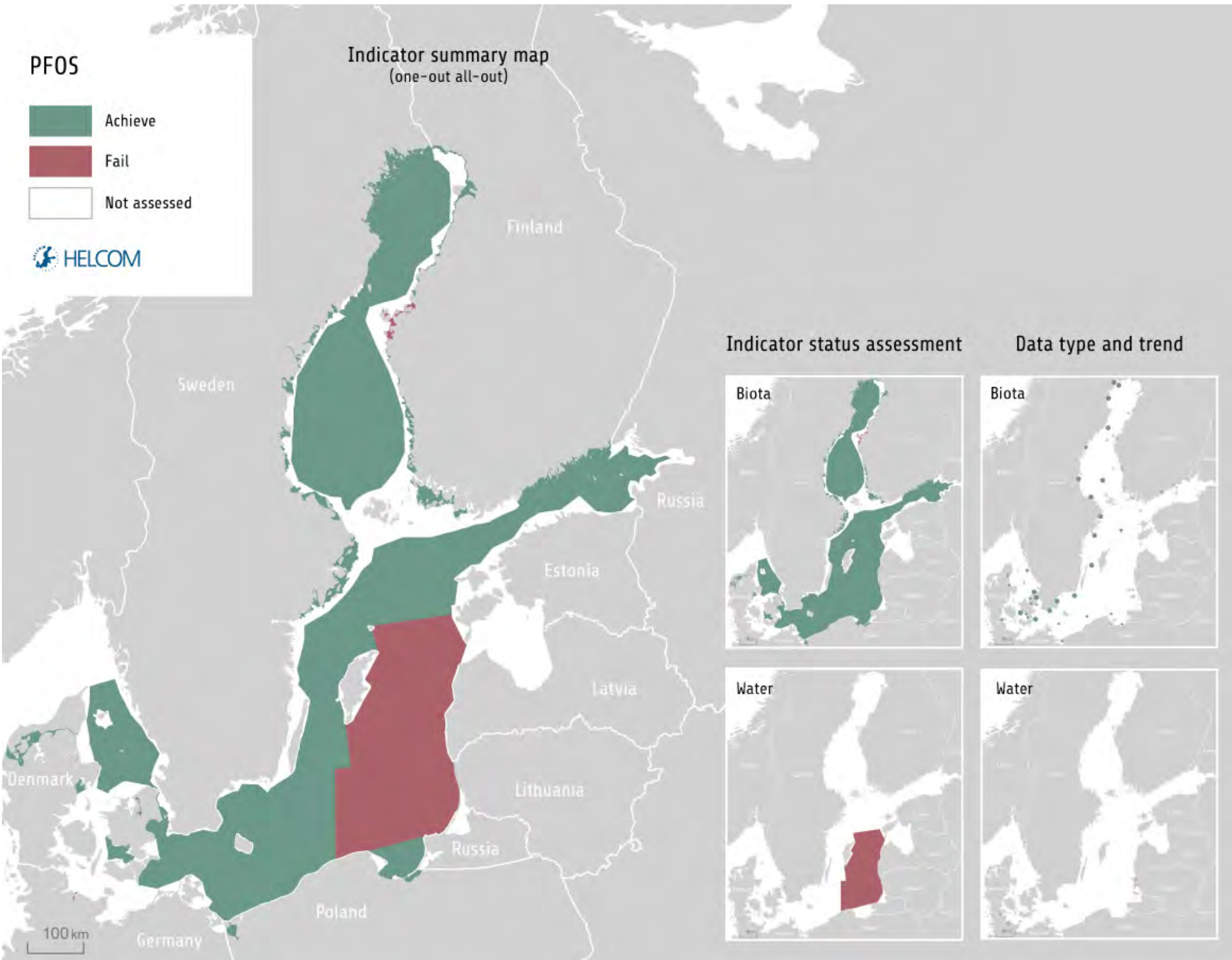


Figure 4.2.6.
Status assessment for perfluorooctane sulphonate (PFOS). The one-out-all-out approach is used to summarise all matrix-threshold combinations (main map), with the primary threshold in biota (top inset row), secondary threshold in water (bottom inset row). Biota analyses is carried out in herring, cod, flounder, dab, eelpout and perch. Symbols on map define data type and trend with downward triangles indicating decreasing concentrations, upward triangles indicating increasing concentrations and circles indicating no detectable trends. For more details, see the Core indicator report: HELCOM (2018w).

▸ ***Perfluorooctane sulphonate***

Perfluorooctane sulphonate (PFOS) is considered a global environmental contaminant. It is a persistent, bioaccumulating and toxic compound with possible effects on the reproductive, developmental and immune systems in organisms, as well as on their lipid metabolism. The substance has been produced since the 1950s and was used in the production of fluoropolymers, and also to provide grease, oil and water resistance to materials such as textiles, carpets, paper and coatings. Perfluorooctane sulphonate has also been widely used in firefighting foams.

Concentrations of perfluorooctane sulphonate are below the threshold value in biota in all the monitored areas (Core indicator report: HELCOM 2018w). However, concentrations in seawater exceed the threshold value (EQS for water) where measured, which is reflected in the red area in summary map (Figure 4.2.6). There are a few downward trends in biota but no general trends are detected.

Perfluorooctane sulphonate has been banned in the EU since 2008 for most of its used categories, but it has been replaced with other similar substances (per- and polyfluoroalkyl substances; PFAS) which have widespread use. Most PFAS are highly persistent and bio-accumulating, and other PFAS (in addition to perfluorooctane sulphonate) are also a cause for concern. Some per- and polyfluoroalkyl substances (PFAS) are listed on the EU candidate list on 'Substances of very high concern' under the REACH regulation (ECHA 2017). Inclusion of additional PFAS as core indicators should be considered in the future to keep track of their use and occurrence in the Baltic Sea region. ▸

Metals

Three heavy metals were assessed: mercury, cadmium and lead. The heavy metals are toxic and some are bio-accumulated in marine organisms, causing harmful effects. The severity of effect mainly depends on the concentration in the tissues. Additionally, both cadmium and mercury are known to biomagnify, meaning that their concentration levels increase in organisms higher up in the food web. A major current source of heavy metals is the burning of fossil fuels, leading to atmospheric deposition.

Legislation is in place to decrease inputs of mercury, cadmium and lead to the Baltic Sea. The atmospheric deposition of cadmium and mercury to the Baltic Sea has decreased since the 1990s (Figure 4.2.7) All three metals are addressed in the Baltic Sea Action Plan, included in the European Water Framework Directive (Lead and cadmium in water, mercury in biota), and represented in the Marine Strategy Framework Directive.

Mercury is analysed in fish muscle as a primary matrix. The most common species in which it is measured are herring and cod in the open sea area and flounder and perch in coastal areas. Mercury concentrations in fish muscle exceeded the threshold level in almost all monitored sub-basins indicating not good status (Core indicator report: HELCOM 2018x, Figure 4.2.8). The threshold value was also failed in some of the coastal areas. Good status was only achieved in the Arkona Basin and in a few coastal Danish and Swedish areas. There is no common general trend for mercury in fish muscle for the investigated time series, though eighteen downward trends, forty-three no detectable trends and five upward trends were recorded.

For cadmium, data on concentrations in seawater, biota and sediment was used for the status assessment. Good status was not achieved in the Northern Baltic Proper, Western Gotland Basin, Eastern Gotland Basin, Gdansk Basin or Bornholm Basin, nor in some Polish, German and Danish coastal areas (Core indicator report: HELCOM 2018x, Figure 4.2.9). Only four downward trends were identified, with thirty-three not detectable trends and one upward trend recorded.

Lead is most widely sampled in biota and sediment. It generally fails the threshold value in biota, with the exception of the Kattegat Bothnian Sea, and a few coastal areas. No general trend can be shown, although there were nineteen downward trends, forty-eight no detectable trends and three upward trends (Core indicator report: HELCOM 2018x, Figure 4.2.10).

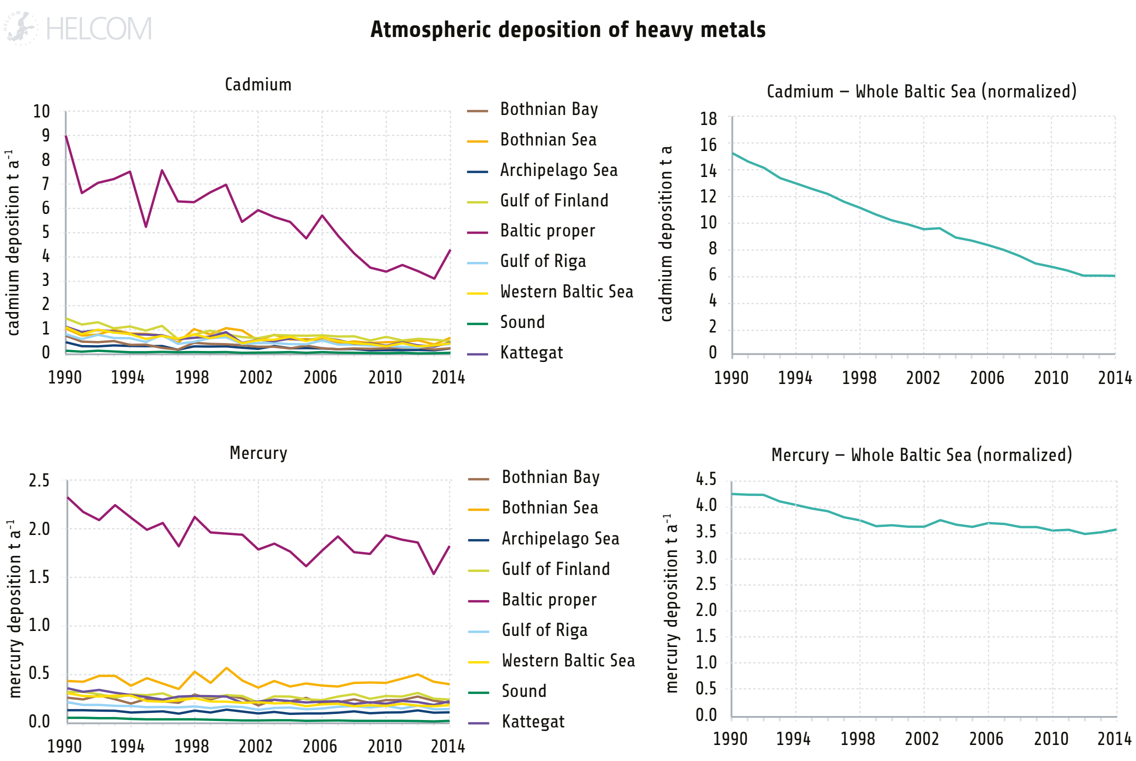


Figure 4.2.7.
Temporal trend in the total annual atmospheric deposition of cadmium and mercury to the Baltic Sea sub-basins. The right hand figures show values for the whole Baltic Sea. These are given as normalised atmospheric deposition to reflect the deposition independently of variability between years in weather conditions. Note that the scales between figures differ. Source: HELCOM (2017).

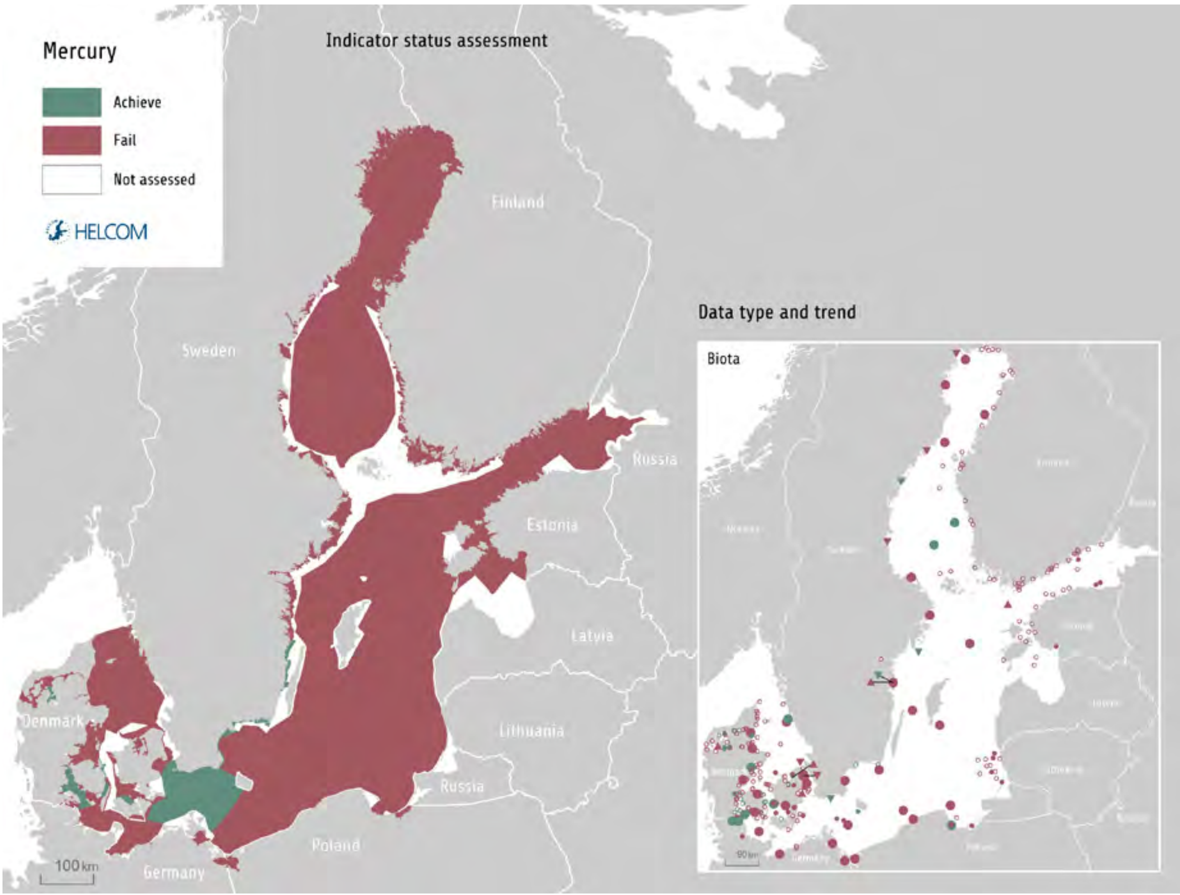


Figure 4.2.8.
Status assessment for mercury. The status is assessed in biota: herring, cod, flounder, dab, eelpout, perch and mussels samples. Symbols on the smaller inset map define data type and trend with downward triangles indicating decreasing concentrations, upward triangles indicating increasing concentrations and circles indicating no detectable trends. For more details, see the Core indicator report: HELCOM (2018x).

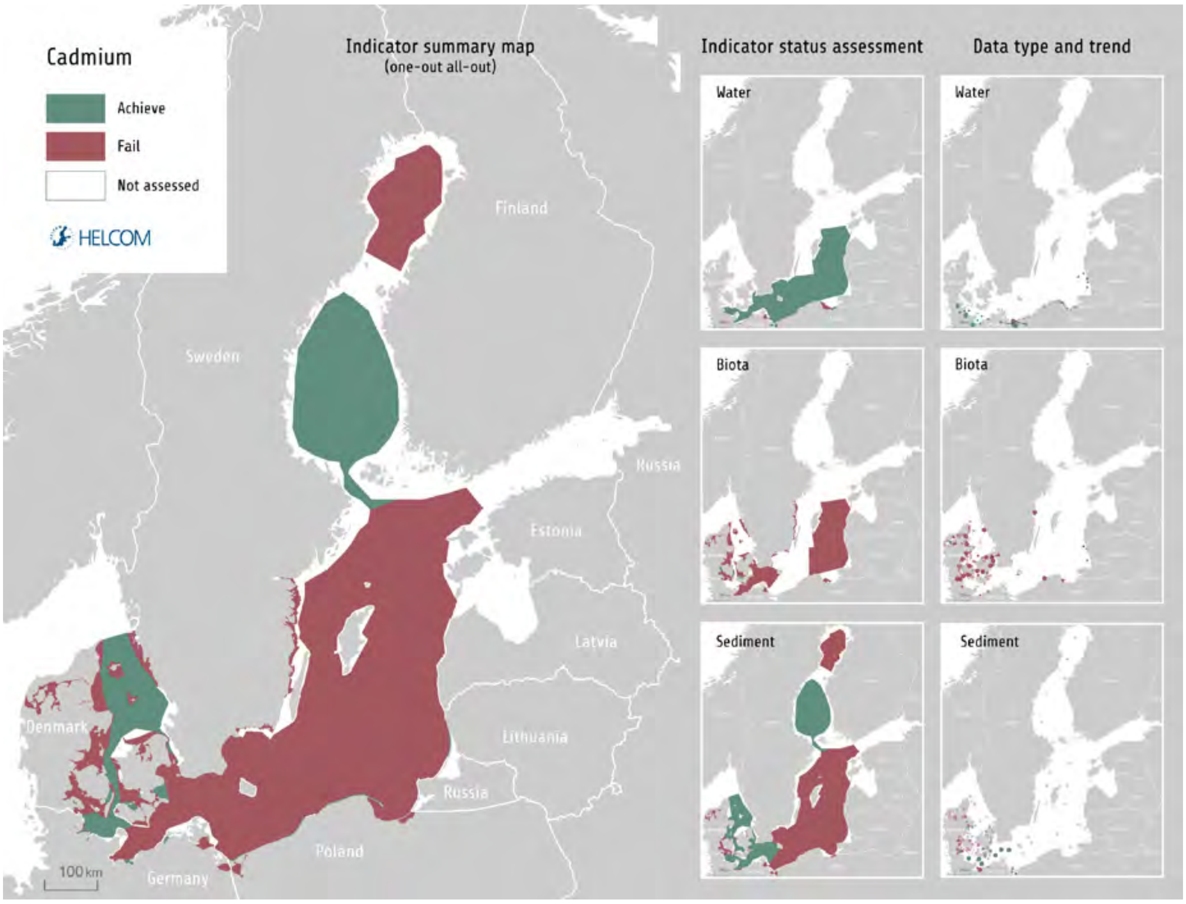


Figure 4.2.9.
Status assessment for cadmium. The one-out-all-out approach is used to summarize all matrix-threshold combinations (main map), with the primary threshold in water (top inset row), secondary threshold in biota (middle inset row) and secondary threshold in sediment (bottom inset row) shown. Biota analyses is carried out on molluscs. Symbols on the map define data type and trend with downward triangles indicating decreasing concentrations, upward triangles indicating increasing concentrations and circles indicating no detectible trends. For more details, see HELCOM (2018x).

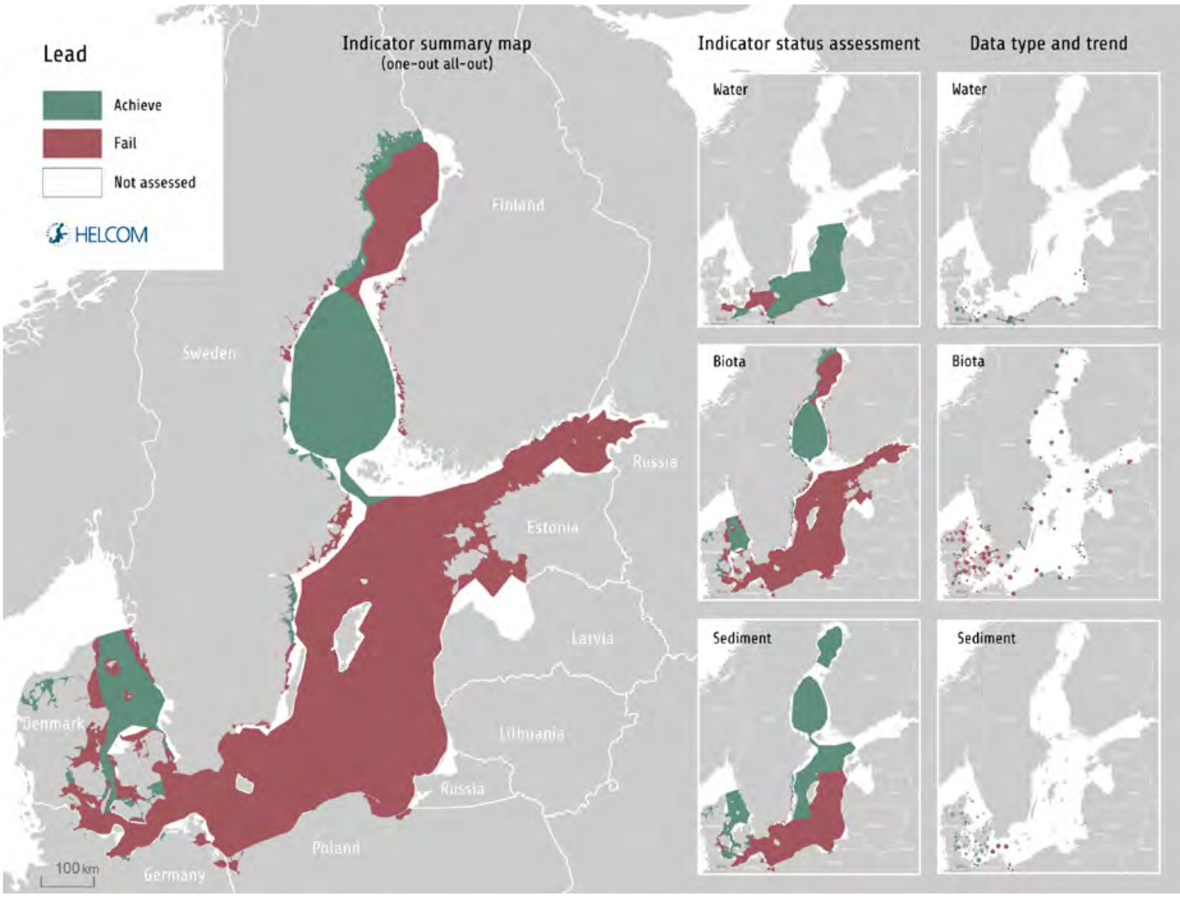


Figure 4.2.10.
Status assessment for lead. The one-out-all-out approach is used to summarize all matrix-threshold combinations (main map), with the primary threshold in water (top inset row), secondary threshold in biota (middle inset row) and secondary threshold in sediment (bottom inset row) shown. Biota analyses was carried out on herring, cod, flounder, dab, eelpout, perch and molluscs. Symbols on map define data type and trend with downward triangles indicating decreasing concentrations, upward triangles indicating increasing concentrations and circles indicating no detectible trends. For more details, see HELCOM (2018x).

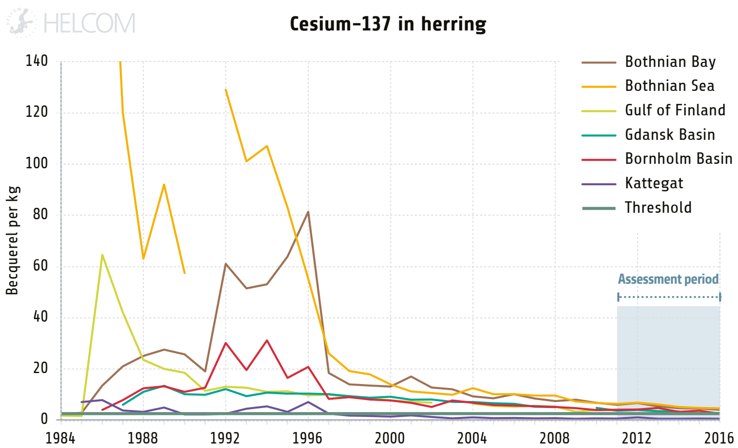
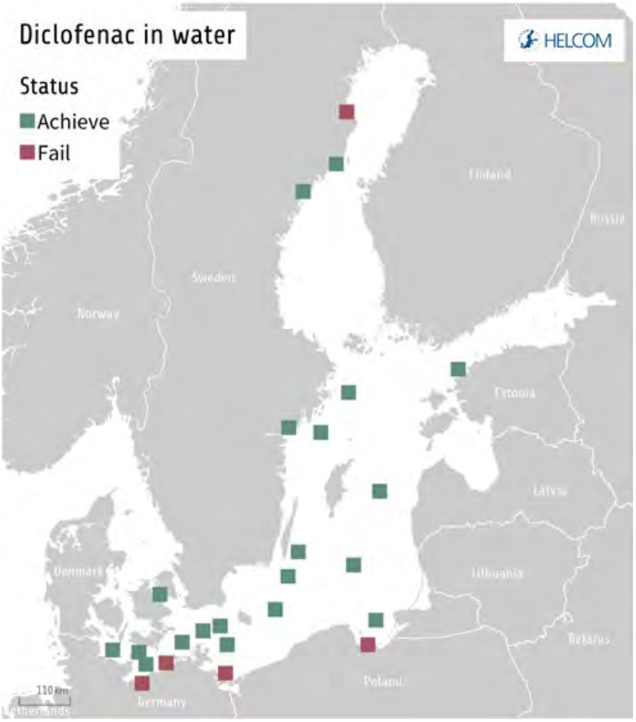


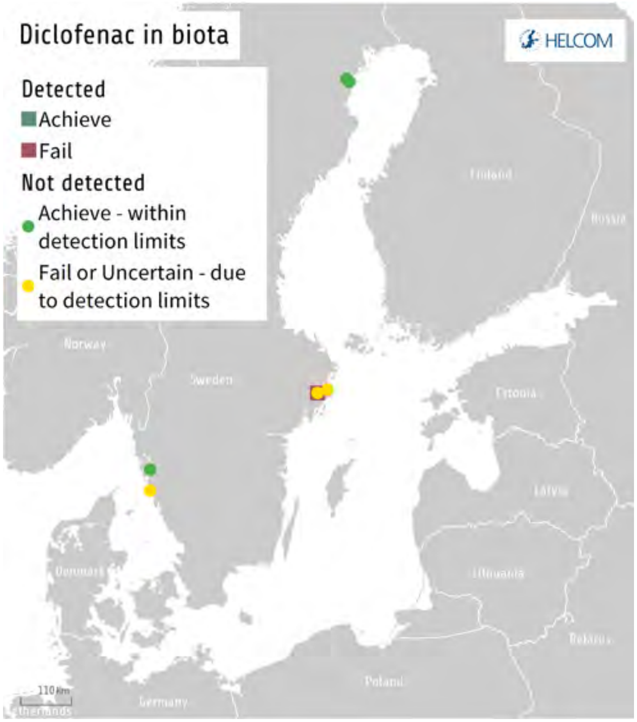
Figure 4.2.11.
Temporal development of the mean concentration of cesium in herring (measured without head and entrails or in filets, by sub-basin). Concentrations are given as Becquerels per kilogram, calculated per wet weight. The green line shows the threshold value.

Radionuclides

Cesium (Cs-137) is the greatest contributor of artificial radionuclides to the Baltic Sea. It emits ionizing radiation, which can have effects at the cellular level and lead to internal damage of organisms. The radionuclide was deposited in the Baltic Sea after the Chernobyl nuclear power plant accident in 1986. Since then it has bio-accumulated in marine flora and fauna, and has been deposited in marine sediments. The concentrations in herring have decreased from the high values in the 1990s in all sub-basins (Figure 4.2.11).

The concentrations of radionuclides are below the threshold value when measured in fish from the Arkona Basin, Bay of Mecklenburg and the Kattegat, indicating good status, but they are above the threshold value in all basins when measured in water (Core indicator report: HELCOM 2018y). Due to the steady half-life of radioactive decay it is expected that concentrations below the threshold value in biota and water may be achieved in all of the Baltic Sea by 2020.





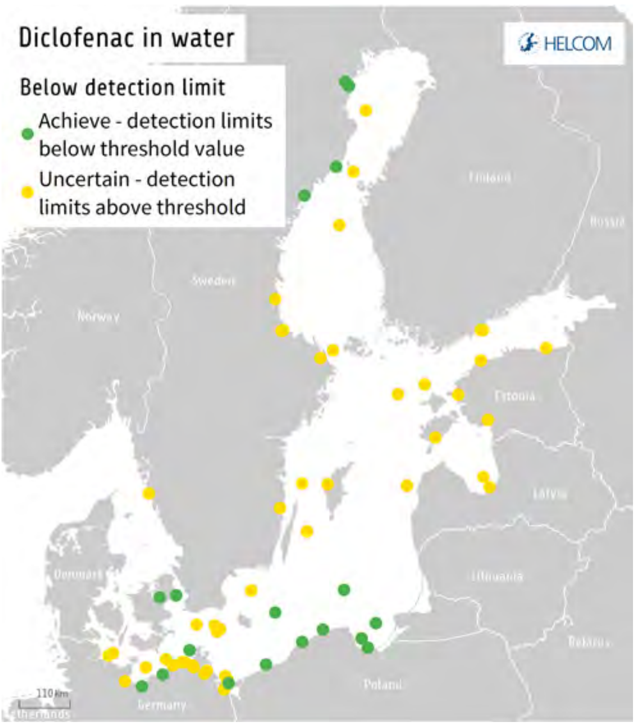


Figure 4.2.12.
Overview of sample location in Baltic Sea water (top left and bottom) and biota (top right) where diclofenac concentrations have been assessed. Samples in which diclofenac were detected are indicated by squares (top left and top right), with colours indicating good (green) and not good (red) status. Circles (bottom and top right) indicate samples in which diclofenac was not detected, with colours indicating the detection limit certainty, green having a detection limit below the set threshold value (i.e. reliable) and yellow having a detection limit above the set threshold value or unknown (i.e. uncertain reliability). The thresholds applied are provisional thresholds and the indicator is a pre-core indicator (HELCOM 2018aa).

▸ Other indicators addressing hazardous substances

Diclofenac

The main source of pharmaceuticals to the Baltic Sea come from humans and animals, via urine and faeces, as well as the inappropriate disposal of unused medical products into sewers. Municipal wastewater treatment plants are considered a major pathway for introduction to the aquatic environment, with an estimated release of about 1,800 tons of pharmaceuticals per year to the Baltic Sea. Current wastewater treatment processes are effective at removing only a few of the detected pharmaceuticals (UNESCO and HELCOM 2017). The fate and impacts of those pharmaceuticals in the environment is still largely unknown.

During 2003-2014, pharmaceuticals were detected in Baltic Sea water, sediment and biota, as well as in wastewater treatment plant influents, effluents and sludge. The most frequently detected pharmaceutical substances belong to the therapeutic groups of anti-inflammatory and analgesics, cardiovascular and central nervous system agents. Diclofenac – an anti-inflammatory drug – was detected in 25 % of samples for which it was analysed (UNESCO and HELCOM 2017).

An indicator for diclofenac is currently being tested in HELCOM (Figure 4.2.12). Pharmaceuticals represent a major group of substances of emerging concern and it is important that an understanding of their distribution, role and fate in the environment is developed.

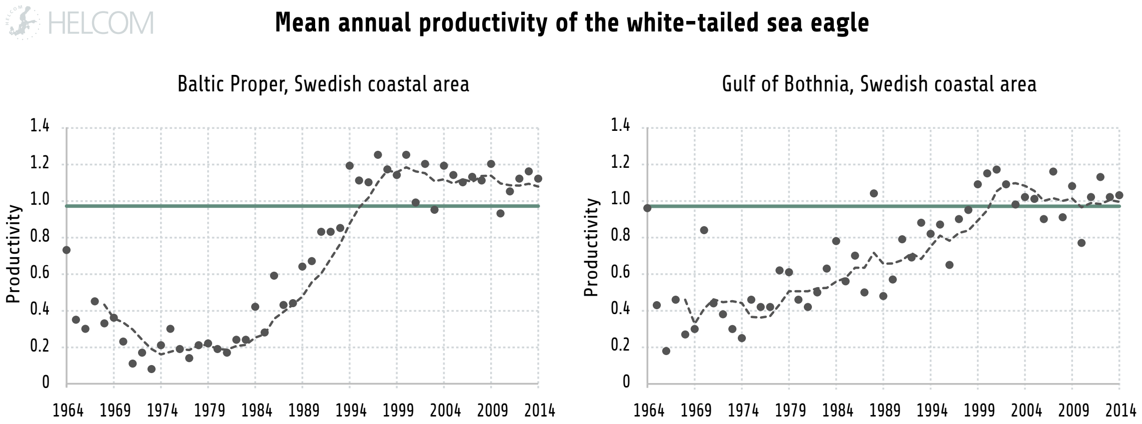


Figure 4.2.13.
Mean annual productivity of the white tailed sea eagle, estimated as the number of nestlings per occupied territory in coastal sub-populations of the Baltic Proper and Gulf of Bothnia (based on data from Sweden) from 1964-2014. The green line illustrates the threshold value of the core indicator. For more information, see the Core indicator report: HELCOM (2018ab).

▸ *White-tailed sea eagle productivity*

White-tailed sea eagles are top predators in the coastal food web, which makes them highly vulnerable to hazardous substances that accumulate and biomagnify. The white-tailed sea eagle has suffered for decades from the effects of persistent chemicals in the Baltic Sea environment. Impacts have been apparent since the 1950s and it was identified at that time that widely used insecticides (DDTs) and possibly polychlorinated biphenyls were major causes.

White-tailed sea eagles are top predators in the coastal food web, which makes them highly vulnerable to hazardous substances that accumulate and biomagnify.
© Cezary Korkosz

Bans on the use of these substances have been in place for decades and positive development has occurred since the 1980s.

Negative effects of long-standing environmental contaminants, as well as emerging new contaminants can become apparent in white-tailed sea eagles before they are visible in other species. Parameters describing the number of hatchlings in nests (brood size) and the proportion of nests producing young (breeding success) can inform on overall productivity (productivity), and can rapidly signal effects from contaminants. While changes in the abundance of adult birds might only occur over a period of several years, an increased mortality of eggs or chicks, and thus a lowered productivity, is often an early warning signal of elevated concentrations of hazardous substances.

The assessment shows that the white-tailed sea eagle productivity reached the threshold value in many coastal areas of the Baltic Sea (Core indicator report: HELCOM 2018ab). In German coastal areas productivity was calculated to be just below the threshold value due to low brood size. In the Gulf of Bothnia Finnish coastal areas, Gulf of Bothnia Swedish coastal areas and Latvian coastal areas brood size also narrowly failed the threshold value, and in the Åland sea Finnish coastal areas the breeding success parameter was at the threshold value (examples shown in Figure 4.2.13). ▸

Operational oil-spills from ships

Oil is the main fuel of ships in the Baltic Sea region, and large amounts of oil are transported across the Baltic Sea. Oil and other petroleum products are released into the sea intentionally or due to negligence, often as oil in bilge water or via dumping of waste oil. Oil may also be released during shipping accidents. Most oil spills are detected along the main shipping routes. Oil spills are a serious threat to the marine environment, causing toxic effects and death of marine animals. Even small amounts of oil on the sea surface can harm waterbirds by contaminating their plumage, which reduces their buoyancy and thermal insulation.

Illegal oil spills have been monitored using aerial surveillance since 1988 in the Baltic Sea area. The aerial surveys today are conducted by all HELCOM Contracting Parties with standardised methods, and cover nearly the whole Baltic Sea area. The effort is focused on the busiest shipping routes. The information collated through the aerial surveillance is used in the core indicator evaluation.

The core indicator 'Operational oil-spills from ships" fails the threshold value in the Bothnian Bay, the Quark, Bothnian Sea, Åland Sea, Eastern Gotland Basin, Western Gotland Basin, the Great Belt, and the Kattegat during the assessment period 2011–2016 (Core indicator report: HELCOM 2018ac). The threshold values are set based on the volumes of oil spills into each sub-basin during a modern baseline status defined by the reference period 2008–2013, when the estimated volume of oil spills was at a historically low level. The long-term goal in HELCOM is to reach a level of zero oil spills.

Both the number of observed illegal oil spills and the estimated volume of detected oil have decreased in all sub-basins during recent decades (Figure 4.2.14). The size of single spills has also shown a decreasing trend, with a significant decrease in spills larger than 10 cubic meters. This decrease has been achieved despite no concomitant decrease in maritime traffic occurring, indicating that measures conducted to decrease oil spills to the environment have been successful.

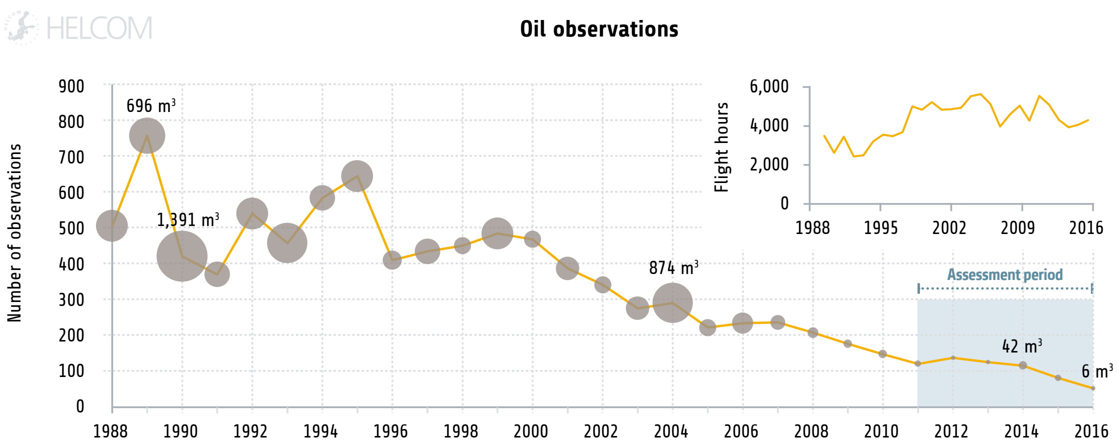


Figure 4.2.14.
The number of oil-spills detected in aerial surveillance by the Baltic Sea countries between 1988 and 2016. The number of flight hours are shown in the inserted figure. The size of the circles indicates the amount of spilled oil in cubic meters. The peaks in the amount of spilled oil detected in 1990 and 2004 were likely caused by single events. In 1990 an accidental spill due to a collision between the Soviet tanker Volgonef 1263 and the West German dry cargo ship Betty at the south coast of Sweden is the main cause, whereas the underlying cause for the high estimated amount of oil in 2004 is undocumented. The peak values highlight that single oil spills may introduce large amounts of oil to the environment, and underline the importance of estimating the volume of introduced oil when evaluating whether the pressure is at a level allowing the environment to reach good status. For more information, see the Core indicator report: HELCOM (2018ac).

Implications and future perspective

The assessment shows that hazardous substances remain a concern in the Baltic Sea, but also that policy and measures do have an impact. Long recovery times are often required for persistent historical contamination. Despite this, and the problem of re-release from historic sediment-deposited contaminants, initial signs of improvement can be detected.

Downward trends are seen for a number of the monitored substances or substance groups. For example, lead inputs have decreased markedly and shows among the largest number of declining trends. Furthermore, a number of substances, such as hexachlorocyclohexane (γ-HCH, lindane), and dichlorodiphenyltrichloroethane (DDT) and its metabolites (DDD, DDE) are no longer considered of significant concern in the Baltic Sea. The improved breeding success in the white-tailed sea eagle is attributed to such reductions. In future assessments it can be expected that radioactive substances will achieve their threshold value, and a number of other substances can be expected to show improvements. Also, it should be recalled that while strong initial decreases may often be observed, latter stages of improvement can be slow, as the levels get closer to the threshold values.

This positive development is however counteracted by the emergence of new contaminants of concern, and by the risk for re-emerging contaminants via secondary sources. Pharmaceuticals is one group of substances of emerging concern, with wastewater treatment plants being identified as a major pathway to the environment (UNESCO and HELCOM 2017). A number of pharmaceuticals considered to be of special concern to the aquatic environment have been included on a 'watch list' under the European Union directive regarding priority substances in the field of water policy (EC 2013b) in a drive to gain greater understanding on the fate and impact of these substances. ■

Pharmaceuticals is one group of substances of emerging concern, with wastewater treatment plants being identified as a major pathway to the environment.

4.3. Marine litter

Marine litter is a clearly visible problem along the Baltic Sea coastline. It also appears under the surface and in many different size classes. The smallest microlitter is invisible to the human eye, but reaches the marine food web when animals ingest it. Larger marine litter deteriorates habitat quality and can cause direct harm to animals when they swallow it or become entangled. Around 70 % of the marine litter in the Baltic Sea is plastic. Plastic materials are of special concern due to their risks to the environment and slow degradation. The regional goal agreed in HELCOM is to reduce the amount of marine litter significantly by 2025 and prevent harm from litter in the coastal and marine environment.

Besides having effects on the environment, marine litter also has a strong socioeconomic dimension. Marine litter may affect human activities and health, reduce the value of tourism and recreation, or result in direct costs for removal. It can also damage fishing gear, contaminate catches or be a risk to navigational safety.

Marine life is impacted both directly and indirectly. Litter may cause harm to animals when they ingest it, by clogging or injuring their digestive tract, or by causing contamination. Another main impact occurs when animals are entangled and strangled in lost fishing equipment or packaging material. Additionally, marine litter affects the quality of habitats by effects on physical structure or local biogeochemistry, and is a possible vector for the transfer of non-indigenous species, leading to effects on biodiversity. The risk associated with microlitter for marine animals is under extensive study (Werner *et al.* 2016). Artificial, polymer materials, more commonly known as plastics, are of special concern due to their longevity, which is further prolonged below the photic zone, and because they may be a pathway for harmful chemicals into the food web.

Globally, it is estimated that 275 million metric tons of plastic waste were generated in 2010, calculated for 192 coastal countries, and that between 4.8 and 12.7 million metric tons entered the ocean, and that the world annual plastic production is still increasing (Jambeck *et al.* 2015). Most plastics are used in packaging or in the building industry and are discarded within a year of their production. In HELCOM, assessment approaches based on core indicators are currently underway for beach litter, litter on the seafloor and microlitter. Threshold values for the assessment are being developed in an EU-process.

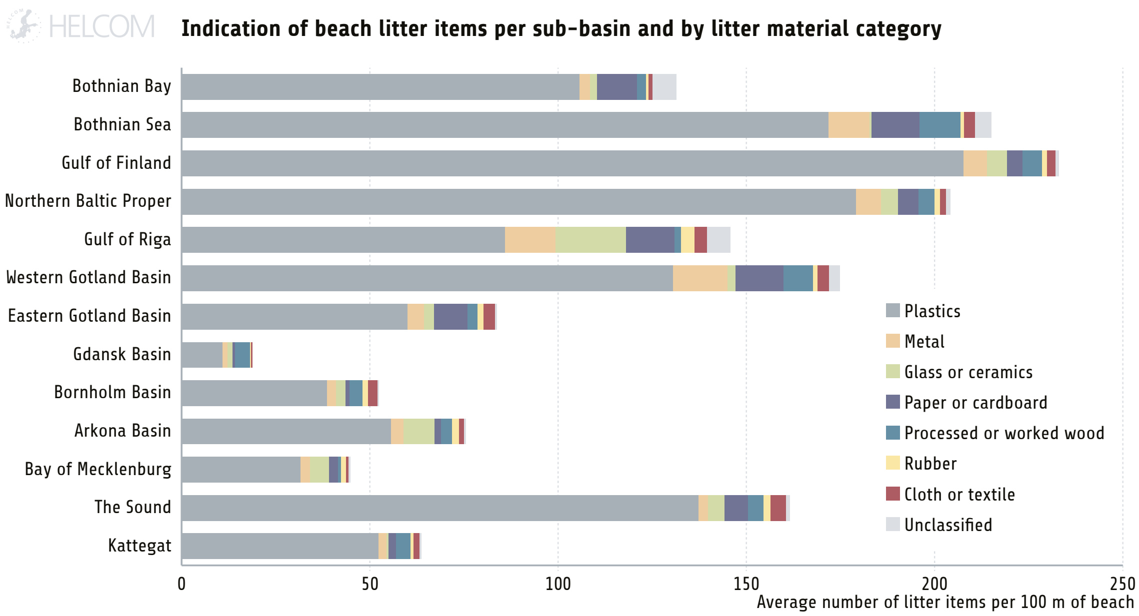


Figure 4.3.1.
Indication of the occurrence of beach litter items in different sub-basins of the Baltic Sea, presented by eight regionally agreed litter material categories ('Plastics' denote all types of artificial polymer materials). The monitoring results have been recalculated to represent the number of litter items per hundred metres of beach. The bars show averages for all countries within the same sub-basin based on available data from Denmark, Estonia, Finland, Germany, Latvia, Lithuania, Poland and Sweden over 2012–2016., However, there is variability with respect to the time period for monitoring and the length of beach monitored in the underlying data. Differences among geographic areas are influenced by the level of local human activities but also by various other factors, such as the shape of coastline, winds and water currents. Source: HELCOM (2018ad).

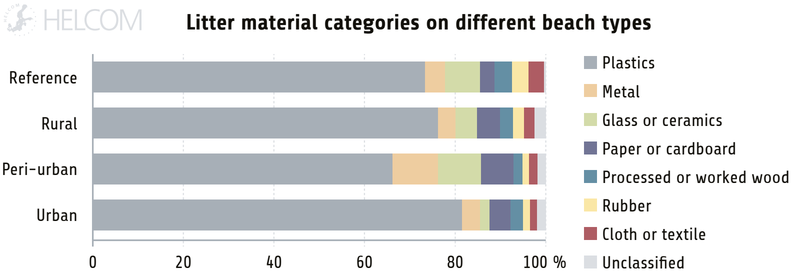


Figure 4.3.2.
Proportions of beach litter items within each of eight regionally agreed litter material categories. The results are presented separately for beaches classified as either urban, peri-urban, rural or reference beaches, based on estimates of the average number of litter items per 100 metre of shoreline in the Baltic Sea using available data for years 2012– 2016. Source: HELCOM (2018ad).

Table 4.3.1.
Ten most frequent litter items at Baltic Sea level at different types of beaches, categorized into urban, peri-urban and rural beaches. The colours identify items categorized as: plastics (artificial polymer materials; grey), paper or cardboard (purple), metals (orange), glass or ceramics (green), and process wood (blue). The results are based on data from Denmark, Estonia, Finland, Germany, Lithuania, Poland and Sweden. Data for reference beaches in Denmark are included under rural beaches. For each survey, the 20 most frequently sampled items were listed, and scores were given to each item. After this, the results for different surveys were merged to provide a regional lists of top ten items. Only data from seasonally monitored sites are included, to prevent from overestimating occasional events. Source: HELCOM (2018ad).

Rank	Urban beach	Peri-urban	Rural beach
1	Drinking related items such as cups, caps, lids (plastic)	Plastic and polystyrene pieces	Plastic and polystyrene pieces
2	Plastic and polystyrene pieces	Food related items such as wrappers, packets (plastic)	Food related items such as wrappers, packets (plastic)
3	Cigarette butts and remains	Cigarette butts	Drinking related items such as cups, caps, lids (plastic)
4	Food related items such as wrappers, packets (plastic)	Drinking related items such as cups, caps, lids (plastic)	Plastic bags
5	Paper and cardboard items	Plastic bags	Bottles and containers (plastic)
6	Drinking related items such as bottle caps, pull tabs (metal)	Single-use cutlery and straws	String and ropes (plastic)
7	Plastic bags	Drinking related items such as bottle caps, pull tabs (metal)	Cigarette butts
8	Single-use cutlery and straws	Glass and ceramic fragments	Glass and ceramic fragments
9	Bottles and containers (plastic)	Foil wrappers and pieces of metal	Industrial packaging
10	Drinking related cans (metal)	String and ropes (plastic)	Processed wood and pieces of processed wood

Marine litter on the beach

Monitoring of beach litter at Baltic Sea regional scale is under development. Currently available data give an indication of how marine beach litter is distributed along Baltic Sea shorelines, suggesting that the highest densities of beach litter occur in the Gulf of Finland, Bothnian Sea, and Northern Baltic Proper (Figure 4.3.1). The differences among sub-basins are attributed to actual differences in littering, as well as in the levels of beach cleaning. In addition, the shape of the coastline, winds, and the direction of water currents appear important in determining where litter accumulates.

The monitored sites are categorized into either urban, peri-urban, rural or reference beaches, based on how close they are to human activities. The average number of beach litter items on reference beaches is about 47 per hundred meters of shoreline, and up to about 280 items per hundred metres on urban beaches (HELCOM 2018ad).

Plastics are clearly the most common litter materials (Figure 4.3.2). In much smaller amounts, paper and cardboard are the second most common materials on urban beaches, whereas metal, glass and ceramics are the second most common on the other three types of beaches. Litter items at urban and peri-urban beaches are more likely to originate from activities on land close to the monitored site, whereas beach litter recorded at rural and reference beaches are more likely to come from sources at sea.

The most frequently occurring beach litter items at Baltic Sea scale are attributed to eating, drinking or smoking activities, such as food wrappings, bottles or lids, as well as plastic pieces of different sizes (Table 4.3.1). These items are common in all parts of the Baltic Sea, together with items related to industrial packaging, such as sheeting, strapping bands and masking tape (based on data from fifteen sub-basins). Derelict fishing gear are among the twenty most common items in the Eastern Gotland Basin, Gdansk Basin and Kiel Bay. It is noteworthy that balloons or balloon-related items are found among the top ten items in nine of the fifteen sub-basins (HELCOM 2018ad).

Litter on the seafloor

Litter that enters the marine environment can be transported over long distances by water currents, and it often accumulates on the seafloor, far away from its original source. Hence, multiple sources can contribute to seafloor litter. However, items associated with maritime activities are a major component. So called 'ghost nets', which are defined as abandoned, lost, or otherwise discarded fishing gear, pose an especially large risk to marine life since they continue fishing, trapping not only fish, but also other marine life including birds and marine mammals over long timeframes. Experiments have shown that the catching efficiency of lost gillnets amounts to approximately 20 % of the initial catch rates after three months, and around 6 % after 27 months (WWF Poland 2011).

Ghost nets are lost fishing gear that continue fishing on the seafloor, catching fish as well as other organisms.
© Wolf Wichmann

Seafloor litter is monitored in connection to fish trawling surveys, by counting litter caught in the fish trawl. The survey provides an indication of litter on the seafloor, but does not cover shallow water areas or complex substrates, and not all parts of the Baltic Sea. For example, the Gulf of Bothnia is not covered. Items made from natural materials, such as wood, natural fibres and paper, and plastic items dominate in most sub-basins (Figure 4.3.3). The proportion of metal items is highest in the Kiel Bay and the Eastern Gotland Basin.

Slightly over half (58 %) of the 1,599 hauls reported in 2012-2016 contained marine litter items (HELCOM 2018ae). The average number of items was clearly highest in the Western Gotland Basin. Plastic was the most common litter material category at the Baltic Sea scale, constituting on average around 30 % of the number of items and 16 % of the weight. A weak but statistically significant increase in seafloor litter representing non-natural materials was seen over the studied time period.

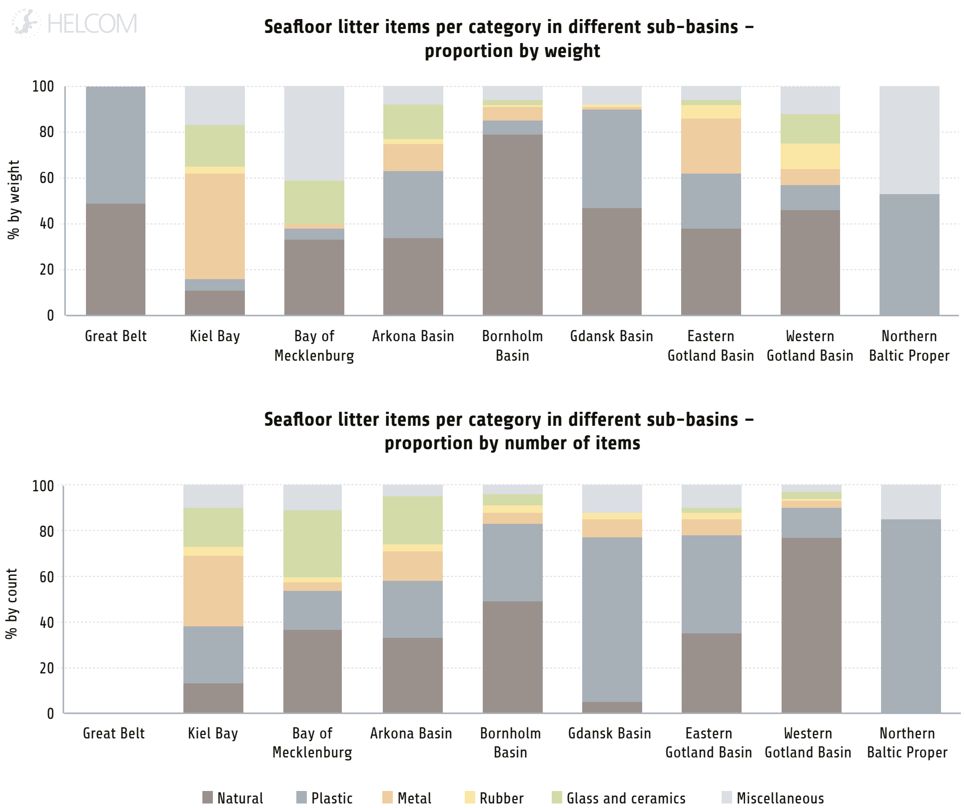
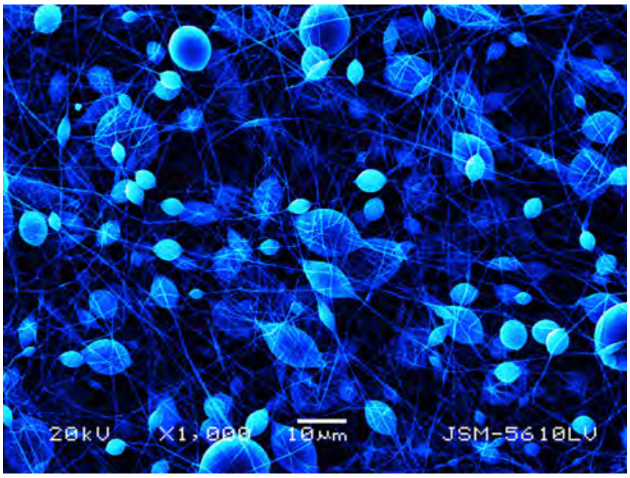


Figure 4.3.3.
Proportion of marine litter material categories in bottom trawl hauls for sub-basins covered by the survey. No data for number of items by category was available for the Great Belt. Based on data from the Baltic International Trawl Survey coordinated by ICES, summed for all years 2012-2106. Source: HELCOM (2018ae).



Electrospun fibers at a scale of 10 µm. Most of the environmental harm of microlitter has been associated with microplastics.

Box 4.3.1

What is microlitter?

The term 'microlitter' is used for litter particles smaller than 5 mm, but they can also be much smaller (GESAMP 2015). Some studies have focused on particles as small as 20 or even 10 µm. The particles can be synthetic and non-synthetic particles, such as plastic, cellulose, cotton, wool, rubber, metal, glass and combustion particles.

Microlitter particles can originate from land-based sources, for example via waste water, but they are also created at sea during the breakdown of larger litter items or by tearing from equipment used for maritime activities (Lassen *et al.* 2015, Welden and Cowie 2017).

Microlitter has been detected inside species in all levels of the food web and may be found in all parts of the environment: on the water surface, within the water column, on the seafloor, and on shore (Lassen *et al.* 2015). Particles with low density, such as many common plastic types, can also reach the seafloor, by being incorporated in marine snow, attached to sinking detritus, or when they are covered with biofilms which increases their density and hydrophobic state.

Microlitter

Most of the environmental harm of microlitter has been associated with microplastics, and the potential risks associated with ingestion of microplastics by marine organisms. The composition of microlitter with respect to different materials has not yet been regionally assessed in the Baltic Sea. Based on the composition of other types of litter in the Baltic Sea, it is likely that the majority of microlitter is derived from the breakdown and usage of larger plastic litter items, although other components may also be important (Magnusson *et al.* 2016, See also Box 4.3.1).

So far, microlitter has only been sampled for a few years in the Baltic Sea and a number of different methods and sampling devices have been used. Coordinated regular monitoring is under development. As one example of results, 0.3-2.1 particles per cubic metre were noted in the Gulf of Finland (Setälä *et al.* 2016) and 0.04-0.09 particles per cubic metre were recorded in the South Funen Archipelago, Belt Sea (Tamminga *et al.* 2018), both studies using Manta trawls with mesh sizes over 333 micrometres.

In comparison to other seas, studies on the abundance of plastic debris near the Swedish city of Stockholm have estimated levels to be similar to urban areas in California, USA, and the overall abundance in the Stockholm Archipelago similar to reports from the north-western Mediterranean Sea (Gewert *et al.* 2017).

Impacts and recovery

Many types of marine litter degrade very slowly and inputs to the sea accumulate in the environment — in the living environments of organisms or inside of species. In addition, the degradation process will change the nature of the problem, so that litter entering as macro-litter may turn into microlitter over time, and may additionally cause chemical effects.

Political will and robust regulatory action are key factors for reducing the pressure from marine litter. Efforts to change consumption patterns are key to stopping litter from entering the marine environment, and are expected to depend strongly on public awareness. In addition, regulatory frameworks and actions to improve waste and wastewater management are of high significance.

A large number of measures have been agreed on by HELCOM over recent years, which directly or indirectly can be expected to result in reducing amounts of marine litter. The 2013 HELCOM Ministerial Declaration (HELCOM 2013a) contains a commitment to achieve a significant quantitative reduction of marine litter by 2025 (compared to 2015) and to prevent harm to the coastal and marine environment. To achieve this goal the effective and timely implementation of land-based, sea-based and educational and outreach actions as defined in the HELCOM Action Plan on Marine Litter is needed (HELCOM 2015c).

4.4. Underwater sound

Sound is continuously present in the underwater environment, and is produced naturally for example by wind, waves, ice, and thunder storms, as well as by animals. Human activities cause additional sounds which may have a polluting effect. These are typically by-products of marine activities and infrastructure, such as shipping, bridges, or underwater construction work, but are also spread deliberately by the use of echo-sounders, sonars and seismic airguns, for example. HELCOM has developed monitoring of underwater sound, and agreed that underwater sound should not have negative impact on marine life in the Baltic Sea.

Explosions are a major source of underwater sound, an import pressure on the Baltic Sea environment.
© Bengt Wikström

Sound waves propagate over long ranges in water and their impact may occur far from the sources, and across national boundaries. Two categories of sound are identified: continuous and impulsive.

Continuous sound from a source can be constant, fluctuating, or slowly varying over a long time interval. Various human activities may generate continuous sound. Examples of activities which influence the local sound environment include bridges, offshore wind turbines, shipping and boating. One concern is that human generated continuous sound may mask animals' communication and signals used for orientation.

Impulsive sound is characterised by short duration and a fast pulse rise time. The sound associated with piling, underwater explosions or airgun signals used in seismic surveying are examples of impulsive sound. This type of sound can displace animals, and scare them away from significant areas for feeding, calving and other social interactions, as well as cause temporary or permanent hearing loss if no mitigation measures are applied.

There is a variation in how well animals hear different frequencies, and therefore different species will perceive different parts of the soundscape in different ways. For example, fish hear low frequencies better than marine mammals, and porpoises hear higher frequencies better than seals. The sound produced from shipping occur at frequencies which overlap with the hearing range of several species, including fish and marine mammals (Figure 4.4.1).

A good environmental status with respect to underwater sound requires that the level and distribution of both continuous and impulsive sounds should not cause negative impacts on marine life (HELCOM 2013a). At this time, such levels have not been defined for sound sensitive species in the Baltic Sea.

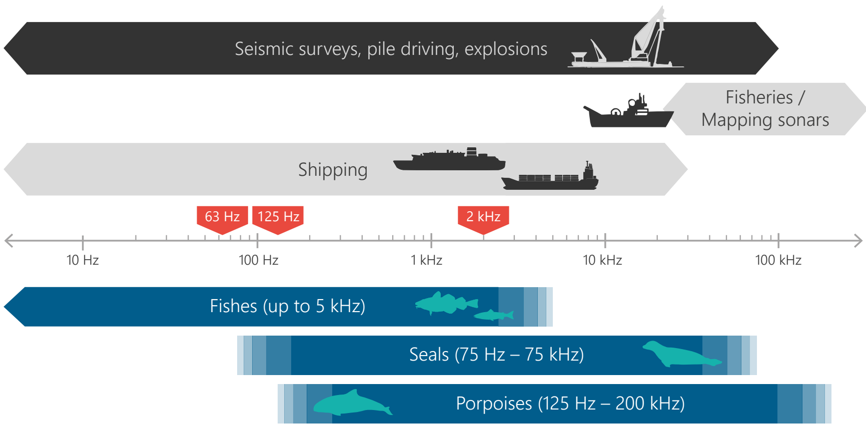


Figure 4.4.1.
Sound frequencies generated by human activities with schematic illustration of auditory range of some marine species present in the Baltic Sea. Both impulsive sound (black bar) and continuous sound (grey bars) are present in the Baltic Sea and can be perceived by for example fish, seals and harbour porpoise at a wide range of frequencies. The frequencies of sound from human activities are indicated broadly, and are highly variable also within the same activity type. For example, sound from pile driving is typically most intense at frequency ranges up to 1kHz, but is also heard at higher frequencies, and the intensity and character of the sound varies depending on several factors, such as which specific method is used and seabed characteristics in the area where the activity takes place. Fish typically hear sound at lower frequency ranges and harbour porpoises at higher frequency ranges. For comparison, the human ear can hear frequencies only at a range in from around 20 Hz to 20 kHz in air. However, the sound pressure levels and distribution of sound under water is not directly comparable to those in air. The red arrows point to the frequency bands monitored within BIAS (see figure 4.4.2). Modified from Scholik-Schlomer (2015) and BIAS (2017).

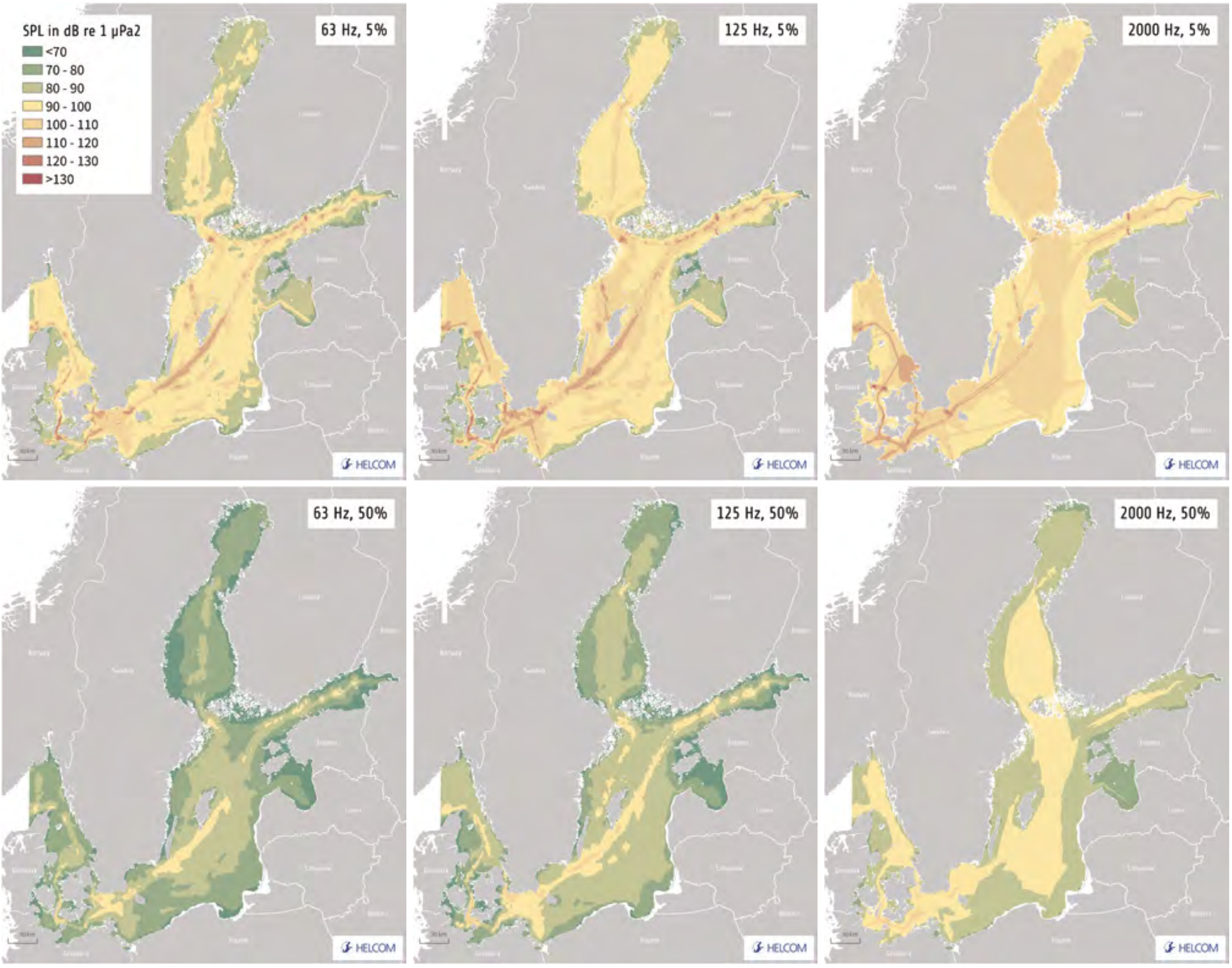


Figure 4.4.2.
Sections of the Baltic Sea soundscape. The maps show the sound pressure level of underwater continuous sound at different frequency bands (measured as dB re 1µPa in 1/3 octave frequency bands centred at 63 Hz, 125 Hz and 2000 Hz, respectively). In each case, the upper row shows the distribution of sound pressure levels exceeded 5% of the time (L5), and the lower row the levels exceeded at least half of the time (L50). For example, areas experiencing sound pressures above 100 dB re 1µPa during more than half of the time are confined to the narrow parts of the main shipping route. A considerably larger area experiences similar sound pressure level 5% of the time. The values represent the whole depth layer from surface to bottom as annual averages for 2014. The results have been extracted with help of the soundscape planning tool of BIAS (2016).

Continuous low frequency anthropogenic sound

Continuous sound in the Baltic Sea was monitored in a comprehensive study using automated hydrophone loggers in 2014 by the project Baltic Sea Information on the Acoustic Soundscape (BIAS). The data were used to develop modelled soundscape maps (Figure 4.4.2), which show the spatial and temporal distribution of continuous sound in different frequency bands across the Baltic Sea (1/3 octave bands of 63, 125 and 2000 Hz). The lower frequency bands assessed are mostly related to ship induced sound, and the higher frequency bands are measured due to their ecological relevance. Areas with high sound levels are identified particularly along major shipping routes, and within these, the highest prevalence is seen in the southernmost areas.

Monitoring of ambient sound is carried out by several countries on a temporary basis, and a regional programme for monitoring continuous underwater sound is under development.

Busy shipping lane in the Stockholm archipelago. Areas with high sound levels are identified particularly along major shipping routes.

Impulsive sound

Impulsive sounds may cause displacement as well as physical damage to marine animals, unless mitigation measures are successfully applied.

The occurrence of activities associated with loud impulsive sounds, such as hydro-acoustic measurements, underwater explosions and pile driving, can (since 2015) be logged in a regional registry established by HELCOM and OSPAR and hosted by ICES (2018). Countries have agreed to register these activities, and reports on sound-generating activities have so far been supplied by six countries during the period 2011–2016 (Table 4.4.1). In the future the registry will provide a quantitative view of activities that generate impulsive sound and their distribution in the Baltic Sea to support future status assessments.

Information from the registry will also support evaluation of possible impacts on species and decisions on mitigation strategies to be applied when conducting impulsive sound generating activities.

Table 4.4.1.
Impulsive event days in the Baltic Sea reported by HELCOM countries, given by event type as reported to the regional registry of impulsive events, by April 2018 (ICES 2018). Values show reported numbers of annual events for the years 2011–2016. Reporting is limited to events meeting predefined criteria relating to pressure categories, and is currently under development. The numbers give an indication of the occurrence of impulsive events, but some events taking place are absent from national registers. 'NR' is shown for cases of no reporting/not known. Note that pile driving activities included in the table often use mitigation measures which reduce the impulsive sound.

Country	Impact pile driving	Sonar or acoustic deterrents	Airgun arrays	Explosions	Generic explicitly impulsive source
Denmark	0* (2015) 24 (2016)	NR (2015) 27 (2015)	NR (2016) 61 (2016)	NR (2015) NR (2016)	NR (2015) 22 (2016)
Estonia	0 (2012-2016)	NR	0 (2012-2016)	90 (2012) 3 (2013) 23 (2014) 67 (2015) 8 (2016)	NR
Finland	NR	NR	NR	32 (2013) 169 (2014) 54 (2015) 372 (2016)	2 (2011)
Germany	95 (2013) NR (2014) NR (2015) NR (2016)	NR	NR	NR	NR
Latvia	NR	NR	NR	NR	NR
Lithuania	NR	NR	NR	8 (2013) 12 (2016)	NR
Poland	NR	NR	NR	25 (2011) 38 (2012) 36 (2013) 36 (2014) 39 (2015) 42 (2016)	NR
Russia	NR	NR	NR	NR	NR
Sweden	NR	90 (2015) 124 (2016)	31 (2015) 20 (2016)	35 (2015) 10 (2016)	NR

* Only data on construction of windfarms were collected, hence other pile driving events might have taken place.

Impacts

Across the Baltic Sea there is strong temporal and spatial variability in sound levels, but there is still considerable uncertainty regarding to what extent marine species may be impacted.

Harbour porpoise and seals are likely to be especially affected by human generated sound of specific frequencies and levels (Kastelein *et al.*, 20110). They have very good underwater hearing abilities and rely on sound for their orientation, communication and foraging. Harbour porpoise also uses echolocation to find prey. Many Baltic fish species hear and produce sound at low frequencies. For example cod uses sound to communicate and to perceive their environment. For most species, including fish, diving birds and the majority of Baltic invertebrates, little is known about what role sound plays, even though it is likely that it is essential in at least some part of their life cycle and that they could be affected by high sound levels.

For the first time in the HELCOM assessment, spatial information of the sound distribution in the Baltic Sea has been compared with maps of key areas for sound-sensitive species. The overlap (Figure 4.4.3) gives an indication of the risks from sound generating activities to different species. Spawning areas for cod and recruitment and foraging areas for harbour porpoise are examples of areas with elevated risk of impact.

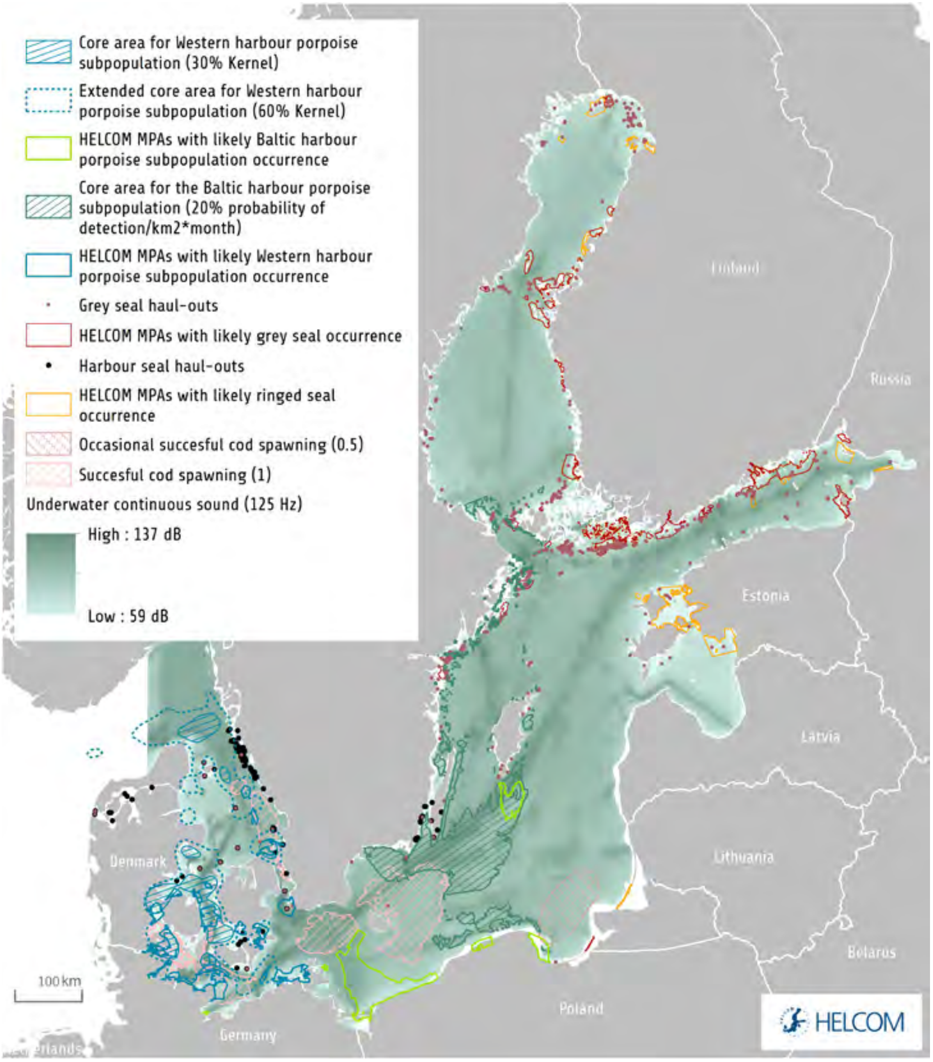


Figure 4.4.3.
Example of how information on the distribution of sound can be compared with important areas for species that are sensitive to sound. The example shows areas identified so far, based on Schack *et al.* (2016, see HELCOM 2016c). The soundscape shown is the sound pressure level (dB re 1uPa) for the 125 Hz frequency band occurring 5 % of the time, for the whole water column (surface to bottom) in June 2014.

Harbour porpoise.

A changing sound environment

There is no data to show how sound levels have changed over time in the Baltic Sea. Looking ahead, at least some of the human activities which may generate underwater sound are likely to increase, such as off-shore construction work, energy installations and shipping, as well as dredging and leisure boating. Depending on the scale of such expansions, as well as technical developments in maritime activities, it is likely that both the level of sound and its character will change over time. There is still limited knowledge about how marine animals may react to or be affected by human induced underwater sound. With respect to areas, species and seasons involving high risks, pre-emptive mitigation measures and the implementation of sound reduction solutions are foreseen to play an important role in counteracting and reducing impacts, as well as maritime spatial planning. ■

4.5. Non-indigenous species

Non-indigenous species are species that have spread or been transferred as a result of human activities, reaching environments in which they previously did not naturally occur. Shipping and aquaculture are important vectors for the introduction and spread of non-indigenous species, since the species are easily transported in ballast water tanks or on ship hulls. To date, around 140 non-indigenous species or new species with unknown origin (cryptogenic species) have been recorded in the Baltic Sea. Of these, twelve were new introductions for the Baltic Sea in the period 2011–2016.

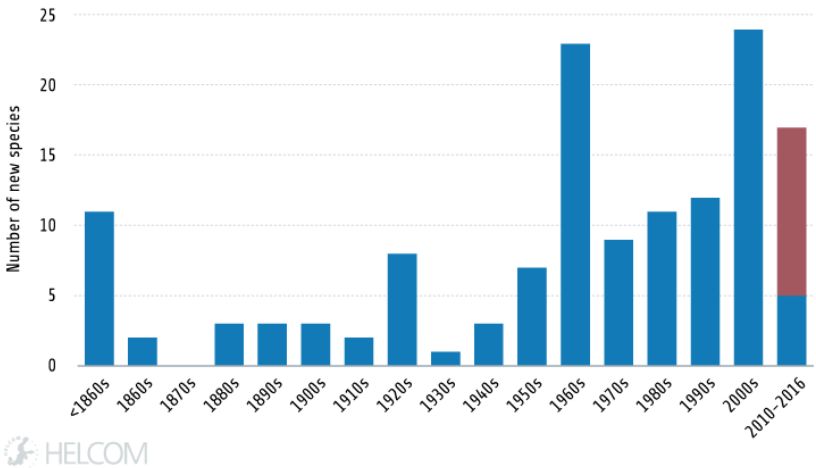
Harbours and ports are hot spots for the introduction of non-indigenous species as they offer extended periods during which ships are stationary, and often offer suitable places for species to settle in shallow water or modified habitats (Lehtiniemi *et al.* 2015). Non-indigenous species are usually not dispersed by natural means, but arrive in their new environments via some form of human-mediated transport, so called vectors. The most probable vectors for non-indigenous species into the Baltic Sea are aquaculture and shipping (Galil *et al.* 2014). These species commonly attach to the ships hulls (so called biofouling) or are transported in ballast water and then released when the water is exchanged. Furthermore, the opening of connections to different river systems created by canals are important vectors for dispersal, and many Ponto-Caspian species have found new routes to the Baltic Sea in this way. Although the Baltic Sea contains numerous non-indigenous species, salinity levels and temperature may in some cases limit the spread and establishment of non-indigenous species within the Baltic Sea (Holopainen *et al.* 2016).

After their first introduction to a new sea area, non-indigenous species may spread further. The rate of spread is often determined by species specific factors, such as environmental tolerance or reproductive rates. For example, the round goby (*Neogobius melanostomus*), a bottom-dwelling invasive fish originating in the Black Sea and Caspian Sea, was observed for the first time in the Baltic Sea in 1990. After a few years with low abundance, the species increased dramatically and it is now a dominant species in many areas of the Baltic Sea, with a capacity to change interactions in the benthic food web (Kotta *et al.* 2016). This pattern of establishment, and consecutive spread, is characteristic of invasive species. However, not all non-indigenous species are invasive, and may not spread widely nor become abundant. Established non-indigenous species may influence biodiversity and the ecosystem in different ways, and their effects are often difficult to foresee. Risk assessments are important to guide the management of non-indigenous species and help to implicate measures at an early stage (Katsanevakis *et al.* 2014).

The HELCOM core indicator assesses the number of new introductions (primary introductions) to the Baltic Sea region for the given assessment period (2011-2016). The threshold value is zero, as it is set in relation to the objective that there should be no primary introductions of non-indigenous species due to human activities during a six year assessment period (Core indicator report: HELCOM 2018af). Thus, the core indicator evaluates the successfulness of management to prevent introductions (Olenin *et al.* 2016).

Table 4.5.1.
Non-indigenous species with primary introductions in the Baltic Sea during 2011–2016. The reporting of observations during 2016 is not yet complete, and additional species for this year will be included in an update in 2018.

Species	Taxonomic group by phylum or division	First reported from	Year
Laonome sp.	Segmented worms (Annelida)	Gulf of Riga	2013
Echinogammarus trichiatus	Crustaceans (Crustacea)	Bornholm Basin	2014
Proasellus coxalis	Crustaceans (Crustacea)	Bornholm Basin	2011
Antithamnionella ternifolia	Red algae (Rhodophyta)	Kiel Bay	2014
Diadumene lineata	Cnidarians; a sea anemone (Cnidaria)	Kiel Bay	2011
Hemigrapsus takanoi	Crustaceans (Crustacea)	Kiel Bay	2014
Sinelobus c.f. *vanhaareni*	Crustaceans (Crustacea)	Arkona Basin	2012
Grandidierella japonica	Crustaceans (Crustacea)	Bay of Mecklenburg	2015
Haminoea solitaria	Mollusks (Mollusca)	Bay of Mecklenburg	2016
Beroe ovata	Comb jellies (Ctenophora)	Great Belt	2011
Chaetoceros concavicornis	Algae; a diatom (Ochrophyta)	Great Belt	2011
Tharyx killariensis	Segmented worms (Annelida)	Kattegat	2012



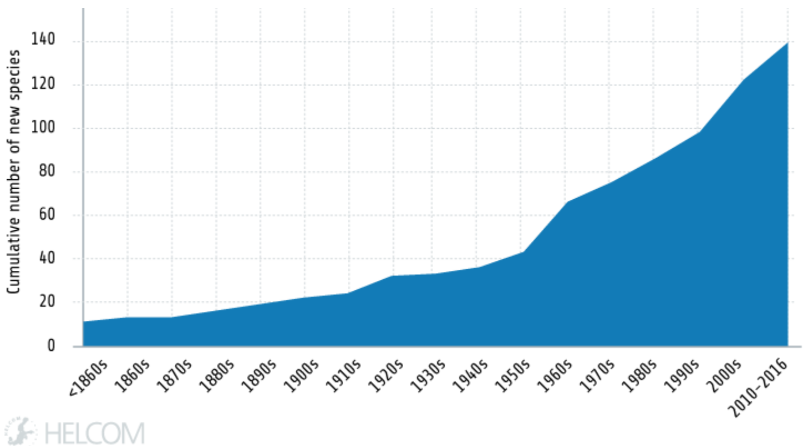


Figure 4.5.1.
Number of new non-indigenous species in the Baltic Sea. Upper graph: Estimated number of new observed non-indigenous species in Baltic Sea per decade. The bars indicate the number of invasions per time period. The red part of the last bar denotes observations from 2011 onwards. Lower graph: The same data set shown as cumulative numbers since the 1900s. Based on data from the data based 'AquaNIS', as used in Ojaveer *et al.* (2016).

Assessment result

Twelve species have arrived as new non-indigenous species in the Baltic Sea between 2011 and 2016. Hence, the core indicator fails the threshold value (zero new introductions) for good status. The animal species were represented by five small crustaceans, three worms (Annelida), and three species belonging to other animal groups. Two algae were also observed; one diatom and one red alga (Table 4.5.1). The estimate may be seen as a minimum count, as it is difficult to ascertain the absence of a new introduction, and the presence of designated monitoring strategies differs greatly between the sub-basins (Core indicator report: HELCOM 2018af). During the assessment period, an unknown number of previously arrived non-indigenous species have also expanded their distribution range to new sub-basins in the Baltic Sea. It is often difficult to ascertain if this secondary spread is due to human activities or not. Secondary spread is not included in the evaluation of the core indicator, which only includes first time introductions. For example, the mud crab (*Rhithropanopeus harrisii*) was observed as a new species to the Swedish Western Gotland basin in 2014, but given that it was previously observed in Poland, Denmark, Germany and the Russian Kaliningrad coast in the 1950s it is not counted as a new arrival in the Baltic Sea for this assessment period.

Human mediated introductions of species to the Baltic Sea have also occurred in the past. A reconstruction of previous events suggest that the rate of introduction of non-indigenous species has increased in recent decades (Ojaveer *et al.* 2016). Introduction rates during the first and second decade of the 2000s seem to be of the same order of magnitude (Figure 4.5.1). However, it is important to note that the likelihood of observing new introductions is dependent on the monitoring effort, and increases with increasing monitoring effort.

Impacts and recovery

Non-indigenous species pose a threat to the marine environment as they may induce changes in the structure and dynamics of the ecosystem. For example, the distribution and abundance of the round goby is a reality to be dealt with in many parts of the Baltic Sea. How this fish, as well as other non-indigenous species, will affect the food web and the ecosystem is important to comprehend so that potential changes can be foreseen.

The impacts of single, let alone multiple, non-indigenous species are complex and may in some cases be hard to distinguish from the impacts of other pressures. Economic impacts occur due to loss of fishing possibilities, expense to industries for cleaning intake pipes, and to remove biofouling, for example. Public health impacts can arise from the introduction of pathogens or toxic algae (Zaiko *et al.* 2011). However, even though the risks are generally known, it is often hard to predict the impacts of non-indigenous species in marine ecosystems, as these are poorly documented (Ojaveer *et al.* 2016).

Once a non-indigenous species has become established and spread to a wide area, eradication is not a viable management option. Full recovery in the sense of returning back to a previous state is not possible. Hence, management should primarily aim to prevent further introductions, along with minimizing the negative effects of the already introduced non-indigenous species.

The entry into force of the IMO Ballast Water Management Convention in September 2017 and its further ratifications can be expected to decrease the pressure and risk of new introductions of non-indigenous species and other harmful organisms to the Baltic Sea. To date, the HELCOM countries Denmark, Estonia, Finland, Germany, Lithuania, Russia and Sweden have ratified the convention. Increased attention will be placed on the development of measures to address biofouling as a vector in the introduction of non-indigenous species. ■

The round goby (*Neogobius melanostomus*) originates from the Black Sea and Caspian Sea.
© Zilvinas Putys

4.6. Species removal by fishing and hunting

Fishing and hunting are traditional sources of livelihood in all Baltic Sea countries. Hunting has a minor role today, but fishing is still an important source of food and income. Stock assessments show that three out of nine internationally assessed fish stocks achieve good status with respect to both biomass and fishing mortality rates. Recreational fishing may contribute considerably to the total mortality, especially in coastal areas, but estimates of its magnitude are uncertain. A current challenge to be met by the fishing sector is to ensure resource utilisation in line with the ecosystem-based approach.

Box 4.6.1.

Methods used in commercial fishery

Cod (*Gadus morhua*) is mainly fished by demersal trawls reaching the seabed. It is also fished with gillnets, often with a by-catch of flatfish, which is also utilised. In times of low cod quotas and high flatfish abundances, flatfishes can become the key target species, especially dab (*Limanda limanda*) and flounder (*Platichthys flesus*). Pelagic commercial species are almost exclusively sprat (*Sprattus sprattus*) and herring (*Clupea harengus*), and are mainly fished by pelagic trawls, in the water column.

Salmon (*Salmo salar*) is caught by long lines during its feeding stage in the sea, or by trap nets or gill nets during their spawning run, and salmon fishing is also sometimes allowed in river mouths. Drift nets have been fully banned in the Baltic Sea since 2008. The coastal fisheries use mainly gill nets, pound nets, trap nets, and in some areas Danish seines. A variety of species are targeted, depending on season and availability, including herring, cod and flounder and coastal freshwater species such as pikeperch (*Sander lucioperca*) and perch (*Perca fluviatilis*). Demersal trawling occurs in some coastal areas, but is forbidden in the coastal zone in many of the Baltic countries.

Fishing net.
© Wolf Wichmann

Commercially exploited fish

The Baltic Sea fisheries target both marine and freshwater species, but the most important species for the commercial fisheries are marine (Box 4.6.1). Cod, herring and sprat represent about 95 % of the total catch in biomass terms. The fish is used for human consumption, but industrial use represents a large share, as oil, fish meal or animal fodder, depending on the market conditions. Other important commercial species are plaice, flounder, dab, brill, turbot, along with the migratory species salmon, and sea trout. Common commercial species with freshwater origin include pike, perch, pikeperch, vendace, and whitefish.

The Baltic Sea fisheries also catch eel, classified as a widely distributed species with a population that extends over several marine regions but which has declined dramatically (see also Box 5.3.1 in Chapter 5.3). Recreational fishing mainly targets the same stocks as commercial fisheries. Incidental by-catches of birds and mammals in connection to the fisheries are evaluated in Chapters 5.4 and 5.5.

The overall objective of the Baltic Sea fisheries is to ensure economically, environmentally and socially sustainable use of fisheries resources in alignment with the ecosystem-based approach. Long term management plans for the internationally managed fish stocks aim to ensure that these are capable of producing a maximum sustainable yield (MSY), as mainly being regulated by the exploitation rate (EC 2016). The status evaluation presented here was based on fisheries management advice provided by the International Council for the Exploration of the Sea (ICES 2017b-f). Two aspects: fishing mortality and spawning stock biomass, were evaluated separately for each stock. Status was evaluated against the condition that the average assessment ratio during 2011-2016 should achieve the reference values for both fishing mortality and spawning stock biomass (see also Box 4.6.2).

Assessment result

One demersal stock (plaice, *Pleuronectes platessa*) and two herring stocks (*Clupea harengus*) achieve good status with respect to both fishing mortality and spawning stock biomass during 2011-2016 (Figure 4.6.1). Three demersal and three pelagic stocks fail the reference value for at least one of these indicators; both cod stocks (*Gadus morhua*), sole (*Solea solea*), two of the herring stocks, and sprat (*Sprattus sprattus*; Figure 4.6.2). The combined status was not possible to evaluate for eight demersal stocks (representing flatfishes).

At the level of each indicator, fishing mortality is assessed as too high for two demersal stocks and three pelagic stocks assessed for this indicator, whereas eight of the assessed stocks are fished at a level consistent with maximum sustainable yield. Spawning stock biomass is below the biomass reference point, indicating not good status, for two out of four assessed demersal stocks, and for one of the pelagic stocks.

Among the migratory species, slightly less than half of the salmon stocks (*Salmo salar*) are assessed to meet the criteria for maximum sustainable yield for 2016, or 14 out of 32 river stocks, also including consideration of recreational catches (ICES 2017d-e). With a few exceptions, the rivers in the northern Baltic Sea area present a better status for salmon than the southern ones. A reduced fishing of sea trout (*Salmo trutta*) was advised for the Gulf of Bothnia, the eastern part of subdivision 26 and the southern parts of subdivisions 22 and 24, to protect weak wild populations in these areas (ICES 2017f).

The status of the widely distributed European eel (*Anguilla anguilla*) is critical, based on stock size and many sources of mortality in addition to fishing (ICES 2017g; Box 5.3.1 in Chapter 5.3).

The level of fishing mortality has been similar over the past ten years for most pelagic stocks, but has been increasing for herring in the Gulf of Bothnia[1] (Figure 4.6.3). The fishing mortality of sprat was too high in five of the assessed years, but achieved the reference value in 2016. With respect to demersal species, the fishing mortality of sole and plaice in the Western Baltic has decreased during the past ten years, to currently achieving their F_{MSY} reference values. The fishing mortality of Western Baltic cod has been very high and above the reference value during all of the same time period (Figure 4.6.3). For Eastern Baltic cod, the relative fishing mortality has, with a few exceptions, been too high over the past decades (No graph; ICES 2017c).

With respect to size structure, a decrease in the biomass of larger fish is noted for Eastern Baltic cod over the past ten years, in particular for fish larger than 40 cm. The relative harvest rate for larger cod is assessed as higher than the average of the stock (ICES 2017c, see also Figure 5.3.6 in Chapter 5.3).

Box 4.6.2
Evaluation method

Fishing mortality was assessed in relation to the level estimated to deliver a long term maximum sustainable yield, referred to as F_{MSY}, based on analytical assessment models. The assessment of spawning stock biomass is made in relation to the associated reference value 'MSY B-trigger' (ICES 2017a). No assessment is yet available for the age and size distribution. The assessment results presented here give the average results for the years 2011 to 2016, using reference values from 2016 (Box 4.6.1).

Proxy reference points are used for some data-limited stocks. For stocks where sufficient data for an analytical assessment are lacking, ICES provides fisheries advice based on historical data on catches, recruitment, harvest rate and biomass.

For the migratory species, ICES gives advice on salmon (*Salmo salar*) individually for each river stock, using a different framework for setting reference values in relation to MSY (ICES 2017d-e), and qualitative overviews for sea trout (ICES 2017f). Results for the HELCOM core indicators on salmon and sea trout (*Salmo trutta*) are shown in Chapter 5.3.

Species which are found and fished in the Baltic Sea, but of limited importance to Baltic Sea fisheries, are not included such as mackerel (*Scomber scombrus*), horse mackerel (*Trachurus trachurus*), ling (*Molva molva*), saithe (*Pollachius virens*) and anchovy (Engraulidae), nor commercial species in coastal and transitional waters which are assessed nationally.

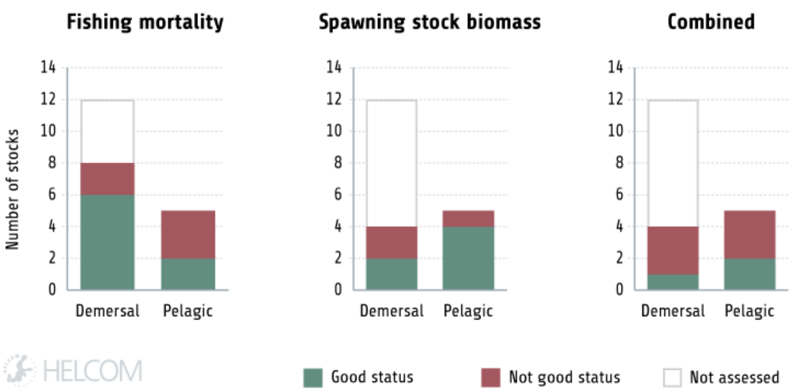


Figure 4.6.1.
Number of internationally managed fish stocks in good and not good status, with respect to fishing mortality (left), spawning stock biomass (middle), and regarding both of these aspects together. The colours denote if the average indicator value during 2011–2016 achieves (green) or fails (red) the 2016 reference point. The number of fish stocks not included in the applied analytical assessment framework is indicated in white. Source: ICES (2017a–b).

1 Non parametric Mann-Kendal tests for monotonic trends, p<0.01.

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	Species	Scientific name	Stock	ICES subdivision	Fishing mortality	Stock size	TOTAL STATUS
DEMERSAL SPECIES	Brill	*Scophthalmus rhombus*	North Sea, Skagerrak and Kattegat, English Channel	4, 3a, 7d, 7e			
	Cod	*Gadus morhua*	Western Baltic Sea*	22–24			
			Eastern Baltic Sea Proxy	24+25–32			
	Dab	*Limanda limanda*	Baltic Sea Proxy	22–32			
	Flounder	*Platichtys flesus*	Belt Sea and Sound Proxy	22–23			
			West of Bornholm, S Central Baltic Proxy	24–25			
			East of Gotland, Gulf of Gdansk	26, 28			
			N Central and Northern Baltic Sea Proxy	27, 29–32			
	Plaice	*Pleuronectes platessa*	Kattegat, Belt Sea, Sound	21–23			
			Baltic Sea excl. Sound and Belt Sea	24–32			
	Sole	*Solea solea*	Skagerrak and Kattegat, W Baltic Sea	3a, 22–24			
	Turbot	*Scophthalmus maximus*	Baltic Sea	22–32			
PELAGIC SPECIES	Herring	*Clupea harengus*	Skagerrak, Kattegat, W Baltic, spring spawners	20–24			
			Central Baltic Sea excl. Gulf of Riga	25–29, 32			
			Gulf of Riga	28.1			
			Gulf of Bothnia	30–31			
	Sprat	*Sprattus sprattus*	Baltic Sea	22–32			
MIGRATORY SPECIES	Salmon	*Salmo solar*	Baltic Sea excl. Gulf of Finland*	22–31			partially
			Gulf of Finland	31			
	Sea trout	*Salmo trutta*	Baltic Sea	22–32			
WIDELY DISTRIBUTED SPECIES	Eel	*Anguilla anguilla*	Throughout its natural range				

Figure 4.6.2.
Status of internationally managed fish stocks in the Baltic Sea during 2011-2016. Commercial fish species are assessed by stocks, which are named by their areal distribution. The numbers give the corresponding ICES assessment units (Subdivisions). The circle colours denote if the average indicator value during 2011–2016 achieves (green) or fails (red) the 2016 reference point (or proxy reference point, if indicated). Total status is assessed by the condition that both indicators should achieve their reference points, as shown in the last column. Salmon is assessed over many stocks, which show variable status (see also Chapter 5.3). White circles denote that no status evaluation in relation to a threshold value is available. Source: ICES (2017a–f).

**Including recreational catches*

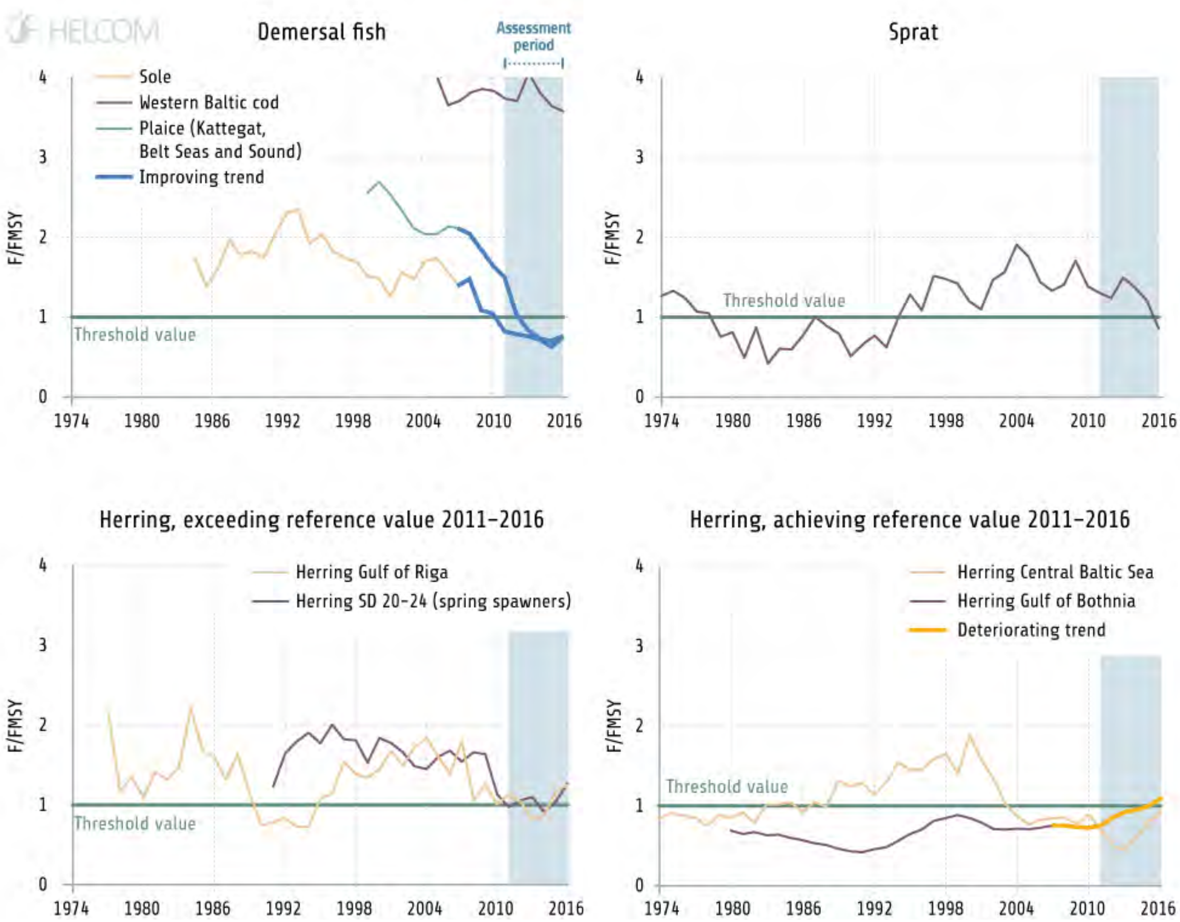


Figure 4.6.3.
Temporal development of fishing mortality relative to the reference point for demersal and pelagic Baltic Sea fish stocks assessed by the Maximum Sustainable Yield approach. Upper row, left: The demersal stocks sole (*Solea solea*), Western Baltic cod (*Gadus morhua*), and plaice (*Pleuronectes platessa*). Upper row, right: sprat (*Sprattus sprattus*). Lower row: herring (*Clupea harengus*). The green line shows the threshold value against which the average fishing mortality over 2011–2016 is evaluated. Source: ICES.

▸ *Impacts and recovery*

Impacts of overfishing include depleted fish stocks and reduced biomass. Since fisheries are typically focused on specific species and larger fish, they may also cause structural changes to populations and the food web. Such changes in overall species composition, and a decreased size and age structure of populations, have been seen both in the Baltic and adjacent areas (Cardinale *et al.* 2009, Eero *et al.* 2008; Svedäng and Hornborg 2014, see also Chapter 5.6 for food web aspects). Overfishing, and the associated changes at population and ecosystem level, affect long term fishing opportunities and food provision, since the changes in population or food web structure make the depleted stocks less productive and more vulnerable to environmental pressures (Berkeley *et al.* 2004, Stige *et al.* 2017).

Fisheries activities in eight Baltic Sea countries are regulated by the EU Common Fisheries Policy (CFP). In 2009, the European community and the Government of the Russian Federation agreed to cooperate over fisheries and conservation of living marine resources in the Baltic Sea. The current revision of the common fisheries policy was adopted in 2013 and aims to promote environmentally, economically and socially sustainable fishing, including measures to end overfishing and eliminate fish discards, for example. Currently, multi-annual plans are in place for the main part of the internationally managed fish stocks, and adjustments to fishing gear are undertaken to mitigate negative impacts on the ecosystem and fish stocks (EC 2016).

In addition to the targeted species and size classes, unselective fishing causes the mortality of smaller sized fish and non-target fish species (as well as incidental by-catches of birds and mammals; see Boxes 5.4.2 and 5.5.1). The unwanted catch of fish has been mostly discarded in the past, and has been monitored and included in stock assessments for cod and some flatfishes. Since 2015, there has been a discard ban in place for cod, sprat, herring and salmon, and since 2017 for plaice. In coming years, the effects of these measures are to be evaluated.

Hunting of seals

Seals have been hunted historically for skin, fur, meat and fat, and they were an important source of income for people, particularly in the Northern Baltic Sea. Seals were also considered a nuisance due to their competition with fisheries, and hunting was encouraged. During the 1900s, bounties were even paid for hunting seals. A combination of hunting and environmental factors led to a dramatic decline in seal populations.

In the 1970s and 1980s, seals were protected by all countries in the Baltic Sea region. The number of seals has increased, and today conflicts with human fishing activities have re-emerged in an increasing number of areas. As a result, controlled hunting is allowed for grey seals in Denmark, Estonia, Finland and Sweden, ringed seals in Finland and Sweden, and harbour seals in Denmark and Sweden. The highest permissible annual quota among these countries is around 2,000 grey seals, 230 ringed seals and 235 harbour seals combining information from all countries. The reported hunting is often below the quotas (Table 4.6.1), however the scale of illegal hunting is not known.

Incidental by-catch of seals in fishing gear is an additional source of human induced mortality for seals that is not included here (Box 5.4.1 in Chapter 5.4).

According to Baltic Sea regional recommendations there should be no hunting of seal populations if they are below a safe biological level, defined by a so called limit reference level (see also Chapter 5.4). Also, hunting of populations above this level is only allowed if their growth rate is positive. These principles are followed in the Baltic Sea region at this time[1].

Table 4.6.1.
Numbers of hunted seals and the shares of highest permissible annual quota in Finland and Sweden in 2016. Finnish hunts of ringed seal represent the hunting year of 2016/2017. The Swedish harbour seal quota partially extends out of the HELCOM area to the Skagerrak. Hunting of grey seals is also allowed in Estonia. In Denmark, licenced fishermen may apply for permission to shoot a limited number of grey seals or harbour seals within close proximity of their fishing gear. Ringed seals are only hunted in Finland and Sweden.

Species	Finland	Sweden
Grey seal *(Halichoerus grypus)*	258 (17 % of quota)	201 (41 % of quota)
Harbour seal *(Phoca vitulina)*	—	180 (62 % of quota)
Ringed seal *(Pusa hispida)*	199 (~100 % of quota)	81 (77 % of quota)

Grey seal. Controlled hunting is allowed for grey seals in Denmark, Estonia, Finland and Sweden.

Hunting of waterbirds

The legislation for bird hunting is highly variable among countries. Waterbirds are hunted in some countries, although the timing is regulated, with hunting prohibited during the spring migration and breeding season (EC 2009). For example, in Denmark there is no hunting of waterbirds allowed between 1 February and 31 August. Southern Baltic Sea countries have a more extensive protection of bird species. For example all sea ducks in Poland are protected, and bird hunting is not permitted within a 3,000 metre strip between the coast and the sea or for 5,000 metres onto land (Polish hunting law 2018). In effect, ducks can be hunted on inland waters but are protected at the coast, for example mallard (*Anas platyrhynchos*), Eurasian teal (*Anas crecca*), common pochard (*Aythya ferina*) and tufted duck (*Aythya fuligula*). A similar legislation is in place in many other countries. Hunting in spring is permitted on the Åland islands.

Where hunting is permitted, common game species include common eider (*Somateria mollissima*), Eurasian teal, mallard, and Eurasian wigeon (*Anas penelope*). Long-tailed duck (*Clangula hyemalis*) is partially hunted (Table 4.6.2). The velvet scoter (*Melanitta fusca*) is hunted in Denmark (Asferg 2016) and protected in Sweden. Species hunted only in some countries include goosander (*Mergus merganser*), tufted duck and red-breasted merganser (*Mergus serrator*), as well as garganey (*Anas querquedula*), pintail (*Anas acuta*), shoveler (*Anas clypeata*) and gadwall (*Anas strepera*). In addition, waterbird populations are hunted elsewhere along their flyways. In Denmark, ▸

1 According to follow-up by the HELCOM SEAL Expert Group of the implementation of the Recommendation on Management principles for the conservation of seals.

Table 4.6.2.
Reports on hunted water birds in Baltic Sea coastal areas, estimated mean numbers per year during 2011–2016. Hunting of these species does not occur in in coastal and marine areas of Germany, Lithuania and Poland, but some of the species are hunted at adjacent inland waters. An 'X' denotes that the species is hunted, but that the number of hunted birds in the Baltic Sea area is not known.

Species	Denmark*	Estonia	Finland	Sweden
Common eider *(Somateria mollissima)*	31,700	0	4,000	1,700
Long-tailed duck *(Clangula hyemalis)*	1,300	7	14,700	30
Common goldeneye (*Bucephala clangula*)	7,300	80	x	8,100
Eurasian teal *(Anas crecca)*	92,700	1,700	x	6,800
Mallard *(Anas platyrhynchos)*	467,800**	3,800	x	205,200
Common scoter *(Melanitta nigra)*	6,100	1	x	100
Velvet scoter *(Melanitta fusca)*	2,200	0	x	na
Goosander *(Mergus merganser)*	1,000	0	x	2,500
Tufted duck (*Aythya fuligula*)	6,000	25	x	2,400
Eurasian wigeon *(Anas penelope)*	33,600	1,000	x	1,100

*) The numbers for Denmark are national numbers covering the whole country and not just the Baltic Sea coastal area
**) This number includes both wildlife release and natural specimens.

hunting of female common eider is no longer permitted in any season since the 2014/2015 season, and hunting of female long-tailed duck and velvet scoter is expected to be similarly prohibited from the 2018/2019 season, in accordance with the AEWA International Single Species Action Plan.

Female common eider, nesting.

The great cormorant (*Phalacrocorax carbo*) is culled after derogation in some countries to mitigate damages to fish stocks and fisheries (HaBiDes 2017). Approximately 3,200 cormorants per year are shot in Denmark, 500 in Estonia, 700 in Finland (Åland), 1,700 in Germany[2], and 2,100[3] in Sweden. As part of such predator control programs, some countries also spray eggs with a substance to prevent them from hatching.

Birds are also decimated by other human induced pressures, such as oil spills and incidental by-catch, with unknown total level (see Box 5.5.1 in Chapter 5.5).

Most of the hunted waterbird species listed in Table 4.6.2 are included in the HELCOM core indicators on waterbirds (Chapter 5.5). The long-tailed duck and common scoter are not included due to the current assessment methodology. The numbers of velvet scoter and long-tailed duck have decreased markedly over time, and the long tailed duck is categorised as endangered in the HELCOM Red List (HELCOM 2013b). Similarly, the common eider and velvet scoter, amongst other waterbird species, are also on the HELCOM Red List.

2 Refers to the area of Mecklenburg-Vorpommern and Schleswig-Holstein 2011-2015.

3 Based on the years 2011-2015. Estimates are for the whole country, not only marine areas.

4.7. Seabed loss and disturbance

Loss and disturbance to the seabed is caused by human activities that inflict permanent changes or temporary disruptions to the physical habitat. Examples of such activities include extraction of seabed sand and gravel, modification of the seabed for installations, maintenance of open waterways by dredging, and bottom trawling. Based on the data available for the assessment period (2011–2016) and current knowledge, less than 1 % of the Baltic Sea seabed is potentially lost due to human activities while roughly 40 % of the seabed area is potentially disturbed. There is currently no regionally agreed method for assessing how loss and disturbance is causing adverse effects on the marine environment.

Several human activities may cause damage to the seabed, and hence to benthic habitats and species. Some activities may affect the seabed directly, but activities may also cause indirect effects, for example by increasing the level of turbidity or dispersal of sediments. Whether an activity leads to a permanent loss or a temporary disturbance of the seabed depends on many factors, such as the duration and intensity of the activity, the technique used, and the sensitivity of the area affected. The loss of a natural habitat may in some cases lead to a new artificial type of habitat, for example when a construction gives rise to hard substrates in a naturally sand-dominated habitat. Such alterations may also lead to ecological changes that are undesirable (Tyrrell and Byers 2007).
Many activities at sea may contribute to both permanent loss and disturbance of the seabed (Figure 4.7.1).

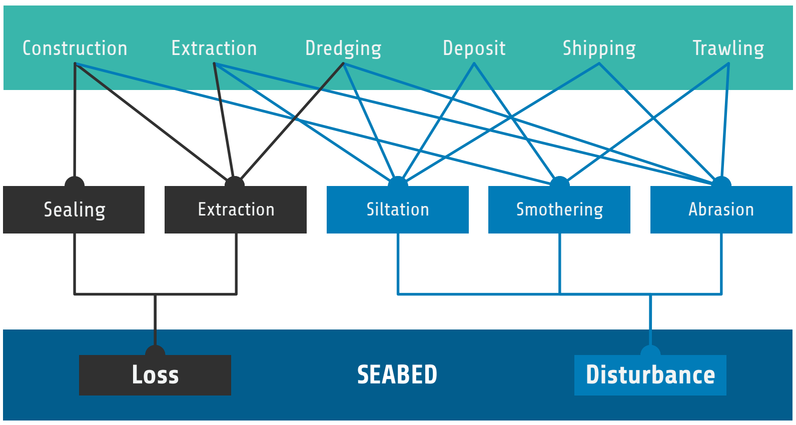


Figure 4.7.1.
Generalised overview of human activity types and the physical pressures they may exert on the seabed. The pressures are further grouped into those causing loss and disturbance of the seabed. Black lines link to potential physical loss of seabed habitats, and blue lines link to potential physical disturbance.

Estimating physical loss and disturbance at a regional and sub-basin scale requires a generalised approach which links together different types of activities with potential loss and disturbance of the seabed, and thereby simplifies the complex reality (Box 4.7.1). There is currently no regionally agreed method for assessing how loss and disturbance is causing adverse effects on the marine environment.

Human activities potentially attributed to seabed loss and disturbance

Construction and installations

Off-shore wind farms, harbours, underwater cables and pipelines are examples of constructions that cause a local but permanent loss of habitat. In addition, disturbance to the seabed may occur during the period of construction and installation. The pressures exerted during the construction phase have similarities with those during seabed extraction or dredging (see below). Installation of off-shore construction may also encompass drilling, pile driving, or the relocation of substrate for use as scour protection. The area lost by scour protection around the foundation of a wind farm turbine has been estimated to be in the order of tens of metres from the wind turbine (van der Wal and Tamis 2014). The scour protection will give rise to a new man-made habitat.

Pipelines may be placed in a trench and then covered with sediment extracted elsewhere, so that the sediment composition differs from surrounding habitat (Schwarzer *et al.* 2014). On hard substrates, cables are often covered with a protective layer of steel or concrete casings. The loss of habitats by smothering and sealing from cables may occur up to a couple of metres from the cable (OSPAR 2008).

Open systems of mariculture affect the seabed habitat through sedimentation of excrements under the fish and shellfish farms, as the accumulated material changes the seabed substrate. However, the extent of the effects in terms of loss and disturbance of the seabed depends on the hydrological conditions and on the properties of the mariculture, and currently limited information exists on the recovery rate when the pressure is removed (but see Kraufvelin *et al.* 2001).

Dredging

Dredging activities are usually divided into capital dredging and maintenance dredging. Capital dredging is carried out when building new constructions, increasing the depth in existing waterways, or making new waterways, while maintenance dredging is done in order to maintain existing waterways.

Dredging causes different types of pressure on the seabed; removal of substrate alters physical conditions through changes in the seabed topography, increased turbidity caused by re-suspended fine sediments, and smothering and siltation of nearby areas due to settling of suspended load. Physical loss occurs during capital dredging, which usually occurs once at a specific location. It may also be connected to maintenance dredging when performed repeatedly at regular intervals. The physical loss is limited to the dredging site, whilst physical disturbance through sedimentation may have a wider spatial extent.

Disturbance through sedimentation may affect animals and vegetation even farther away from the dredging activity, on the scale of hundreds of metres (LaSalle 1990, Boyd *et al.* 2003, Orviku *et al.* 2008). In addition, remobilisation of polluted deposited sediments may contribute to contamination and eutrophication effects.

Box 4.7.1

Method to estimate loss and disturbance of the seabed

Physical loss is defined as a permanent change of seabed substrate or morphology, meaning that there has been change to the seabed which has lasted or is expected to last for a long period (more than twelve years (EC 2017a). The following activities were considered in the assessment as potentially causing loss of seabed: construction at sea and on the shoreline (including cables and pipelines, marinas and harbours, land claim, mariculture, extraction of sand and gravel, and dredging) (Figure 4.7.1).

Physical disturbance is defined as a change to the seabed which can be reverted if the activity causing the disturbance ceases (EC 2017a). The same activities as in the assessment of physical loss, and trawling, were considered as causing physical disturbance (acting via the pressures of siltation, smothering, and abrasion). In addition, shipping was included as potentially causing physical disturbance (Figure 4.7.1).

The potential extent of loss and disturbance of the seabed was estimated by identifying the spatial distribution of human activities exerting these pressures. The extent of pressures was estimated based on information from literature, and the data sets were aggregated into two layers, representing physical loss and physical disturbance, respectively. Whether an activity in reality leads to loss of or disturbance of habitats depends on many factors, such as the duration and intensity of the activity, the technique used and the sensitivity of the area affected.

The identification of which activities lead to loss and/or physical disturbance is still under development and therefore the categorisations used up to now are preliminary.

The aggregated layers were also compared with information on the spatial distribution of broad benthic habitat types, in order to estimate the potentially lost and disturbed areas of benthic habitats. For more information, see the thematic assessment; HELCOM (2018E).

The results are presented descriptively as an indication of the potential extent of the pressure. However, no threshold values are defined for physical loss and disturbance and thus no value judgement of status is placed on the results.

Confidence in the assessment has not been calculated because the data layers include only information on which potential pressures are present, while their absence according to the data may reflect a true absence or missing information. Therefore the potential loss and disturbance can be underestimated in some sub-basins due to lack of data on specific pressures. It is however possible to qualitatively evaluate gaps in the pressure layers based on knowledge of the national data sets that are underlying the Baltic wide layers. The data layers used in this assessment include all layers listed in HELCOM (2018E).

Sand and gravel extraction

During sand and gravel extraction sediment is removed from the seabed, for use in construction, coastal protection, beach nourishment and landfills, for example.

Sand and gravel extraction can be performed using either static dredging or trailer dredging. When static dredging is used, the exerted pressures are of similar type as during dredging, potentially leading to partial or complete physical loss of habitat (depending on the extraction technique and on how much sand or gravel is removed) and altered physical conditions (through changes in the seabed topography, increased turbidity caused by re-suspended fine sediments, smothering or siltation on nearby areas). When performing trailer dredging, the pressure exerted to the seabed is more limited compared to static dredging, although the dredged area is greater. The intensity of the pressure is also dependent on the site. In areas where sediment mobility and dynamics are naturally high, the impacts of sand and gravel extraction are typically lower than in areas with more stable sediment types.

There is high mortality of benthic organisms at the sites of sand and gravel extraction, as the species are removed together with their habitat (Boyd *et al.* 2000, 2003, Barrio Frojan *et al.* 2008). Since the extracted material is sieved at sea (to the required grain size) and the unwanted matter is discharged, the extraction may also result in changed grain size of the local sediment on the seabed. Adjacent areas are also affected by the activity albeit less severely (Vatanen *et al.* 2010).

Importantly, there are modern techniques and concepts which, if applied, can help to reduce the extent and intensity of physical disturbance of benthic organisms. Recolonization by sand- and gravel dwelling organisms is for example facilitated if the substrate is not completely removed. Precautionary measures are also recommended in HELCOM Recommendation 19/1 on 'Marine Sediment Extraction in the Baltic Sea Area'.

Deposit of dredged material

Deposit of dredged material may cause covering of the seabed, smothering of benthic organisms, and lead to loss of habitat if the sediment characteristics are permanently changed. In addition, increased turbidity during the activity causes increased siltation on the site and in its adjacent areas. In some cases, deposited material may contain elevated concentrations of hazardous substances or nutrients.

The impacts on the species depends mainly on the seabed habitat type, and the type and amount of deposited material. Burial of benthic organisms may cause mortality, but some species have the ability to re-surface (Olenin 1992, Powilleit *et al.* 2009). The probability of survival is higher on unvegetated soft bottoms, whereas vegetation and fauna on hard substrates die when covered by a ▸

few centimetres of sediment (Powilleit *et al.* 2009, Essink 1999). The spatial extent of the disturbance is similar to that during dredging (Syväranta and Leinikki 2015, Vatanen *et al.* 2015).

Shipping

Ship traffic can cause disturbance to the seabed in several ways; propeller induced currents may cause abrasion, resuspension and siltation of sediments, ship-bow waves may cause stress to littoral habitats, and dragging of anchors may cause direct physical disturbance to the seabed.

Disturbances to the seabed from shipping mainly occur in shallow areas. The effects are often local, concentrated to shipping lanes, and in the vicinity of harbours. For larger vessels, the effect on turbidity has been observed down to depths of thirty metres (Vatanen *et al.* 2010). Mid-sized ferry traffic has been estimated to increase turbidity by 55 % in small inlets (Eriksson *et al.* 2004). Erosion of the sea-floor can be substantial along heavy shipping lanes, and has been observed to cause up to one metre of sediment loss due to abrasion (Rytkönen *et al.* 2001).

Bottom trawling

Bottom contacting fishing gear causes surface abrasion. During bottom trawling it may also reach deeper down into the sediment, causing subsurface abrasion to the seabed.

The substrate that is swept by bottom trawling is affected by temporary disturbance, and bottom dwelling species are removed from the habitat or relocated (Dayton *et al.* 1995). The impact is particularly strong on slow growing sessile species which may be eradicated. Since the same areas are typically swept repeatedly, and due to high density of trawling in some areas, the possibility to recover may also be low for more resilient organisms, and a change in species composition may be seen (Kaiser *et al.* 2006, Olsgaard *et al.* 2008).

In addition, the activity may mobilise sediments into the water, which may be transported to other areas and cause smothering of hard substrates, or may release hazardous substances that have been previously buried in the seabed (Jones 1992, Wikström *et al.* 2016).

Dredging causes different types of pressure on the seabed.
© Bengt Wikström

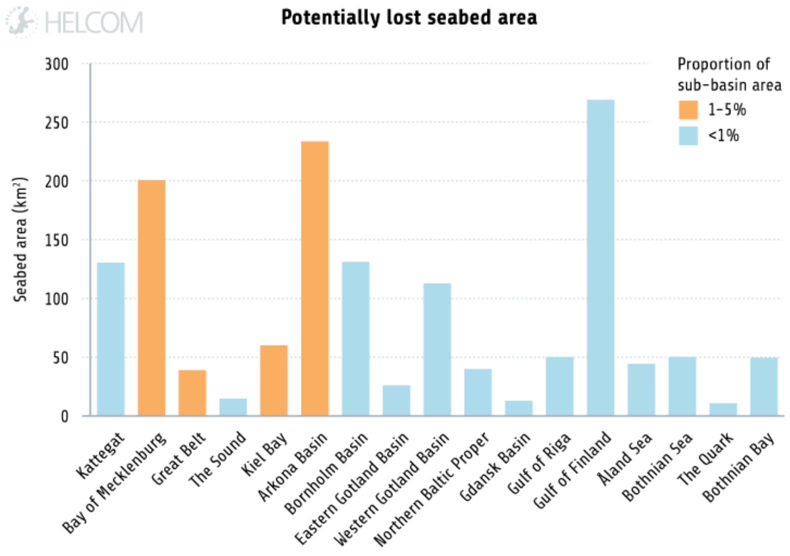


Figure 4.7.2.
Estimate of seabed area (km²) potentially lost due to human activities per Baltic Sea sub-basin. The estimation is calculated from spatial data of human activities causing physical loss, as listed in the text.

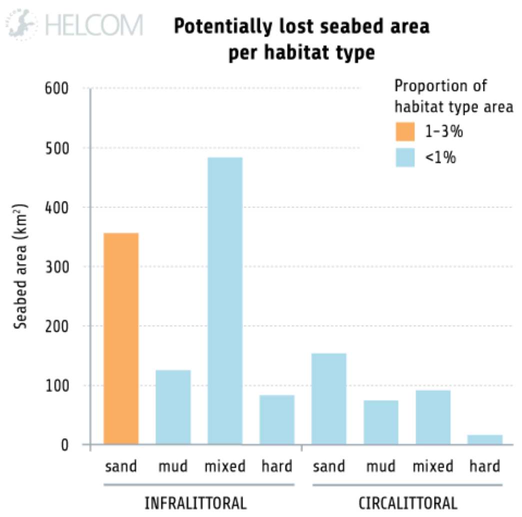


Figure 4.7.3.
Estimate of area of broad benthic habitat types potentially lost due to human activities. 'Infralittoral' is the permanently submerged part of the seabed that is closest to the surface, typically with benthic habitats dominated by algae. 'Circalittoral' is the zone below the infralittoral, and is in the Baltic Sea typically dominated by benthic animals.

Estimation of physical loss

The level of long term physical loss of seabed in the Baltic Sea was estimated to be less than 1 % on the regional scale (up to the year 2016). Highest estimates of potential loss at the level of sub-basins were found in the more densely populated southern Baltic Sea and ranged between 1 and 5 % in the Sound, the great Belt, the Arkona Basin and the Bay of Mecklenburg. In the majority of the sub-basins, less than 1 % of the seabed area was estimated to be potentially lost (Figure 4.7.2).

The human activities mainly connected with seabed loss were sand extraction, dredging and depositing of dredged material, harbours and marinas, and to a lesser extent offshore installations and mariculture. In terms of broad benthic habitat types, the highest proportion of area potentially lost was 'infralittoral sand', but the highest total area potentially lost was estimated for 'infralittoral mixed' substrate' (Figure 4.7.3).

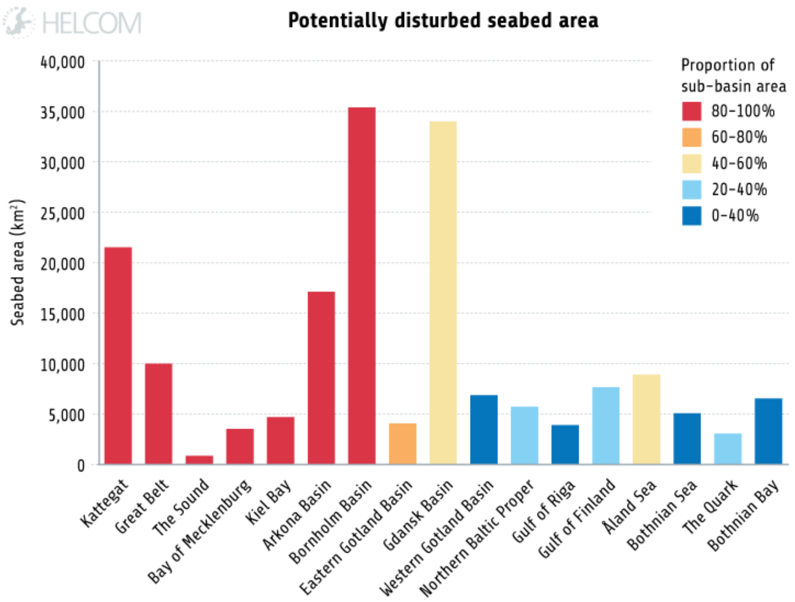


Figure 4.7.4.
Estimate of seabed area (km²) potentially disturbed in the Baltic Sea sub-basins. The color of the bars indicate the proportion of potentially disturbed seabed area per sub-basin. The area is estimated based on spatial information of the distribution of human activities connected to physical disturbance, as explained further in the text. The estimate is based on any presence of human activity connected to the pressure, and does not consider the level or severity of the disturbance.

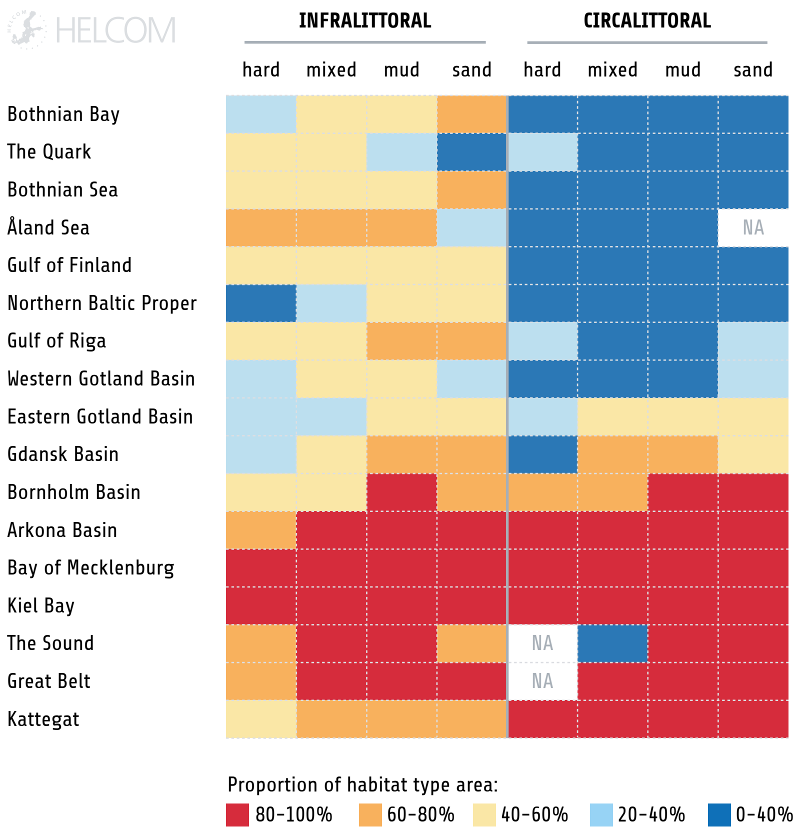


Figure 4.7.5.
Estimate of the proportion (%, given in ranges) of the different broad benthic habitat types potentially disturbed due to human activities per sub-basin. The estimate is based on the total number of human activities linked to potentially causing this pressure, and does not reflect the actual level of impact. 'NA' denotes that the habitat type is not represented.

Estimated physical disturbance

Around 40 % of the Baltic seabed was estimated to have been potentially disturbed (180 000 km2) during 2011–2016. The spatial extent of potential physical disturbance to the seabed varied between 8 and 95 % per sub-basin (from around 900 to 35,500 km2; Figure 4.7.4). However, the estimation does not reflect whether these areas are associated with adverse effects to the benthic habitats, since the intensity of the disturbance is unknown. The intensity or severity of the disturbance is an important aspect which is intended to be covered in future indicator-based assessments.

The activities connected to the widest potential physical disturbance are bottom-trawling, which is common in the southern parts of the Baltic Sea, shipping, and recreational boating. At a local scale, physical disturbance may be caused by dredging and the deposit of dredged material. The largest areas of potentially disturbed seabed were estimated in the Bornholm Basin and the Eastern Gotland Basin, which are also both comparatively large sub-basins (Figures 4.7.4 and 4.7.5). The sub-basins with the highest proportion of potentially disturbed seabed were found in the southern Baltic Sea, between the Kattegat and the Bornholm Basin.

Importantly, these estimates are based on best available data about the extent of the activities concerned. In some cases, due to limited data, areas licensed for an activity, such as dredging, deposit of dredged material and extraction of sand and gravel, were used in the calculations. This type of information does not necessarily reflect the extent of the exerted pressure, as the activity may be undertaken only in parts of the licensed area. These limitations in data add to the uncertainties of the estimate.

The number of species in the Baltic Sea is low compared to most other seas due to the low salinity. However, due to its unique salinity gradient and high variability in habitat types, the Baltic Sea contains a greater biodiversity and variety of plant and animal life than might be expected under such conditions. Achieving a good status of biodiversity is a HELCOM priority, strengthened by, among other things, the revised Helsinki Convention in 1992 and the Baltic Sea Action Plan. However, many species are still under threat. It is anticipated that biodiversity will show signs of improvement in the coming years, as the effects of recently implemented measures start to be seen, but continued efforts to improve the environmental status of biodiversity are of key importance.

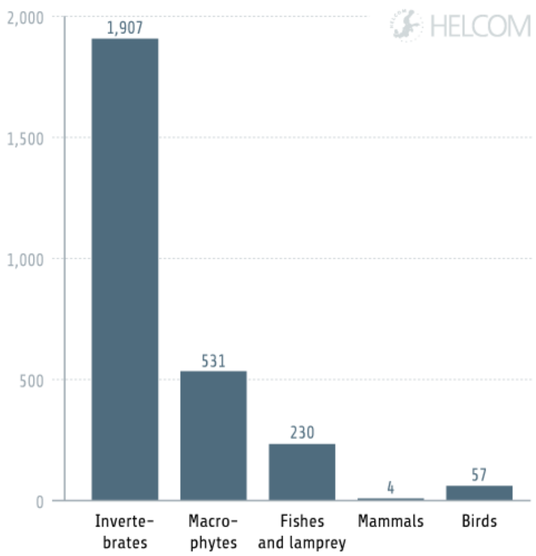


Figure 5.0.1.
Number of macroscopic taxa in the Baltic Sea within different species groups. Based on HELCOM (2012a).

THE BALTIC SEA is home to about 2,700 macroscopic species and innumerable smaller microscopic species (Figure 5.0.1). Around 1,600 macroscopic species are found in the Kattegat, which is the most marine sub-basin of the Baltic Sea. In the most freshwater-influenced area, the Bothnian Bay, only around 300 species occur (HELCOM 2012a, 2013a). This change reflects the effect of low salinity on the distribution of many species of marine origin (See also Figure 1.2 in Chapter 1).

The goal of the Baltic Sea Action Plan is to reach a favourable conservation status of Baltic Sea biodiversity by 2021. HELCOM Recommendations are important additional regional agreements for achieving this goal. For example, HELCOM countries have agreed to take measures to improve the status of threatened species according to the HELCOM Red List (HELCOM 2013b, HELCOM 2016d). Marine Protected Areas (MPAs) are important tools to conserve both species and habitats in the Baltic Sea. This is expressed through a HELCOM Recommendation to establish an ecologically coherent and effectively managed network of HELCOM MPAs (HELCOM 2014b).

This biodiversity assessment, to follow up on the goal, builds on work over many years in HELCOM to develop core indicators for key species and species groups, including their abundance, distribution, productivity, physiological and demographic characteristics (HELCOM 2013c). Hitherto, ten regionally agreed biodiversity core indicators have been made operational, and additionally three are included for testing purposes. With the new core indicators and an updated integrated assessment approach, this assessment represents a milestone in HELCOM development of monitoring and assessment. The long term aim of HELCOM countries is to continuously include more aspects of biodiversity in a Baltic-wide assessment, and to strengthen existing indicators.

While the biodiversity assessment has been considerably strengthened since the initial holistic assessment (2010a), there is still room for improvement. For example, the current set of biodiversity core indicators does not encompass the condition of habitats and biotopes, and only one operational indicator, on zooplankton, represents the pelagic community. Developments are ongoing in HELCOM in this regard.

The Baltic Sea contains a greater biodiversity and variety of plant and animal life than might be expected.
© Laila Suortti

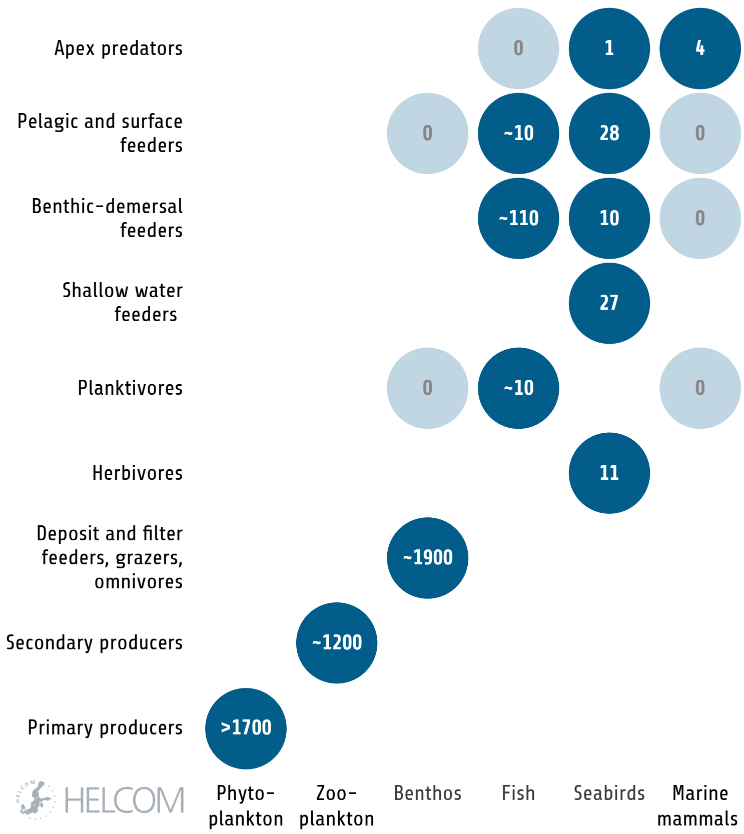


Figure 5.0.2.
Estimated numbers of species in the Baltic Sea. HELCOM core indicators are operational to address ecosystem components in all dark blue fields, to different levels of extent depending on the development status of the regionally agreed indicators. Light blue fields indicate species groups which do not occur in the Baltic Sea, although they are typical to marine waters in general. The numbers are shown in relation to functional groups on the vertical axis and by taxonomy on the horizontal axis. Data sources for phytoplankton and zooplankton: Ojaveer *et al.* (2010); benthic fauna: HELCOM (2012a); fish (HELCOM 2012a); birds: ICES (2016b). 'Fish' includes species classified as regularly or temporarily occurring by HELCOM (2012a) and are biologically classified based on Fishbase (2017).

Assessment overview

The integrated assessments were carried out using the BEAT tool, separately for the five key ecosystem components: benthic habitats, pelagic habitats, fish, mammals, and water birds. The biodiversity core indicators were supplemented with additional indicators in this assessment, with the aim of achieving an evaluation that is as comprehensive as possible, and representative at the Baltic Sea scale (Figure 5.0.2). Selected core indicators of eutrophication were included in cases where no directly corresponding biodiversity indicators are currently available. In coastal areas, national indicators have been used for benthic and pelagic habitats. Results for commercial fish were obtained from the International council for exploration of the sea (ICES). Descriptions of the core indicators are found in the core indicator reports (HELCOM 2018r, 2018ag-at; see also HELCOM 2018n, 2018p-q).

The integrated assessment is carried out using the BEAT tool, with the results being presented as so called biological quality ratios (BQR). The biological quality ratios are used as a way to scale the indicators and make them comparable with each other, as the indicators are originally assessed by a variety of assessment approaches and measured by different units. Biological quality ratios are presented in five equal-distance categories between 0 and 1, where values above 0.6 are interpreted as reflecting good integrated status (For details, see Thematic assessment: HELCOM 2018D).

The seabed of the Baltic Sea encompasses several types of habitats, from species-rich seagrass meadows and macroalgae in shallow areas, to soft bottom fauna which can also thrive deeper down. Habitat loss and disturbance affect benthic habitats and many benthic communities are also negatively affected by eutrophication. Of special concern is the large area with low oxygen, or no oxygen at all, in deep waters of the central Baltic Sea, which limits the distribution of benthic fauna and has implications for overall food web productivity.

The conspicuous salinity gradient is reflected in the species composition of Baltic Sea benthic communities, and there is a decreasing species diversity along with decreasing salinity towards the inner sub-basins (Gogina *et al.* 2016). Due to its small size and narrow inlet the majority of the Baltic Sea has no significant diurnal tides and as a result species are continuously submerged.

The southern Baltic Sea is dominated by marine species, such as polychaete worms and molluscs, including the bivalves *Arctica islandica* and *Astarte borealis*. Eel grass (*Zostera marina*) is an important macrophyte species on shallow sandy bottoms in the southern and central Baltic Sea. The benthic vegetation on hard substrates is dominated by brown and red seaweeds.

Eel grass (*Zostera marina*).
© Wolf Wichmann

The relative dominance of marine species decreases with decreasing salinity, and freshwater macrophytes become gradually more abundant. Typical animal species further in along the salinity gradient include amphipods (mainly *Monoporeia affinis*), the isopod *Saduria entomon*, and the Baltic clam (*Limecola balthica*). Many freshwater animals also thrive in the brackish water. In all areas, crustaceans, worms, snails and mussels are important food sources for water birds and many fish species. Among macrophytes, for example *Potamogeton* species become increasingly common. Various species of characean algae occur on soft bottoms in shallow coastal areas in most of the Baltic Sea, but are dependent on suitable water quality. Bladderwrack macroalgae (*Fucus* spp.) are structurally important on hard bottoms in many parts of the Baltic Sea, transforming bare rock into living environments for many other species.

Indicators for assessing benthic habitats

The assessment of benthic habitats in the open sea was limited to soft bottoms, and was based on the biodiversity core indicator 'State of the soft- bottom macrofauna community' which assesses changes in the species diversity and species sensitivity composition based on how sensitive different species are to disturbance (Core indicator report: HELCOM 2018r). In addition, the eutrophication core indicator 'Oxygen debt' was used in order to give information on living conditions for macrofauna in deeper areas (Core indicator report: HELCOM 2018q). The indicators are not yet operational in all sub-basins.

Coastal areas were assessed using national indicators, mainly used to report the status of coastal regions according to the Water Framework Directive, including indicators on soft-bottom macrofauna, mixed substrates, macrophytes and oxygen conditions, as well as water transparency, to indicate the potential depth distribution of vegetation. The national indicators are not directly comparable across coastal areas as different parameters are used and the indicators are not always intercalibrated.

The applied indicators are biased towards addressing impacts from eutrophication, and the assessment may overlook the influence of other pressures on benthic habitats. For example, impacts on benthic habitats from physical loss and disturbance are not directly assessed with the currently available indicators. HELCOM is currently developing a core indicator on 'Condition of benthic habitats' aiming to evaluate the area, extent and quality of specific benthic habitats in relation to a quantitative threshold value, and on 'Cumulative impact on benthic biotopes' to assess adverse effects from physical disturbance. In addition, the development of indicators for benthic communities on hard bottoms is identified as a priority.

Integrated assessment results for benthic habitats

The integrated assessment of benthic habitats shows good status in six of the thirteen open sea assessment units that were assessed (Figure 5.1.1). Good integrated status coincides with sub-basins assessed only by the benthic community indicator, representing soft-bottom habitats. Based on the results, over half of the Baltic Sea open sea area is assessed as not achieving good status in 2011-2016 (Figure 5.1.2).

Although a large proportion of the Baltic Sea is covered by the assessment, both core indicators included have only partial coverage. The indicator 'State of the soft-bottom macrofauna community' (Figure 5.1.3) is only applied above the halocline in assessment units with a permanent halocline. The indicator achieves the threshold value in all areas where it is assessed except in the Bay of Mecklenburg. The indicator 'Oxygen debt' does not achieve the threshold value in any of the assessment units where it is included. Long term data show that the oxygen debt below the halocline has increased over the past century in the Baltic Proper, and also in the Bornholm Basin (See Chapter 4.1). Coastal hard bottoms are widely monitored around the Baltic Sea but currently there is no common core indicator for macrophytes (See also Figure 5.1.4).

Coastal areas have good integrated status in around half of the area that was assessed, measured by area covered, or in 39 out of 128 assessed units[1] (Figure 5.1.2).

The confidence in the assessment varies between intermediate and high in both coastal and open sea areas for habitat types covered by the indicators. The Bornholm Basin and the Gdansk Basin are only assessed with the core indicator 'Oxygen debt', as threshold values for the 'State of the softbottom macrofauna community' have not yet been agreed for these sub-basins. Open sea areas in the Kattegat, the Sound, Belt Seas and Arkona Basin are not assessed by any indicator, due to lack of threshold values for the benthic indicator and because the oxygen debt indicator is not applicable.

1 Not including coastal areas of Denmark.

Macroalgae near Hanko, Finland (June 2013). The bladderwrack (*Fucus vesiculosus*) is covered by enhanced amounts of other algae, resulting from eutrophication.

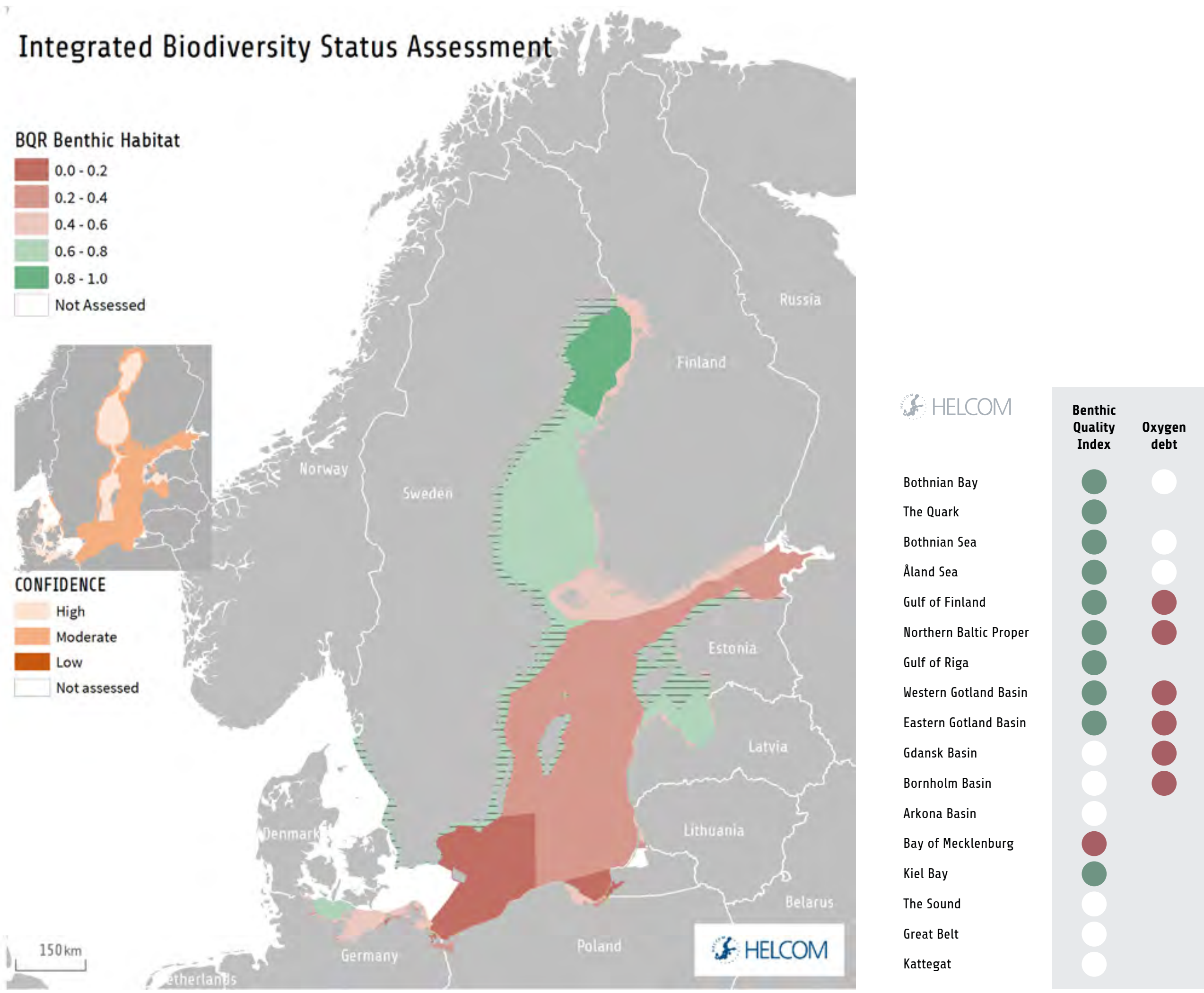


Figure 5.1.1.
Integrated biodiversity status assessment for benthic habitats. Status is shown in five categories based on integrated biological quality ratios (BQR). Values of at least 0.6 correspond to good status. The assessment is based on the core indicators 'State of the soft-bottom macrofauna community' and 'Oxygen debt'[1] in open sea areas, with some variability among sub-basins (See table). Coastal areas were assessed by national indicators, and may not be directly comparable with each other (striped areas). The integrated confidence assessment result is shown in the smaller map, with darker shaded areas indicating lower confidence. The table (right) shows corresponding assessment results for the core indicators in each open sea assessment unit, with green denoting 'good status' and red 'not good status'. White circles denote that the area is not assessed by the indicator and empty points that the indicator is not applicable.

[1]) The scaling of the eutrophication core indicator oxygen debt is here based on BEAT principles. Thus, the result differs from the integrated eutrophication assessment (Chapter 4.1). For more details, see Thematic assessments: HELCOM 2018B, 2018D.

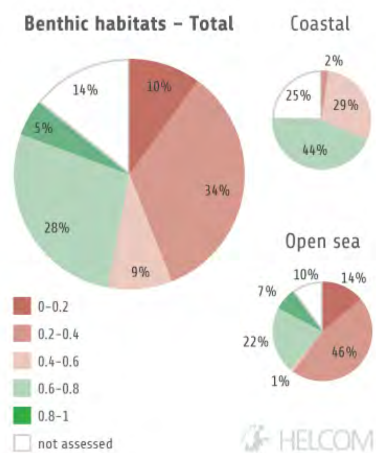


Figure 5.1.2.
Summary of the integrated assessment result for benthic habitats, showing the proportion of the Baltic Sea, by areal coverage, within each of the five BEAT assessment categories. The assessment is focused on soft bottom habitats, and does not reflect the status for all benthic habitat types. The legend shows the status categories in relation to the integrated biological quality ratios (BQR). Values of at least 0.6 correspond to good status. White sectors represent unassessed areas, including areas not assessed due to the lack of indicators or data and all Danish coastal areas.

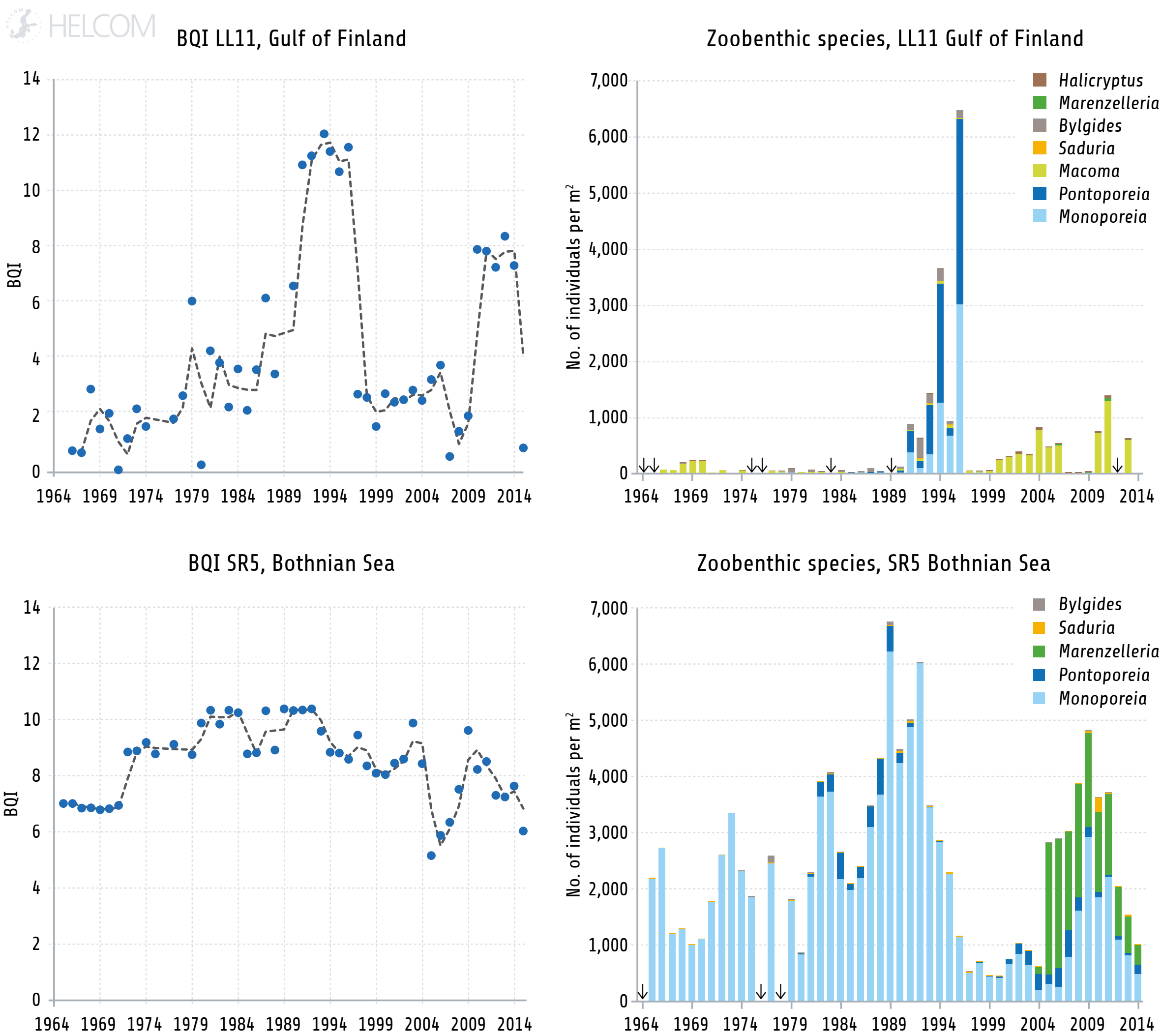


Figure 5.1.3.
The biodiversity core indicator 'State of the soft-bottom macrofauna community' is evaluated at the level of assessment units by the Benthic Quality Index (BQI). This index addresses the species composition of benthic fauna while accounting for the relative proportion of sensitive and tolerant species, species richness and abundance of benthic animals. This figure shows examples of the index at the underlying station level. At the station in the Gulf of Finland (LL1), there is a peak in the index in the early 1990s, reflecting improved oxygen conditions at the seabed. A similar peak is also seen at other monitoring stations in the Gulf of Finland during the same years (data not shown). Data from the Bothnia Sea station (SR5) shows strong variability over time in the abundance of the amphipod *Monoporeia affinis*. In addition, the introduction of the non-indigenous species *Marenzelleria* sp. can be noted in 2004. The dashed lines represent five-year moving averages. Arrows point to years with no data.

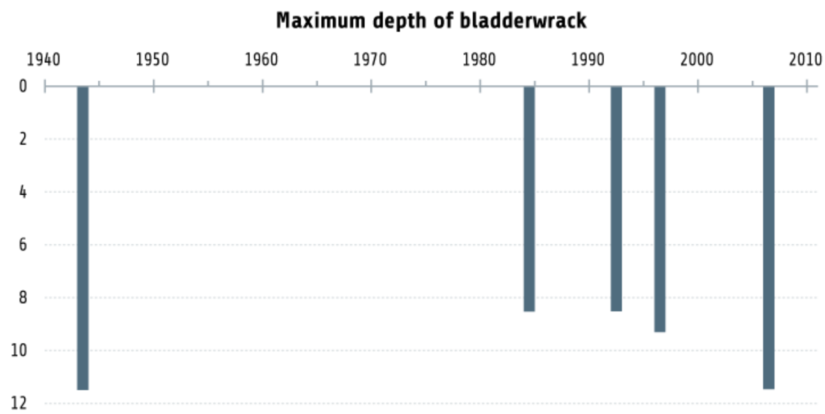


Figure 5.1.4.
Living environments at benthic hard bottoms are in many cases shaped by structure-forming seaweeds. These are affected by various environmental factors, including changes in water clarity and sedimentation rates. Due to the indirect effects of eutrophication, the distribution and density of macroalgae is diminished in many coastal areas of the Baltic Sea. This figure shows an example of how the depth distribution of bladderwrack (*Fucus vesiculosus*) has changed over time in the Singö Archipelago, Åland Sea. In this case, an improvement is seen in more recent years. Based on monitoring data from Stockholm and Uppsala University, Sweden.

▸ ***Red-listed benthic species and habitats***

The HELCOM Red List gives information on the status of benthic species in addition to that provided by the core indicators. The Red List includes nineteen species of macrofauna categorised as threatened in the Baltic Sea (HELCOM 2013b). A majority of these occur in the Kattegat or the westernmost Baltic Sea, some of them at the border of their distribution area with respect to salinity. Fifty-one species are red-listed in all, but not all species occurring in the area have been evaluated. Out of 317 assessed macrophytes, three species are categorised as endangered, four as vulnerable, and four as near threatened.

A HELCOM threat assessment has also been made for characteristic living-environments for species, so called biotopes and biotope complexes (HELCOM 2013e). Seventeen biotopes are evaluated as threatened. The biotope 'aphotic muddy bottoms dominated by the ocean quahog (*Arctica islandica*)', which occurs above a salinity of 15 (psu), is categorised as critically endangered. However, at the time of the assessment (HELCOM 2013e), data availability was relatively poor for many biotopes in the Baltic Sea, which is reflected in the confidence of the assessment. In the assessment process ten HELCOM HUB biotope complexes were identified, which are comparable to 'habitats types' as defined in Annex 1 of the EU Habitats Directive (EC 1992). These complexes were included in the assessment and all ten complexes are subsequently red-listed. Eight of those are considered threatened. For example, coastal lagoons (1150) and estuaries (1130) are assessed as endangered and critically endangered, respectively. All habitat types and habitats associated with species listed under the Habitats Directive require protection, for example through the designation of marine protected areas.

Future perspectives

Plants and animals at the seabed are essential for several functions in the marine ecosystem and a deteriorated status of these habitats may also have profound impacts on other ecosystem components.

Benthic animals living in the sediment, mainly bristleworms, mussels and amphipod crustaceans, influence local oxygen conditions via their digging and burrowing activities, and this activity can also mobilise substances to the water column (Norkko *et al.* 2015, Josefson *et al.* 2012). Benthic animals also have important roles as deposit feeders, decomposing organic matter that sinks to the seabed, and as grazers in shallow areas (Törnroos and Bonsdorff 2012). Further, many benthic species are a fundamental food source for fish and birds, or are important because they form shelter or breeding areas for mobile species. As an example, seaweeds and plants in the coastal area provide important environments for many fish species, which depend on these habitats for their reproduction (Seitz *et al.* 2014).

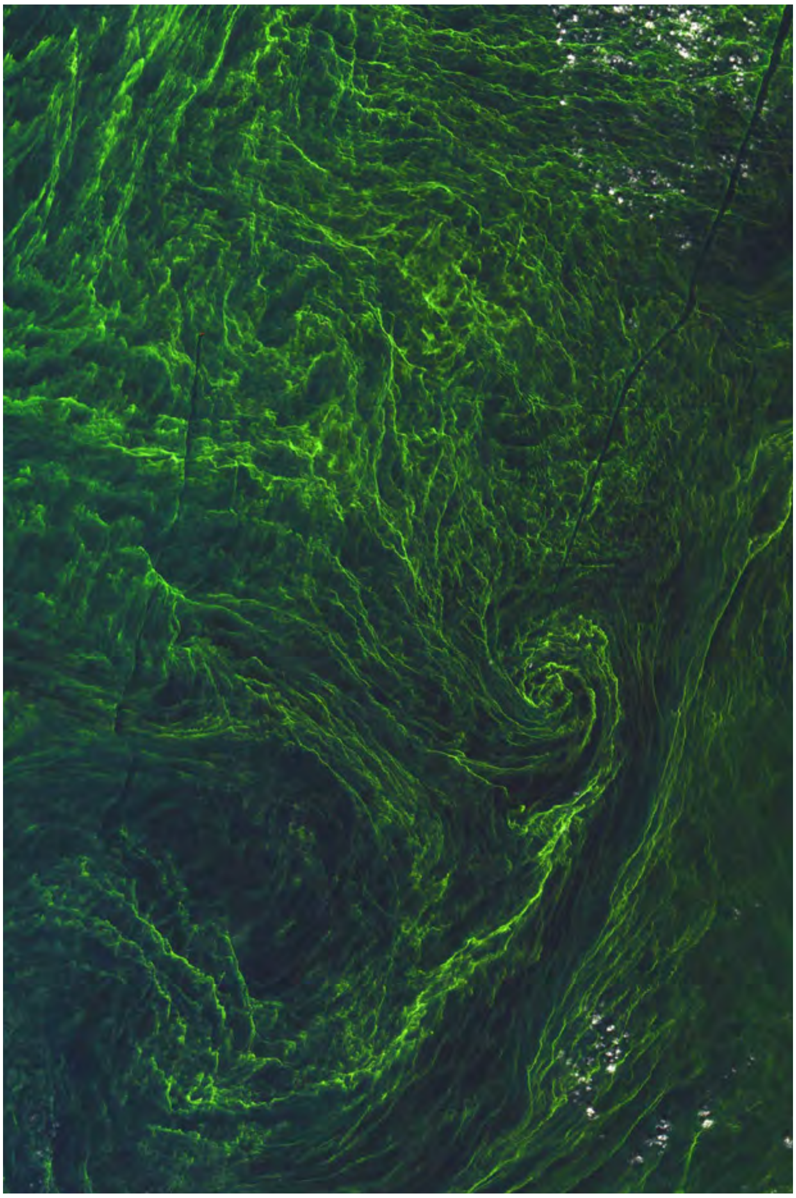
Reducing pressures and prioritising conservation are of key importance for ensuring these functions. Benthic habitats are potentially impacted by several pressures from human activities occurring at the same time, including pollution and alterations of the physical habitat (Villnäs *et al*. 2013, Sundblad *et al*. 2014). The large distribution of areas with poor oxygen conditions in the open sea is a key area of concern for the future status of benthic habitats (Casini *et al*. 2016, Villnäs *et al*. 2012). ■

Shore crab (*Carcinus maenas*) carrying the leftovers of a blue mussel (*Mytilus edulis*) in the Southwestern Baltic Sea.
© Ansgar Gruber (CC BY-SA 4.0)

5.2. Pelagic habitats

The open water column is the key setting for productivity in the Baltic Sea. Microscopic primary producers support the growth of zooplankton, which all fish species depend upon during at least some part of their life. The status of pelagic habitats is affected by human induced pressures such as eutrophication and hazardous substances, as well as by natural and human-induced changes in climate. Zooplankton are only assessed in part of the region, indicating variable results. Primary producers generally do not achieve good status, except in the Kattegat.

Algal bloom in the middle of the Baltic Sea, captured by the ESA's Sentinel-2A satellite. © Copernicus Sentinel data/ESA (CC BY-SA 3.0)



Phytoplankton form the base of the pelagic food web. They support the growth of species at higher trophic levels via being food for zooplankton, or by a more complex route that includes the microbial loop. 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 (Vahtera *et al.* 2007).

Zooplankton are represented by very small crustaceans and several other animal groups. The production of zooplankton is important for the productivity of higher trophic levels in all pelagic habitats. Cladocerans and copepods are the dominating groups of crustaceans in open sea areas of the Baltic Sea, and represent key food items for pelagic fish.

Indicators for assessing pelagic habitats

The status of the pelagic habitats in the open sea was assessed using the biodiversity core indicator 'Zooplankton mean size and total stock', which evaluates the zooplankton community structure (Core indicator report: HELCOM 2018ag). In good status, zooplankton is dominated by large-bodied species. Not all open sea areas could be assessed due to lack of agreed threshold values.

Further, the eutrophication core indicator 'Chlorophyll-a' (Core indicator report: HELCOM 2018n), and the pre-core indicator 'Cyanobacterial bloom index'(HELCOM 2018p) were used in order to represent changes in primary producers. Chlorophyll-*a* concentration is used as a proxy of phytoplankton biomass. It increases along with eutrophication as a result of higher nutrient concentrations. The 'Cyanobacterial bloom index'[1] evaluates the accumulation of cyanobacteria in the surface water and the biomass of cyanobacteria during summer.

Coastal areas were assessed using national indicators on chlorophyll-*a,* and phytoplankton biovolume, as used for assessments under the Water Framework Directive. The corresponding indicators are also used in the assessment of eutrophication (Chapter 5.1). However, the results of the biodiversity assessment may differ from results of the eutrophication assessment in coastal areas, due to differences in the scaling methods of the BEAT tool as applied here, and in the HEAT tool used for eutrophication assessment.

For the status of higher trophic level species connected to the pelagic environment, see subsequent sub-chapters.

1 Included as test.

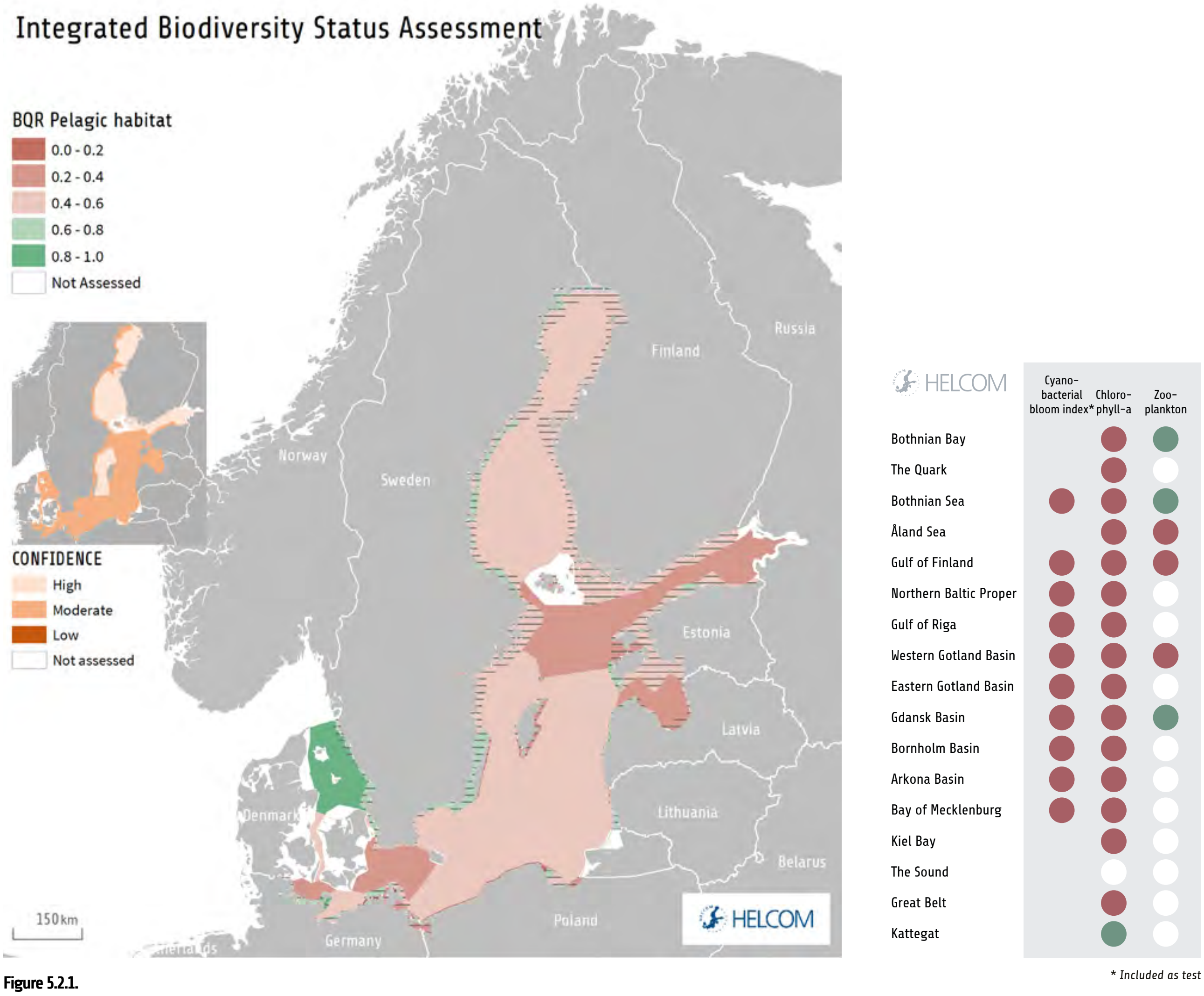


Figure 5.2.1.
Integrated biodiversity status assessment for pelagic habitats. Status is shown in five categories based on the integrated biological quality ratios (BQR). Values of at least 0.6 correspond to good status. Open sea areas were assessed based on the core indicators 'Zooplankton mean size and total stock' and 'Chlorophyll-a', as well as the pre-core indicator 'Cyanobacterial bloom index'.[1] Coastal areas were assessed by national indicators. The integrated confidence assessment result is shown in the smaller map, with darker shaded areas indicating lower confidence. The table shows corresponding assessment results for the core indicators in each open sea assessment unit, with green denoting 'good' and red 'not good' statuses. White circles denote that the area is not assessed by the indicator and empty points that the indicator is not applicable.

[1]) Included as test

Integrated assessment results for pelagic habitats

Good status for pelagic habitats is achieved in the Kattegat, but not in any other open sea sub-basin during 2011-2016 (Figure 5.2.1). The most deteriorated status is seen in the Arkona Basin, Gulf of Riga, Gulf of Finland, Åland Sea, and the Western Gotland Basin.

Results for the zooplankton indicator are variable, indicating good status in the Bothnian Bay, Bothnian Sea and Gdansk Basin, but not in the Gulf of Finland, Åland Sea, or the Western Gotland Basin. In the Western Gotland Basin both the zooplankton mean size and the biomass have decreased from the 1970s to the present.

In general, the indicators assessing primary producers do not show good status, with the exception of the Kattegat where the core indicator 'Chlorophyll-a' achieves the threshold value. 'Chlorophyll-a' indicates the worst status for the Arkona Basin, relative to other basins. Historically, chlorophyll-*a* concentrations have increased in most sub-basins east of the Bornholm Basin since the 1970s, but the increase levelled off in the late 1990s at the levels seen today. In the Kattegat and Danish Straits the chlorophyll-*a* concentrations have decreased since the late 1980s (Core indicator report: HELCOM 2018n).

The 'Cyanobacterial bloom index'[2] fails the threshold value in all sub-basins where it is assessed. Long term data from the Eastern Gotland Basin, the Northern Baltic Proper and the Gulf of Finland, however, indicate an improving trend during the past decades in the 'Cyanobacterial bloom ▸

2 Included as test

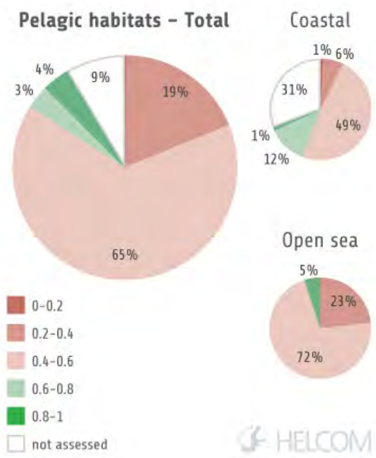


Figure 5.2.2.
Summary of the integrated assessment result for pelagic habitats, showing the proportion of the Baltic Sea area, by areal coverage, within each of the five BEAT assessment categories. The legend shows the status categories in relation to the integrated biological quality ratios (BQR). Values of at least 0.6 correspond to good status. White sectors represent unassessed areas, including areas not assessed due to lack of indicators or data, and all Danish coastal areas.

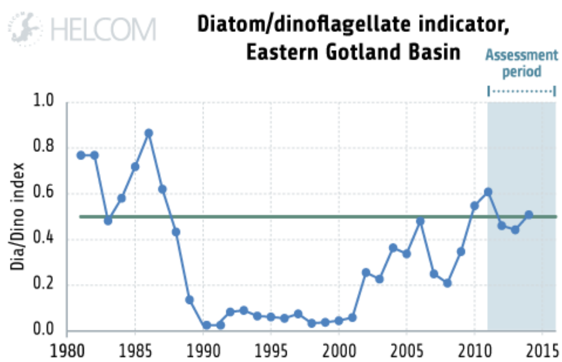


Figure 5.2.3.
Trend over time in the 'Diatom/Dinoflagellate index'[1] in the Eastern Gotland Basin. The green line shows the minimum threshold value, which is set at 0.5 in this basin (Source: HELCOM 2018ah, Wasmund *et al.*, 2017a).

[1]) Included as test.

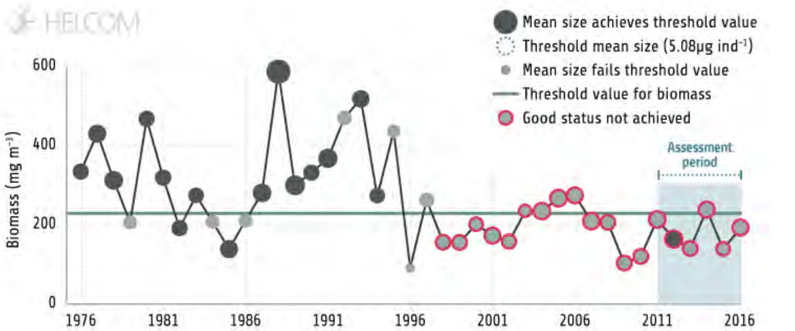


Figure 5.2.4.
The assessment of the core indicator 'Zooplankton mean size and biomass' requires that a minimum level of both the total biomass and the mean size of the zooplankton community is reached. The figure shows the long term trend in the core indicator in the Western Gotland Basin, as an example. The size of the circles corresponds to mean size of the zooplankton community, which ranged from 2 to 13 µg per individual. Black circles denote years when the mean size achieves the threshold value, and grey circles denote years when the mean size is below the threshold value. Circles marked with a red outline indicate years significantly below the threshold value for the core indicator, considering both mean size and biomass.

index' in the Baltic Proper (HELCOM 2018p).

The results for coastal areas show slightly higher geographical variability than those for the open sea. Good status is indicated in 26 out of 128 assessed coastal areas, corresponding to 20 % of the area assessed in the Baltic Sea region[3] (Figure 5.2.2).

The confidence in the assessment is between moderate and high in the open sea, and low in coastal areas.

Changes in species and size structure

The function of the pelagic food web is not only dependent on productivity, but also on the relative abundance of different species and species groups. At the base of the food web, the timing and relative abundance of phytoplankton species, particularly those dominating the biomass, influence the availability of food for zooplankton or other grazers. Cyanobacteria, dinoflagellates, diatoms and the ciliate *Mesodinium rubrum* are common dominant phytoplankton groups in the Baltic Sea. Changes in phytoplankton can, for example, be monitored by the ratio of diatoms to dinoflagellates, which are both dominating species groups during the spring bloom, and by evaluating the seasonal succession of dominating phytoplankton groups. Indicators for these aspects are currently tested (HELCOM 2018ah-ai).

The relative abundance of diatoms and dinoflagellates may be influenced by changes in eutrophication as well as climate change (Wasmund *et al.* 2017a,b). For example, clear shifts in relative abundance occurred in the late 1980s in connection to a series of mild winters (Wasmund *et al.* 2013). Such fluctuations may affect the nutrition of zooplankton and may also lead to subsequent changes in other parts of the food web.

Whereas dinoflagellates stay longer in the water column, diatoms produced in the pelagic habitat are additionally important for the benthos, as they sink quickly after the bloom. In the Eastern Gotland Basin, an indicator comparing the ratio of diatoms to dinoflagellates has been tested, showing that good status is not achieved in the assessment period (Figure 5.2.3).

Understanding the seasonal succession of phytoplankton groups may offer additional insights into ongoing changes in the marine environment, including potential effects of human induced pressures. By comparing the coincidence of seasonal succession of dominating phytoplankton groups against a reference period, it is possible to evaluate the number of occurrences when the regular successional pattern deviates, and this can be measured against a specific threshold value. The challenge is to find a suitable reference period as it is difficult to find historical data from unaffected ecosystems. In those areas where the seasonal succession of dominating

3 Not including coastal areas of Denmark

phytoplankton groups[4] has been evaluated, the proposed threshold values are not achieved in the Bay of Mecklenburg[5] Arkona Basin open sea, Bornholm Basin open sea, Eastern Gotland Basin open sea, Gulf of Riga including Estonian and Latvian coastal waters, Northern Baltic Proper including Swedish coastal waters, or the Gulf of Finland Estonian coastal waters, but are achieved in Lithuanian coastal waters in the Eastern Gotland Basin and the Gdansk Basin open sea areas (HELCOM 2018ai).

Among the zooplankton, cladocerans and copepods are important food sources for fish. Since zooplankton of larger sizes are typically more nutritious, the biomass and size distribution of the zooplankton community, as evaluated by the zooplankton core indicator (Figure 5.2.4) is a useful measure of the status of the pelagic food web (Gorokhova *et al.* 2016). The indicator 'Zooplankton mean size and total stock' shows variable results in different sub-basins. Changes over time observed in the Gulf of Finland have been attributed to a decline in cladocerans, whereas decreases in total zooplankton biomass in the Western Baltic Sea and the Bornholm Basin have been attributed to a decline in copepods. At the general level, an increase in the proportion of small-sized taxa and groups is observed in all sub-basins where good status is not achieved.

4 Included as test.

5 Assessed together for open sea and coastal areas.

Future perspectives

The status of pelagic food-webs is strongly dependent on nutrient levels, and hence on the success of measures to reduce eutrophication. In addition, both phytoplankton and zooplankton are influenced by climate-related environmental changes, such as increases in temperature and acidity. These factors may affect both the overall pelagic productivity, species composition and size structure. Further, changes in the composition of higher trophic level species, such as fish communities, may influence both zooplankton and primary producers by increasing or decreasing the levels to which these are grazed upon (Casini *et al.* 2008).

The productivity, species composition and size structure are important for the roles of phytoplankton and zooplankton communities as food for higher trophic levels. Most visibly, blooms of cyanobacteria can include toxic species. As another example, an increase in small-sized zooplankton and decrease in zooplankton total biomass is likely to result in a weaker food base for pelagic feeding fish, such as herring, sprat and juvenile cod (Rönkkönen *et al.* 2004, Gorokhova *et al.* 2016). Other effects of a deteriorated pelagic system are decreased recreational value, enhanced oxygen consumption and the extension of areas with low or no oxygen in benthic habitats (Vahtera *et al.* 2007).

The recovery of pelagic habitats in the Baltic Sea depends to a large degree on the success of eutrophication management, but importantly also on maintaining the structural integrity of the Baltic Sea food web. Both primary producers and zooplankton are directly affected by changes in temperature and seasonality, leaving the pelagic system highly responsive to changes in climate (Dippner *et al.* 2001, Möllman *et al.* 2005).

The diatom *Coscinodoscus granii*.
© Susanne Busch

5.3. Fish

Many fish species are a human food source, but fish are also prey for marine mammals and sea birds. Fish themselves feed on benthic species, zooplankton, and smaller fish, and are thereby a link between different parts of the food web. When migrating, they also have an ecological role in connecting different areas of the sea. The assessment of fish from a biodiversity perspective indicates good status for coastal fish and migrating fish in about half of the evaluated assessment units. Three out of eight currently assessed commercial stocks show good status. The status of eel continues to be critical.

Coastal and open sea areas are characterized by different species of fish, and there are also clear differences in species composition among sub-basins due to the salinity differences. About 230 fish species are recorded in the Baltic Sea (HELCOM 2012a).

Marine species are the most common in the southwestern Baltic Sea and in open sea areas. Coastal areas are the key habitats for freshwater species, such as perch (*Perca fluviatilis*) and cyprinids (Cyprinidae), and are also spawning and feeding areas for many marine species, such as cod (*Gadus morhua*), flounder (*Platichtys flesus*), and herring (*Clupea harengus*). The anadromous migrating species, such as salmon and sea trout (*Salmo salar, Salmo trutta*), but also sea lamprey (*Lampetra fluviatilis*) and some populations of whitefish (Coregoniidae), are born and spawn in rivers but spend most of their growth phase in the Baltic Sea. The European eel (*Anguilla anguilla*) is a diadromous migrating species spawning in the Sargasso Sea, with Baltic Sea eel being part of the same population as all other European eels.

Herring (*Clupea harengus*)
© Torsten Kellotat (CC BY-ND 2.0)

Indicators for assessing fish

The integrated assessment of fish in coastal areas included core indicators representing characteristic Baltic Sea coastal fish species and functional groups (Core indicator reports: HELCOM 2018aj-ak).

— The 'Abundance of key coastal fish species' is based upon changes over time in perch (*Perca fluviatilis*) or flounder (*Platichtys flesus*), with the species chosen depending on the natural distribution of these species. Perch is used in the eastern and northern coastal areas, and flounder in the south. Good status is achieved when the abundance is above a site-specific threshold value (HELCOM 2018aj).
— 'Abundance of coastal fish key functional groups' evaluates the abundance of selected functional groups of coastal fish in the Baltic Sea: piscivores and a lower trophic level component (cyprinids/mesopredators). Low values in the core indicator component on 'piscivores' indicates disturbed food webs. The 'lower trophic level' component is most often measured as the abundance of fish from the taxonomic family cyprinids, for which high values are associated with eutrophication. Good status is achieved when the abundance of piscivores is above a site-specific threshold value, and the abundance of cyprinids or mesopredators is within an acceptable range for the specific site (HELCOM 2018ak).

The open sea assessment was based on results for internationally assessed commercial fish stocks, using information on spawning stock biomass and fishing mortality from ICES (2017a-b). Data for cod (*Gadus morhua*), sole (*Solea solea*), plaice (*Pleuronectes platessa*), herring (*Clupea harengus*) and sprat (*Sprattus sprattus*) were included in the integrated assessment, as these were the ones for which assessment results in relation to both spawning stock biomass and fishing mortality were available (For more information on the indicators and reference points to define good status for open sea fish, see Figure 4.6.2 in Chapter 4.6).

Further, the two core indicators on migrating fish, 'Abundance of salmon spawners and smolt' and 'Abundance of sea trout spawners and parr' represent species which migrate between freshwater and sea areas: salmon (*Salmo salar*) and sea trout (*Salmo trutta*; see also Box 1.2 in Chapter 1).

— 'Abundance of salmon spawners and smolt' is based on the production of smolt in rivers with wild salmon stocks. It is applicable in all HELCOM countries except Denmark, Germany, Poland and Russia. The estimated smolt production is compared to an estimated potential smolt production capacity of the rivers, with the threshold value defined as 75 % of the production capacity (HELCOM 2018al).

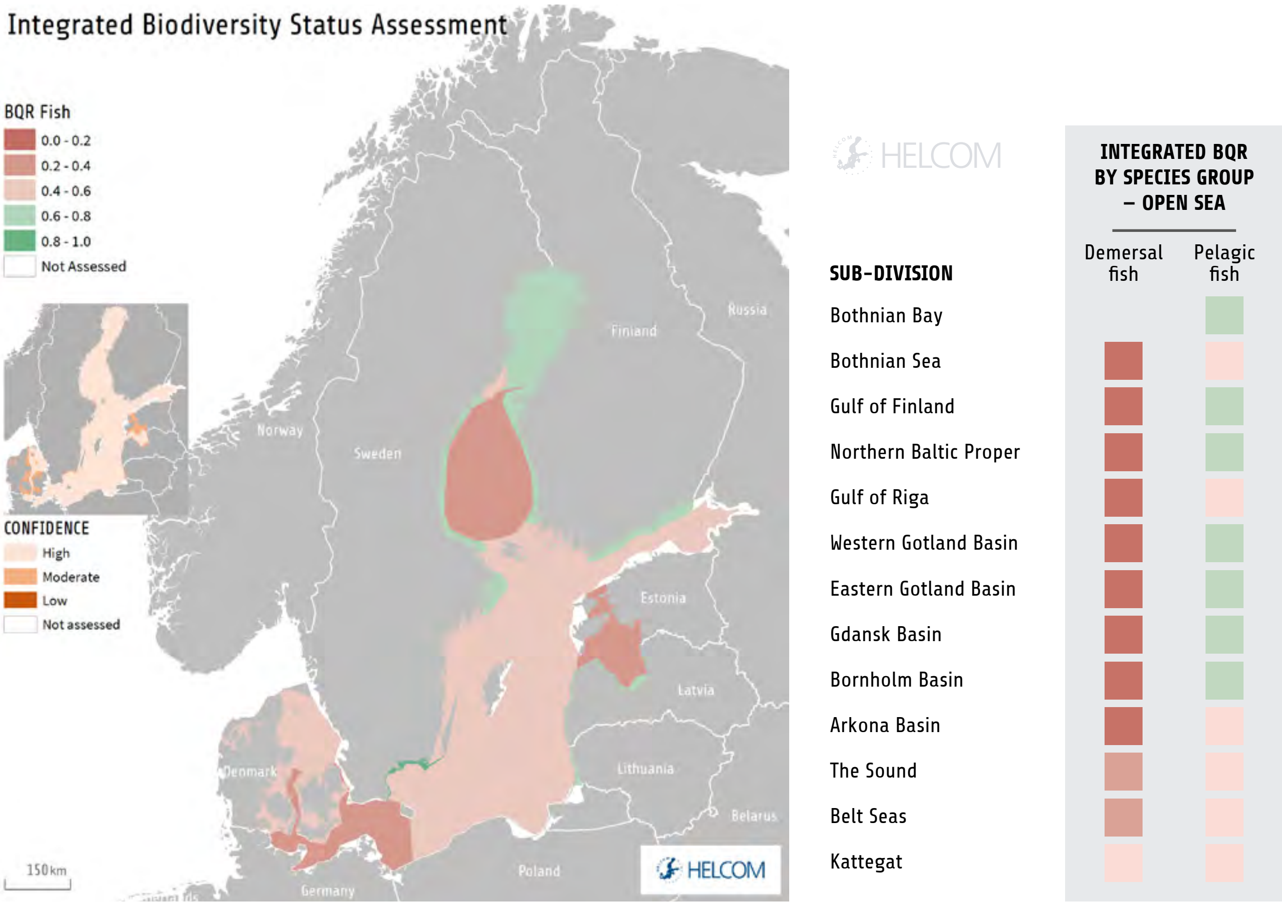


Figure 5.3.1.
Integrated biodiversity status assessment for fish. Status is shown in five categories based on the integrated biological quality ratios (BQR). Values of at least 0.6 correspond to good status. Open sea areas were assessed based on data from ICES (For more details, see Chapter 4.6 and the thematic assessment: HELCOM 2018D). Coastal areas were assessed based on core indicators. Assessment units for the open sea are ICES subdivisions, and are not shown where they overlap with coastal areas. The assessment of commercial fish is provisional. It does not comply with the multiannual plans and needs to be developed further for the next assessment period. The integrated confidence assessment result is shown in the smaller map, with darker shaded areas indicating lower confidence. The table (right) shows corresponding integrated assessment results separately for the groups of demersal and pelagic species, by the same five level scale as used in the map. Emtpy cells denote that the assessment is not applicable.

— The indicator 'Abundance of sea trout spawners and parr' is based on a comparison of the observed parr densities in rearing habitats with reference potential parr densities in the specified habitats. The indicator is applicable in all HELCOM countries. Good status is achieved when the moving parr densities average over 4-5 years remains above 50 % of the reference parr density (HELCOM 2018am).

The core indicators on salmon and sea trout were not included in the integrated assessment of fish. The endangered European eel (*Anguilla anguilla*) was assessed descriptively.

All assessed fish indicators focus on aspects relating to the abundance or biomass of fish. HELCOM work is ongoing to develop indicators to represent the demographic characteristics of fish communities, for example size distribution, as an important complement to the assessment in the future. A summary on the size structure and key species in the open sea is provided descriptively.

Since the biodiversity assessment includes all fish species in the Baltic Sea area covered by operational indicators and for which data was available, the total list of assessed species differs from that assessed under the assessment of commercial fishing as a pressure (Chapter 4.6).

Integrated assessment results for fish

The integrated status of fish is generally not good, although with some exceptions.

The status of commercial fish in the open sea is assessed as good in the Bothnian Bay, where only herring is included (Figure 5.3.1). In the other open sea sub-basins, the integrated results reflect a deteriorated status of cod (*Gadus morhua*), and in some cases also of sprat or herring (*Sprattus sprattus, Clupea harengus*). The group of demersal fish is only represented by cod and does not show good status in any sub-basin where it is included. The group of pelagic fish is below good status west of Bornholm, in the Bothnian Sea or Gulf of Riga. Results for the different stocks are shown in more detail in Chapter 4.6.

The integrated status of coastal fish is good in about half of the twenty-one assessed coastal areas. The assessment covers around 75 % of the Baltic Sea coastal areas, but the density of monitoring sites within each assessment unit is low.

Coastal fish

At core indicator level, 'Abundance of key coastal fish species' shows good status in 13 out of 21 assessed coastal areas. For the core indicator 'Abundance of key coastal fish functional groups', the component addressing piscivores achieves the threshold value in most of the assessed coastal areas (13 out of 16), and the group cyprinids/mesopredators achieves the threshold valued in about half of them (7 out of 16; Figure 5.3.2).

Low abundance of predatory fish indicates disturbed food webs. Fishing is one key pressure influencing the indicator, but it may also be affected by changes in pressures affecting recruitment and growth, and may for example benefit from increasing temperatures (HELCOM 2018g). The lower trophic level component is in most cases evaluated based on the abundance of fish within the taxonomic family cyprinids (*Cyprinidae*), for which high abundances are associated with eutrophication. Cyprinids do not occur naturally in more saline areas, and in those cases, the total abundances of coastal lower trophic level fish species are evaluated.

Over a longer time perspective, a continuously deteriorating status has predominated in both cyprinids and coastal predatory fish during the past three decades, and a slight increase in the share of coastal areas with improving status is seen only during the years of the current assessment period (Bergström *et al.* 2016).

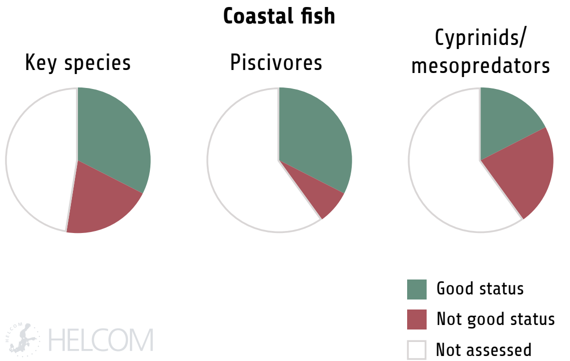


Figure 5.3.2.
Core indicator results for coastal fish showing the shares of assessment units, out of 40 in total, achieving good status (green), not good status (red) and not assessed due to lack of data (white; see also Core indicator reports: HELCOM 2018aj–ak).

Migrating fish species

Salmon (*Salmo salar*) and sea trout (*Salmo trutta*) spend the first few years of their life cycle in rivers as parr. After this, they become smolt and start their feeding migration to the sea. The two core indicators 'Abundance of salmon spawners and smolt' and 'Abundance of sea trout spawners and parr' show different results in different parts of the Baltic Sea (Figure 5.3.3).

The salmon indicator shows good status in the Gulf of Bothnia and the Western Gotland Basin, but not in the Eastern Gotland Basin or the Gulf of Finland. The indicator is not applicable south of the Gotland basins.

The sea trout indicator, on the other hand, shows good status in the southernmost basins that were included, but not in the Gulf of Bothnia, and shows varying statuses in the Baltic Proper. Overall, the seatrout indicator achieves the threshold value in 60 % of the 31 assessment units included in the evaluations. It is estimated that sea trout reproduces in 720 rivers or brooks around the Baltic Sea. About 90 % of these consist fully of wild populations whereas 10 % are mixed rivers where the population is enhanced by stocking.

For both species, there is an additional number of rivers around the Baltic Sea which have lost their salmon and sea trout populations due to damming of rivers for hydropower, or because of dredging. The number of currently unsuitable rivers for salmon and trout reproduction is not reflected in the indicators. Both species are also affected by targeted fishing as well as the occurrence of incidental bycatch in other types of fisheries. The restoration of river habitats and management of river fisheries to strengthen Baltic Sea salmon and sea trout is a regional commitment of the Baltic Sea Action Plan.

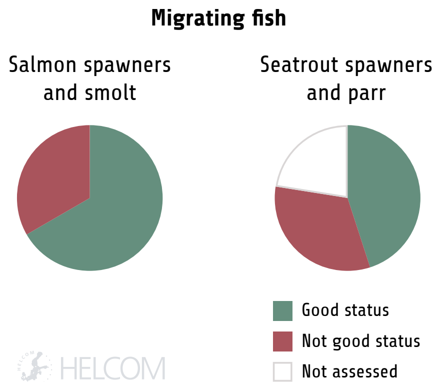


Figure 5.3.3.
Core indicator results for migrating fish showing shares of assessment units, out of 6 for salmon and 31 for sea trout, achieving good status (green), not good status (red) and not assessed due to lack of data (white; see also Core indicator reports: HELCOM 2018al–am).

Commercial fish species in the open sea

Internationally assessed commercial fish in the Baltic Sea encompass seventeen demersal and pelagic fish stocks, representing nine species. The stocks were assessed in relation to the objective

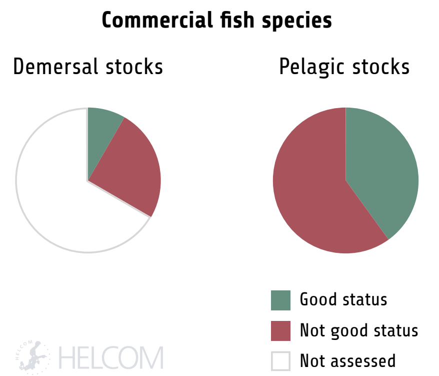


Figure 5.3.4.
Results for internationally assessed commercial species showing the number of demersal and pelagic stocks in good status (green), not good status (red) and not assessed (white; see also Chapter 4.6).

that both the spawning stock biomass and the fishing mortality should be at levels that are consistent with long term sustainability.

Six of the assessed stocks do not show good status, and three show good status on average during 2011-2016. Eight stocks lack assessment results (Figure 5.3.4). Plaice (*Pleuronectes platessa*) in the Kattegat is the only demersal stock achieving good status. Its spawning stock biomass has shown an increasing trend over the past decade (Figure 5.3.5). Sole (*Solea solea*), as well as Western and Eastern Baltic cod (*Gadus morhua*), does not achieve good status.

Among pelagic stocks, sprat (*Sprattus sprattus*), herring (*Clupea harengus*) in the Gulf of Riga, and herring spring spawners in the Western Baltic and Kattegat do not achieve good status. These stocks fail the reference value with respect to fishing mortality, and the herring spring spawners also show too low stock size. Their spawning stock biomasses have been at relatively constant levels over the past decade. The herring stocks of the Gulf of Bothnia

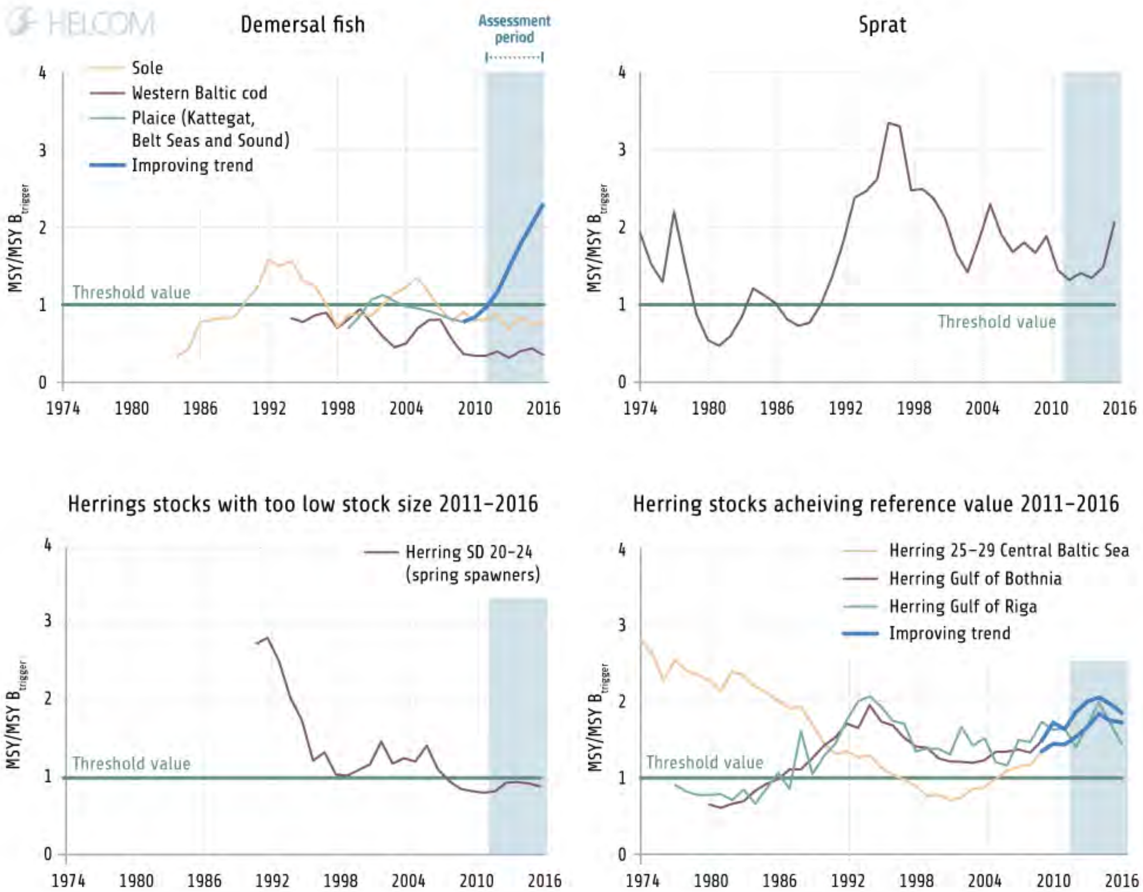


Figure 5.3.5.
Development over time in the spawning stock biomass of internationally assessed fish species.
Upper left: Demersal fish including plaice and sole; Upper right: Sprat; Lower row: herring. Values above 1 mean that the spawning stock biomass achieves the reference value, as indicated by the green line. The overall status of each stock is assessed by additionally considering the level of fishing mortality. For trends in fishing mortality, see Chapter 4.6. Source: ICES.

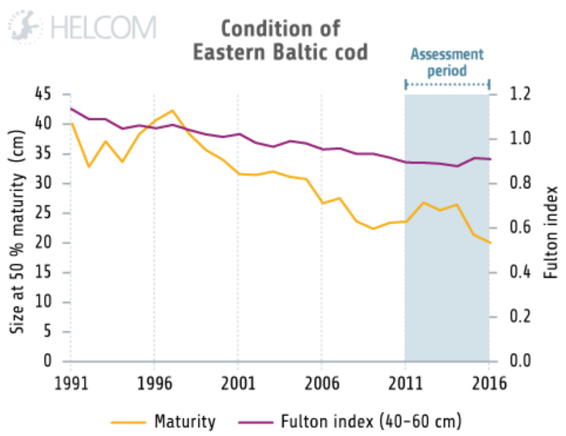


Figure 5.3.6.
The size structure and condition of Eastern Baltic cod are sharply decreasing. The dark blue line shows the size at which half of the fish population is mature. The light blue line shows changes over time in the condition of cod. The condition is calculated as the Fulton's index* for cod between 40 and 60 cm length. Based on data from the Baltic International Trawl Survey, Quarter 1.

) Fulton's condition factor measures individual fish's health as 100(Weight/Length^{-3}) where W is the whole body wet weight in grams and L is the length in centimetres. The factor 100 is used to bring K close to a value of one.

Box 5.3.1.
The red-listed eel

Eel (*Anguilla anguilla*) has been a common species across the Baltic Sea historically, occurring even in the far north. With a common recruitment area in the Sargasso Sea all eel in Europe and the Mediterranean are part of the same (panmictic) population, occurring in scattered marine, coastal, river and lake ecosystems.

Eel is listed as critically endangered (HELCOM 2013b). A main concern is that the recruitment of eel has decreased sharply since the 1980s (Moriarty and Dekker 1997, ICES 2016c). Probably, a decreasing trend has been present even longer (Dekker and Beaulaton 2016). Eel is subject to many pressures in its natural environment, and the recent declines can likely be explained by a combination of several factors, including overfishing, inland habitat loss and degradation, mortality in hydropower turbines, contaminants, parasites and climatic changes in the spawning area (Moriarty and Dekker 1997, ICES 2017f).

The status of the eel stock has been poorly documented until recently, with incomplete catch statistics being one issue. There are indications that the eel in the Baltic Sea constitutes about a quarter of the total population of European eel today. Fishing yield all over Europe has gradually diminished since the mid-1900s, and is now below 10 % of the quantity caught in the past. In the Baltic Sea, there is a decreasing number of licensed fishermen targeting eel, and there have been efforts to ban recreational fishing and to decrease the number of licensed fishers (ICES 2016c).

In 2007, the EU eel regulation implemented a distributed control system, setting a common restoration target at the international level, and obliging EU countries to implement the required protective measures. The aim is to ensure that 40 % of mature eels make it to the sea, in relation to estimated pristine conditions. The required minimum protection has not yet been achieved, and although eel management plans are being established on a national level, no joint management and assessment actions have been achieved. Eel has recently been included in Appendix II of the Convention of Migratory Species, and they are also conserved through the EU Habitats Directive.

and Central Baltic Sea show good status, and increasing spawning stock biomass over the past decade (Figure 5.3.5)[1].

Size structure and condition of fish

Changes in the size and condition of individual fish are important measures of the overall status of fish populations, in addition to monitoring aspects of abundance or biomass.

Most noticeably in the Baltic Sea, the condition and proportion of larger individuals of Eastern Baltic cod is continuously declining, and the latter has decreased sharply in particular since 2013 (Figure 5.3.6). The condition and mean weight of pelagic fish declined substantially in the 1990s, after which it has remained at a lower level (Casini *et al.* 2011).

There are many potential reasons for the declines, but so far no conclusive explanation has been identified. A deteriorated size structure has, for example, been attributed to changes in fishing patterns, predation by other species, or a reduced growth rate. The declining condition of Eastern Baltic cod has also been related to changes in feeding opportunities and the spread of areas with poor oxygen conditions in the Baltic Sea, and possibly to factors such as increased parasite infestation, attributed to increased abundance of grey seals, or fisheries selectivity (Eero *et al.* 2015, Casini *et al.* 2016).

Red-listed species of fish and lamprey

Fourteen species of fish and lampreys have been evaluated as threatened according to the HELCOM Red List (HELCOM 2013b). The American Atlantic sturgeon (*Acipenser oxyrinchus*), which used to be common in the Kattegat and more rarely occurring in the Sound, is considered regionally extinct.

The list of critically endangered species includes the European eel (Box 5.3.1), as well as grayling (*Thymallus thymallus*) in coastal areas of the Bothnian Sea. The sharks porbeagle (*Lamna nasus*) and spurdog (*Squalus acanthias*) in the Kattegat are also listed in this category, likely reflecting the impact of pressures occurring outside of the Baltic Sea region to a large extent, as the species are represented by populations that are widely distributed in the Northeast Atlantic.

Further, three fish species are listed as endangered and seven as vulnerable, including sea lamprey (*Petromyzon marinus*). All shark and ray species in the Kattegat and western Baltic Sea are included in the HELCOM Red List. As they are at the border of their distribution in the Kattegat, the status of the shark and ray stock and their return to this area is also dependent on management outside of the HELCOM region.

1 In the assessment, reference levels and estimates of stock size and fishing mortality in individual years change over time as new data became available. Hence, a fishing mortality above F_{MSY} or a spawning stock biomass below the MSY B-trigger on average do not necessarily demonstrate that the advice from ICES on fishing opportunities was exceeded. For example, sprat fishing mortality is consistently above F_{MSY} in the period but the realised catches were below the advised catch options from ICES in three years out of five.

Future perspectives

The status of fish is influenced by several currently acting pressures and ongoing changes in the ecosystem. Overfishing is a main pressure connected with reduced population sizes. Further, fishing targeting certain species and size classes is often connected to a shortage of large predatory fish, and an overrepresentation of smaller fish and fish of lower trophic levels (Pauly *et al.* 1998). Such effects are also seen in the Baltic Sea, and are likely to influence the long term ecosystem resilience and food web productivity (Svedäng and Hornborg 2017).

Other pressures affecting fish include eutrophication (causing indirect effects on habitat quality and feeding opportunities) and physical alteration of habitats (causing impacts on recruitment, spawning and feeding areas).

A gradual but continued deterioration is a particular concern in shallow coastal areas and river mouths, as desirable areas for development and construction often coincide with important areas for recruitment (Seitz *et al.* 2014). In the open sea, the most important spawning area for Eastern Baltic cod (currently) - the Bornholm Basin - is only a fraction of its historical area due to increasing oxygen deficiency. The Gdansk Basin and the Gotland Basin have a very limited contribution to cod recruitment since the 1990s (Köster *et al.* 2017).

In addition, climate change is expected to have an increasing influence in the future. Climate change can cause changes to fish directly, by effects on recruitment success and growth, or it may influence the distribution range of species, prey availability or other ecological interactions (MacKenzie *et al.* 2007). For example, changes in temperature and seasonality may affect the reproductive season for fish, or the availability of zooplankton during critical life stages when fish are dependent on these for food. Any decreases in salinity would likely have a strong effect on the open sea fish community in the Baltic Sea, if marine species are disadvantaged and habitats suitable for freshwater species expand.

Cod (*Gadus morhua*)
© Hans Hillewaert (CC BY-NC-ND 2.0)

Four marine mammal species are resident in the Baltic Sea: the grey seal, harbour seal, ringed seal and the harbour porpoise. These mobile top predators have an important role in regulating the food web, but are also sensitive to pressures in all their areas of distribution, as well as to changes in the food web. Their exposure to accumulated pressures make marine mammals important indicators of the health of the ecosystem. The overall status of marine mammal species is unfavourable. However, at species level, grey seals and harbour seals show increasing population sizes. Of particular concern are the local population of harbour porpoise in the Baltic Proper, with a population size recently estimated at around 500 animals. Ringed seal is in a critical state in the Gulf of Finland, where it is currently only represented by around 100 animals and has a decreasing abundance.

Out of the four species of marine mammals in the Baltic Sea, grey seal (*Halichoerus grypus*) occurs in the whole region, whereas harbour seal (*Phoca vitulina*) is restricted to the southwestern Baltic Sea and the Kattegat, and ringed seal (*Pusa hispida*) to the eastern and northern Baltic Sea. Harbour porpoise (*Phocoena phocoena*) occurs mainly in the Kattegat and the southern parts of the Baltic Sea.

Hunting has been a major pressure on marine mammals in the Baltic Sea historically. The populations were severely reduced due to hunting in the beginning of the 1900s. Environmental contaminants caused further decimation of the populations in the 1960s and 1970s, by severely reducing the fertility of ringed and grey seals (Helle 1980). The harbour seal sub-populations in Kattegat and the Danish Straits have experienced two cases of mass mortality in recent times, caused by the 'Phocine distemper virus', resulting in more than 50 % of the sub-population dying in 1988 and about 30 % in 2002 (Härkönen *et al.* 2006). For harbour porpoise, drowning in fishing gear is a main pressure of concern. In all, these events have resulted in severe reduction of the abundance of marine mammals in the Baltic Sea, although today, the situation has improved for several seal populations.

Harbour porpoises (*Phocoena phocoena*).
© Florent Nicolas

Indicators for assessing marine mammals

The status of seals was assessed within population-specific management units, which are jointly agreed on in HELCOM. The following two indicators were applied to all seal species:

— 'Population trends and abundance of seals' is assessed based on the population size in each respective management unit, needing to be above the limit reference level (10,000 individuals) in order to have good status, and that a species specific growth rate should be achieved. Seals are counted as the numbers of hauled-out individuals during moult (HELCOM 2018an).
— 'Distribution of Baltic seals' reflects the occurrence of seals at haul-out sites and the range of seals at sea. Good status is achieved when the distribution of the species is close to pristine conditions. If pristine conditions cannot be achieved due to irreversible long term environmental changes, good status is achieved when all currently available haul-out sites are occupied (HELCOM 2018ao).

Grey seals were additionally assessed by two core indicators reflecting nutritional and reproductive status of the population.

— 'Nutritional status of seals' evaluates the blubber thickness of a specimen of the population in relation to a minimum threshold value (HELCOM 2018ap).
— 'Reproductive status' measures the proportion of adult grey seal females being pregnant or giving birth over the age of 6 years during July to February in relation to a minimum threshold value (HELCOM 2018aq).

There is currently no operational core indicator for harbour porpoise. HELCOM is developing indicators on the abundance and distribution of harbour porpoise, as well as on the number of drowned

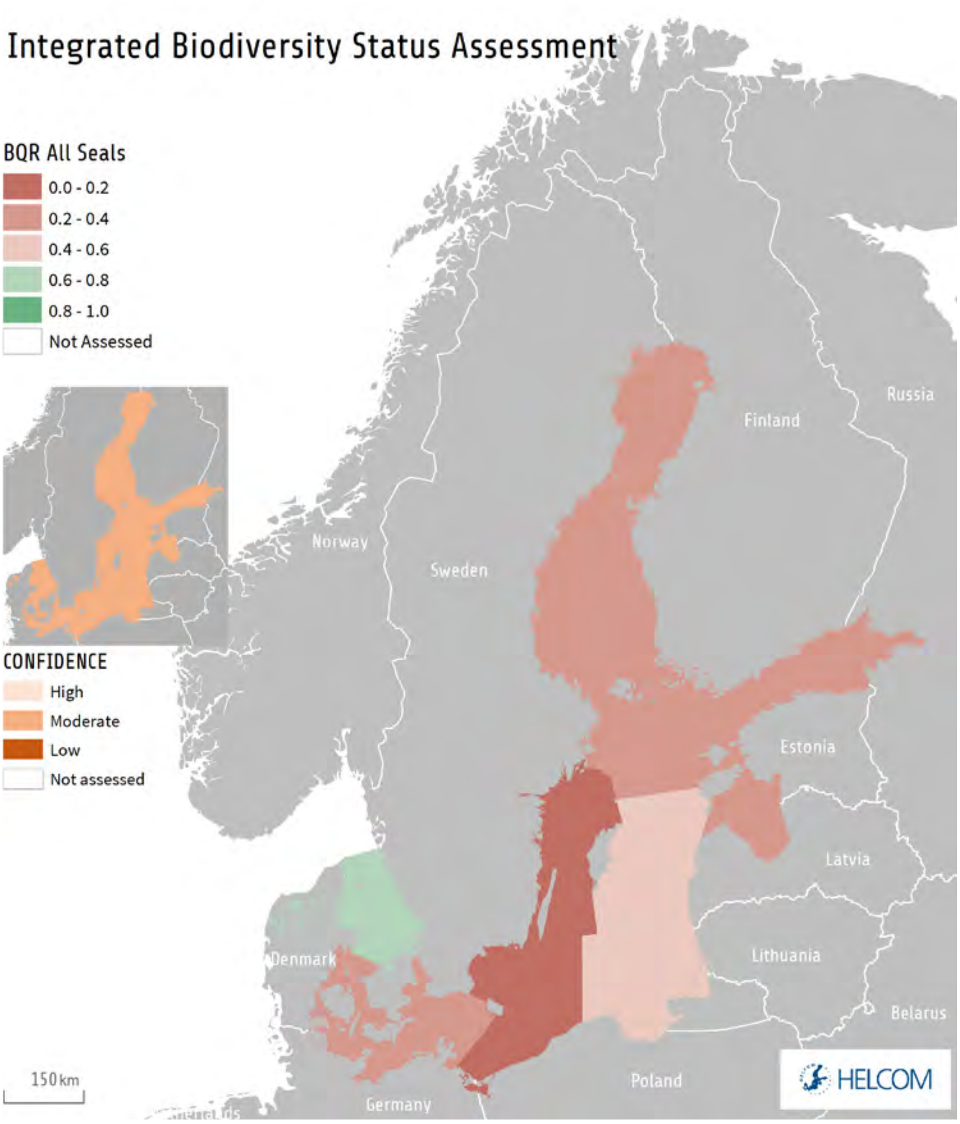


Figure 5.4.1.
Integrated biodiversity status assessment for seals. Status is shown in five categories based on the integrated biological quality ratios (BQR). Values of at least 0.6 correspond to good status. The assessment of seals is based on the one-out-all-out approach, which means that indicator reflecting the worst status determines the status. The map reflects the BQR for the indicator furthest away from good status in each assessment unit (See Figures 5.4.2, 5.4.4, and 5.4.6 for corresponding results by species). The integrated confidence assessment result is shown in the smaller map, with darker shaded areas indicating lower confidence.

mammals caught in fishing gear. However, at present there are no defined threshold levels against which the status can be assessed, and these aspects are presented descriptively.

Integrated assessment results for seals

The status of seals is not good in most parts of the Baltic Sea, according to the integrated assessment. Seals show good status in the Kattegat, where the harbour seal population is assessed based on indicators of abundance and distribution (Figure 5.4.1). The assessment approach for seals requires that all included indicators and populations should achieve their threshold values in order for seals to have good status in the assessed spatial unit. Confidence in the integrated assessment of seals is classified as intermediate. Results for each species are presented further below.

The three Baltic seal species have also been evaluated under the EU Habitats Directive in 2013. The results may differ from those presented here, as the Habitats Directive assessment is bounded by national borders, and the HELCOM assessment is carried out based on populations or sub-populations equivalent to regionally agreed management units. Another difference is that species are evaluated in comparison to a modern or historic baseline under the Habitats Directive, while threshold values in the HELCOM assessment are set in relation to the future viability of the management unit (Härkönen *et al.* 2017).

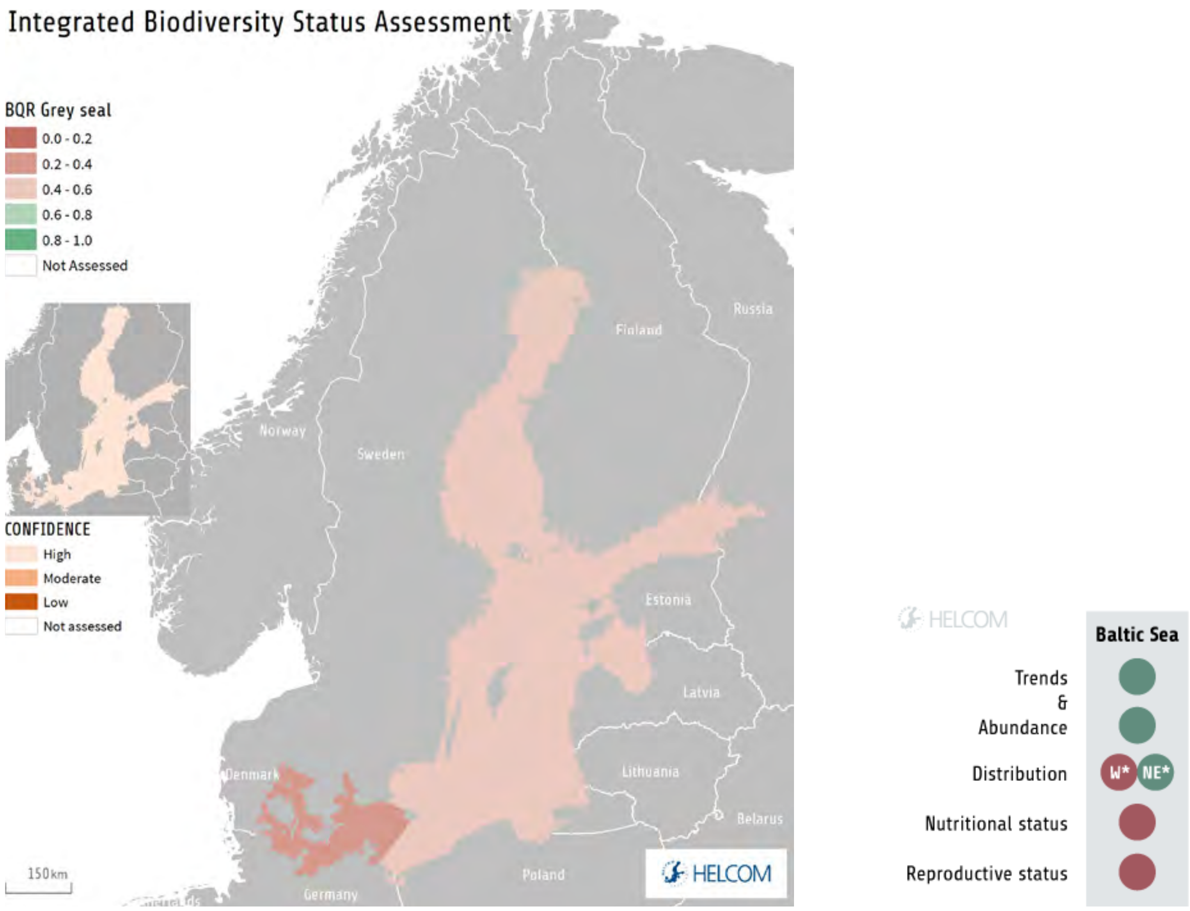


Figure 5.4.2.
Integrated status of grey seals. Status is shown in five categories based on the integrated biological quality ratios (BQR). Values of at least 0.6 correspond to good status. The assessment is based on the one-out-all-out approach, which means that the indicator reflecting the worst status determines the status of the species. The map reflects the BQR for the indicator furthest away from good status in each assessment unit. The integrated confidence assessment result is shown in the smaller map, with darker shaded areas indicating lower confidence. The table (right) shows corresponding assessment results for the core indicators, with green denoting 'good' and red 'not good' statuses. The indicator 'Trends and abundance' consists of two parameters, and results for these are shown separately. However, 'good status' for the indicator requires that the threshold value is achieved for both parameters. All assessed grey seals belong the same management unit (Baltic Sea), but the indicator grey seal distribution is assessed separately for two areas: West of Bornholm, as well as east and north of Bornholm. The assessment is not applicable in the Kattegat.

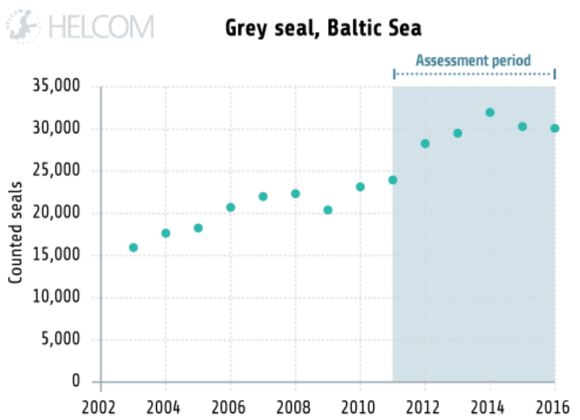


Figure 5.4.3.
Counted number of grey seals during 2002-2016, based on monitoring at haul-outs during moulting time. Although the population development can be followed reliably, it should be noted that not all seal individuals are encountered during monitoring. The growth rate has levelled off in recent years, suggesting that grey seal is approaching its carrying capacity. This management unit is currently assessed against so called second criteria (HELCOM 2018an), according to which the 'trends' parameter is considered to be in good status.

▸ *Grey seal* (*Halichoerus grypus*)

The number of grey seals counted in the whole Baltic Sea region in 2016 is 30,000 individuals, compared to the limit reference level of 10,000 individuals, and the population trend is assessed as achieving the threshold value. However, the overall status of the grey seal is estimated as not good, since the indicators on reproductive and nutritional status do not achieve the threshold values (Figure 5.4.2).

The low reproductive and nutritional condition of grey seal may be connected to density dependent effects, if the seal population is approaching its ecological carrying capacity, which is likely the case for the grey seal population (See also Figure 5.4.3).

The grey seals of the Baltic Sea all belong to the same management unit, as they forage across the entire region. However, the abundance of grey seals varies between sub-basins. The number of grey seals in their core area of moulting distribution (covering the Bothnian Sea, Archipelago Sea and Western Estonian waters), is counted at over 25,000 in 2016. Around 1,300 grey seals are estimat- ▸

ed for the other parts of the Gulf of Bothnia, 2,000 for the southern Baltic Sea and less than 1,000 for the Gulf of Finland. Monitoring along the Polish coast show a count of less than 200 individuals in a recently established haul-out. Some known historic grey seal haul-outs in the southern Baltic Sea are currently not used, and some have vanished due to exploitation of sand. According to the core indicator on the distribution of grey seals, good status is not achieved in the southwestern Baltic Sea.

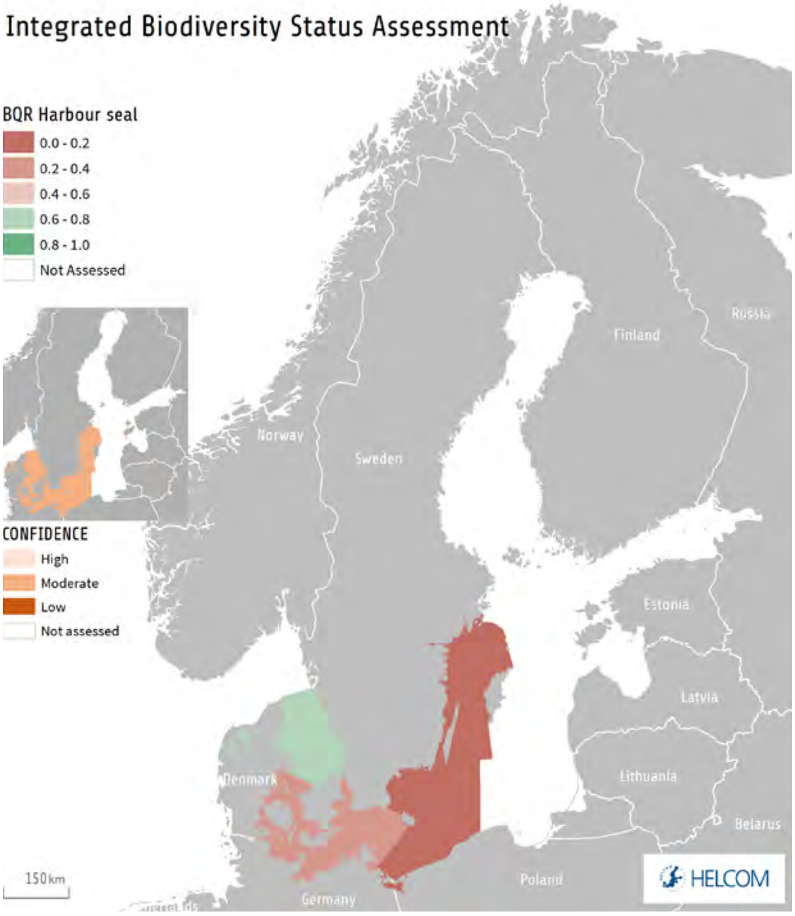
Harbour seal **(Phoca vitulina)**

Three management units of harbour seals occur in the HELCOM area: the Kattegat-southwestern Baltic metapopulation, the Kalmarsund and the Limfjord. Only harbour seals in the Kattegat show good status, while harbour seal in the management units of the southwestern Baltic and Kalmarsund do not achieve the threshold value for one or both core indicators included (Figure 5.4.4). For harbour seals in the Limfjord, knowledge regarding stock structure and connectivity to other areas is insufficient to evaluate the status.

Harbour seals in the southwestern Baltic and the Kattegat are connected, and are assessed as one so called metapopulation with respect to abundance. The size of this metapopulation achieves the threshold value[1]. For example, it was estimated at about 16,000 animals in 2015. However, the two sub-populations are assessed separately with respect to growth rate, and the threshold value for this parameter is not achieved in the southwestern Baltic Sea (See also Figure 5.4.5). Population studies suggest that the Limfjord harbour seal is an independent sub-population from the Kattegat population, but there is currently a lack of data on its genetic composition (Olsen *et al.* 2014).

The Kalmarsund population is genetically divergent from the other populations of harbour seal. The total abundance is only about 1,100 seals in 2016. The growth rate is close to, but does not reach, the threshold value. The Kalmarsund population is categorised as vulnerable in the HELCOM Red List (HELCOM 2013a).

1 For details on the Limit Reference Level for the metapopulation, see HELCOM (2016e).



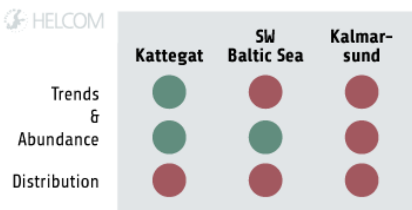


Figure 5.4.4.
Integrated status of harbour seals. Status is shown in five categories based on the integrated biological quality ratios (BQR). Values of at least 0.6 correspond to good status. The assessment is based on the one-out-all-out approach, which means that the indicator reflecting the worst status determines the status of the species. The map reflects the BQR for the indicator furthest away from good status in each assessment unit. The integrated confidence assessment result is shown in the smaller map, with darker shaded areas indicating lower confidence. The table (right) shows corresponding assessment results for the core indicators, with green denoting 'good' status and red 'not good' statuses. The indicator 'Trends and abundance' consists of two parameters, and results for these are shown separately. However, 'good status' for the indicator requires that the threshold value is achieved for both parameters. The harbour seals in the Baltic Sea are separated into three management units: the Kattegat, the southwestern Baltic Sea, and the small Kalmarsund population which resides in the Western Gotland Basin and Bornholm Basin. The assessment is not applicable in the white areas of the map.

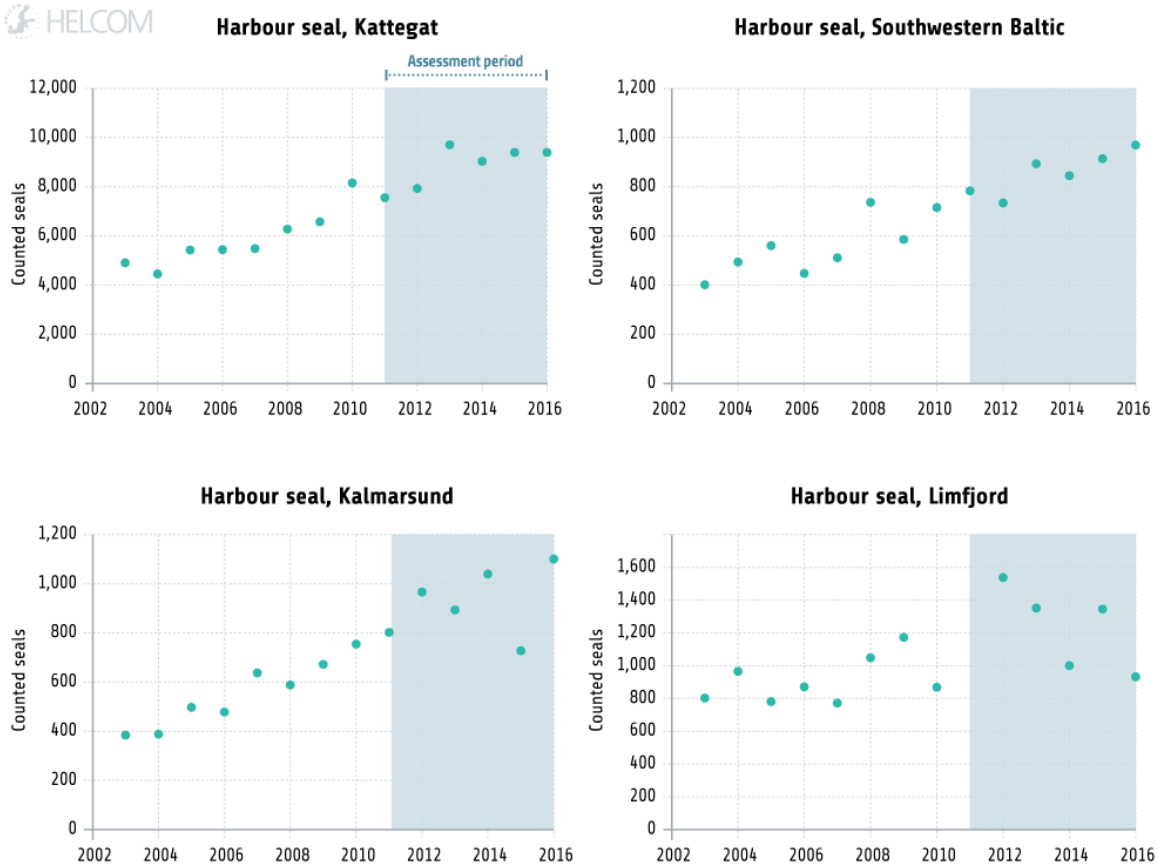
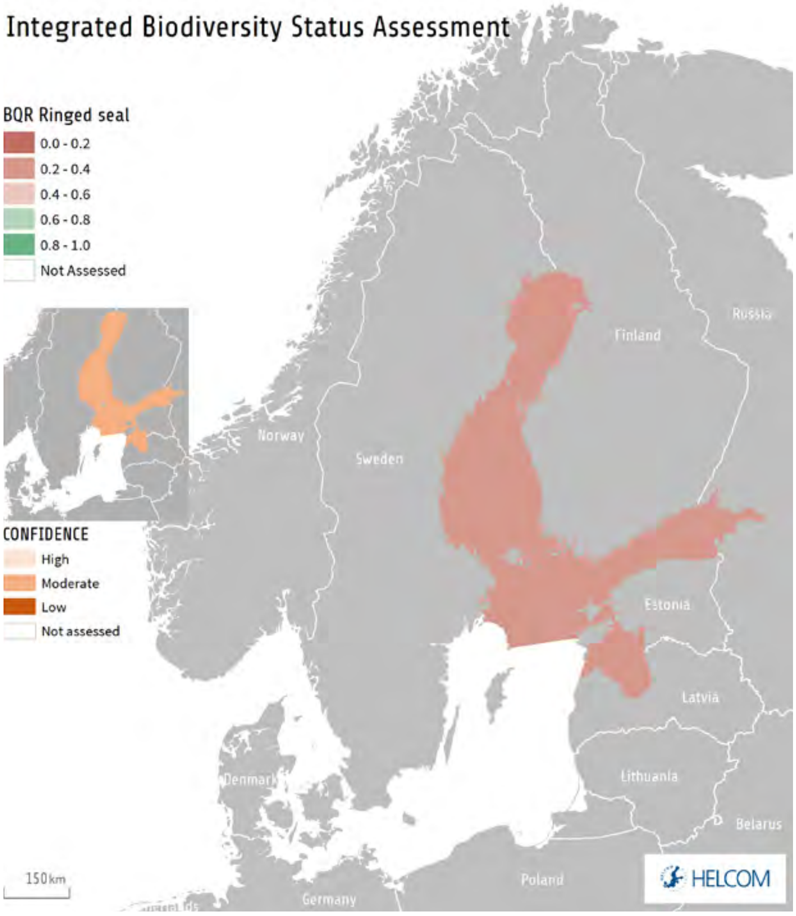


Figure 5.4.5.
Counted number of harbour seals during 2002–2016, based on monitoring at haul-outs during moulting time. The growth rate of the Kattegat population (top left) is levelling off, which is a sign that it is approaching its carrying capacity. This management unit is currently assessed against so called second criteria (HELCOM 2018an), according to which the 'trends' parameter is considered to be in good status even though the specific growth rate is not achieved in recent years. For the Southwestern Baltic population (top right), the annual growth rate is positive but still below the threshold value. The Kalmarsund population (bottom left) is close to but does not reach the threshold value for growth rate, and the number of individuals is clearly below the limit reference level. Although the population development can be followed reliably in the graphs, it should be noted that not all individuals are encountered in the monitoring.

Harbour seal.
© Christof Hermann



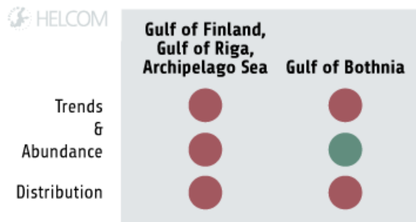


Figure 5.4.6.
Integrated status of ringed seals. Status is shown in five categories based on the integrated biological quality ratios (BQR). Values of at least 0.6 correspond to good status. The assessment is based on the one-out-all-out approach, which means that the indicator reflecting the worst status determines the status of the species. The map reflects the BQR for the indicator furthest away from good status in each assessment unit. The integrated confidence assessment result is shown in the smaller map, with darker shaded areas indicating lower confidence. The table (right) shows corresponding assessment results for the core indicators, with green denoting 'good' and red 'not good' statuses. The indicator 'Trends and abundance' consists of two parameters, and results for these are shown separately. However, 'good status' requires that the threshold value is achieved for both parameters. The ringed seals belong to two different management units: the Gulf of Bothnia and an assessment unit covering the Gulf of Finland, Gulf of Riga, Estonian coastal waters and the Archipelago Sea. The assessment is not applicable in the white areas of the map.

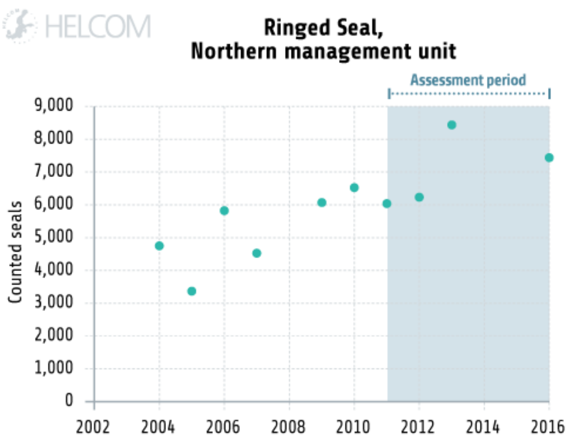


Figure 5.4.7.
Counted number of ringed seals during 2002-2016, based on monitoring at haul-outs during moulting time. The annual growth rate is positive but it is below the species specific threshold value. Although the population development can be followed reliably, it should be noted that not all individuals are encountered in monitoring. The total number of ringed seals in the Bothnian Bay is estimated at more than 20,000.

▸ *Ringed seal* (Pusa hispida)

The status of the ringed seal is assessed as not good (Figure 5.4.6). Ringed seals in the Gulf of Bothnia management unit are at a population size above the Limit Reference Level of 10,000 seals, but the threshold values for growth rate or distribution are not achieved (See also Figure 5.4.7). In the southern management unit, the status of ringed seal is critical. In this area, covering the Archipelago Sea, Gulf of Finland, Gulf of Riga and Estonian coastal waters, the population is decreasing. The eastern part of the Gulf of Finland has only around 100 animals.

Despite the weak results (Figure 5.4.6), the status of the ringed seal in the integrated assessment is likely overestimated for the southern management unit. Due to a lack of estimates for population size, this parameter was included qualitatively in the assessment tool, which likely gave a stronger result than if quantitative estimates had been available.

The breeding of ringed seal is restricted by the availability of suitable sea ice. The ringed seal needs compact and very close pack ice where snow can accumulate, which makes it particularly sensitive to climate change (Sundqvist *et al.* 2012). The ringed seal is categorised as vulnerable on the HELCOM Red List (HELCOM 2013a).

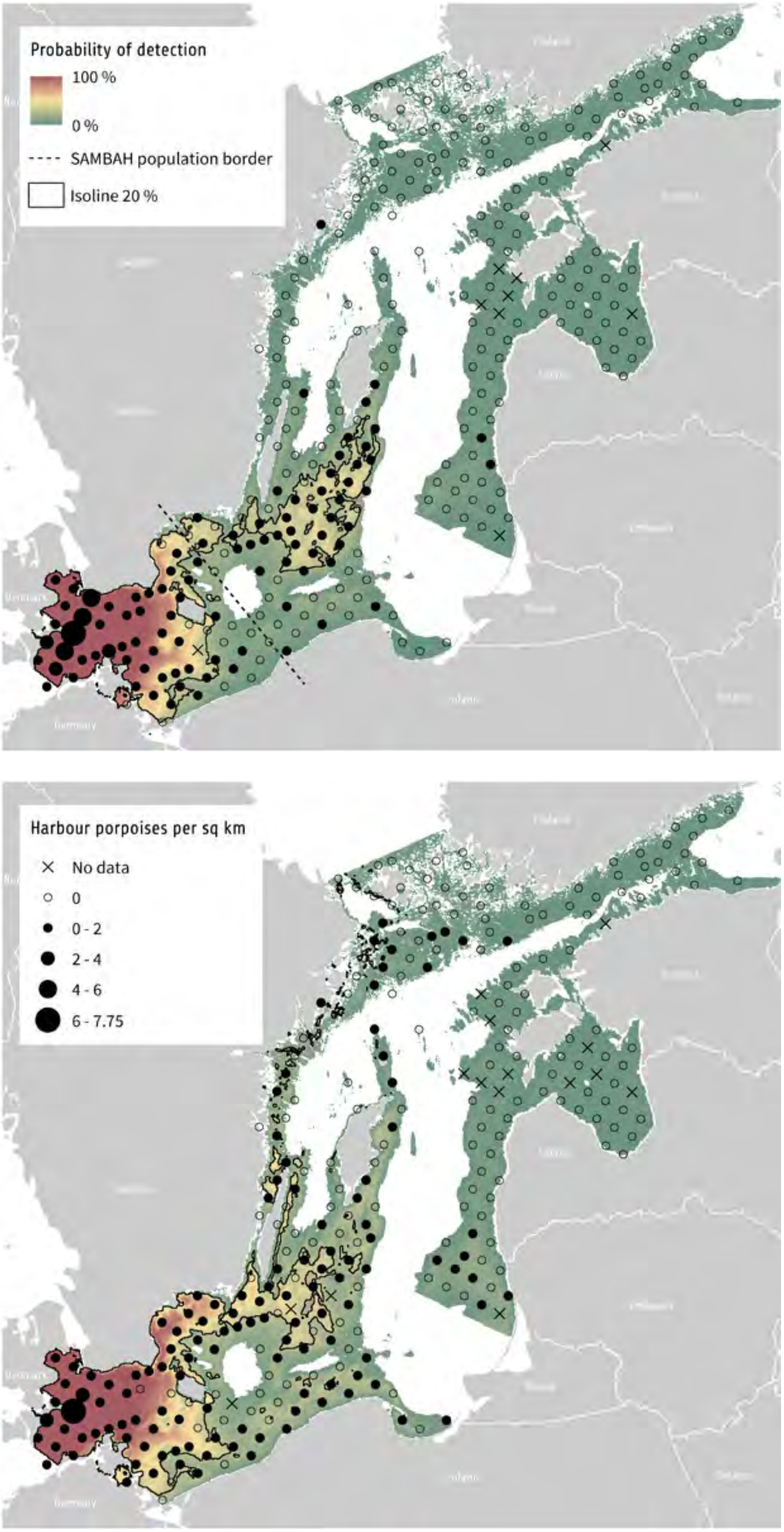


Figure 5.4.8.
Harbour porpoise in the Baltic Proper: Predicted probability of detecting harbour porpoise per month between May and October (upper graph) and between November and April (lower graph). The black line delineates areas with 20 % probability of detection (Denoted 'Isoline 20 %' in the legend). These areas correspond approximately to the area which encompasses 30 % of the population, and the limit is often used to define high-density areas. In the upper figure, the hatched line indicates the spatial separation between the Belt Sea and Baltic harbour porpoise populations during May to October. White colour denotes areas that were not surveyed. Source: SAMBAH project (Anonymous 2016).

▸ *Harbour porpoise* (Phocoena phocoena)

A major study conducted in 2011–2013 using passive acoustic recorders supports the presence of two sub-populations of harbour porpoise in the Baltic Sea: one mainly occurring east of Bornholm in the Baltic Proper and the other one occurring in the southern Kattegat, the Belt Sea, and the southwestern parts of the Baltic Sea (Anonymous 2016; Figure 5.4.8). A recent population genomics approach also emphasised notable differences between the Kattegat, Belt Sea, Western Baltic and the Baltic Proper (Lah *et al.* 2016).

Due to the lack of indicator, harbour porpoise was not included in the integrated assessment. However, the Baltic Proper sub-population is categorised as critically endangered in the HELCOM Red List (HELCOM 2013b). The number of animals is estimated to be around 500 (95 % confidence range 80 to 1,091). A large part of this sub-population occurs around the shallow offshore banks south of Gotland in summer, during calving and mating.

The Kattegat-Belt Sea-Western Baltic sub-population is also assessed as threatened (HELCOM 2013b), albeit with the lower threat status 'vulnerable'. The population is estimated at around 40,500 animals (95 % confidence range 25,614 to 65,041) using a visual line transect survey (Viquerat *et al.* 2014). Based on a later survey of small cetaceans in European Atlantic waters and the North Sea, Kattegat and Belt Sea (SCANS) there is no statistical support for a change in abundance over the period 1994 to 2016 (Hammond *et al.* 2016).

By comparing the age structure with the average age at sexual maturity, it has been estimated that around 28 % of the female harbour porpoises found dead along the German Baltic coast of Schleswig-Holstein had lived long enough to reach sexual maturity. In comparison, about 45 % of the dead females from the North Sea had reached sexual maturity. About 30 % of the animals were suspected to be by-caught, based on pathological findings. The low proportion of harbour porpoises reaching sexual maturity in the Baltic Sea supports the need to reduce the magnitude of bycatches (Kesselring *et al.* 2017; see also Box 5.4.1).

The harbour porpoise requires strict protection under the EU Habitats Directive as a species listed ▸

- under Annex IV (concerning Animal and plant species of community interest in need of strict protection). For the Habitats Directive's reporting period 2007 to 2012, the conservation status of harbour porpoise in the Baltic region (which includes both the Belt Sea population and the Baltic Proper population) is assessed as in the worst status class ('unfavourable–bad') by all countries that reported on the species in the Baltic Sea region: Denmark, Germany, Poland, and Sweden.

The situation of the status for Baltic Proper harbour porpoise is recognised by the agreement on the conservation of small cetaceans in the Baltic, North East Atlantic, Irish and North Seas (ASCOBANS) and is reflected in the ASCOBANS recovery plan for Baltic harbour porpoises (Jastarnia plan, ASCOBANS 2016) and HELCOM Recommendation 17/2 (HELCOM 2013f).

Box 5.4.1.

Incidental by-catch of mammals in fishing gear

A HELCOM core indicator to assess the number of drowned mammals and waterbirds caught in fishing gear is undergoing further development. Drowning in fishing gear is believed to be the greatest source of mortality for harbour porpoise populations in the Baltic Sea, and is also a concern for seals (Core indicator report: HELCOM 2018ar). The risk of incidental by-catch is highest in various types of gillnets but other stationary fishing gear, such as fyke nets and push-up traps also have incidental by-catches (ICES 2013a, Vanhatalo *et al.* 2014).

Incidental by-catches of harbour porpoise in the Kattegat and Belts Seas were calculated at 165 to 263 animals in 2014, based primarily on information from CCTV cameras on commercial vessels in combination with data on fishing (ICES 2016d). However, the numbers are associated with high uncertainties, concerning both incidental by-catch numbers and the amount of fishing activity taking place. Documentation of incidental by-catch of harbour porpoise in the Baltic Proper is fragmented, typically amounting to a few animals per year from the countries that are reporting by-catch of this species. However, dead harbour porpoises showing signs of having been entangled in gillnets are found and reported regularly, so it is likely that by-catch in gillnets is adversely affecting the critically endangered central Baltic Sea population (ICES 2017a).

The annual incidental by-catch of grey seals in trap nets and gill nets was estimated at around 2,180- 2,380 seals in 2012, based on interviews with fishermen from Sweden, Finland and Estonia, and accounting for the variability in seal abundance, fishing activity, and underreporting (Vanhatalo *et al.* 2014). There are no estimates of the incidental by-catch of ringed seals or harbour seals.

Future perspectives

Recognizing the importance of ensuring the long term survival of the Baltic Sea seals, HELCOM agreed in 2006 on a Recommendation of the 'Conservation of seals in the Baltic Sea' (HELCOM 2006). The Recommendation is a regional agreement on joint management principles, management units for the different seal populations, limit reference levels for the respective management unit, and coordinated monitoring programmes. Today, the population trends are indicating recovery of most populations.

However, the overall status of the seal populations is still of concern, particularly for the ringed seal. Future perspectives are species specific, due to different habitat preferences and different pressures. Current ongoing pressures affecting marine mammals include climate change, fish stock depletion and contamination. Decimated populations are also threatened by mortality resulting from incidental by-catch, and harbour seals have previously been vulnerable to viral epidemics (1988, 2002 and 2014). In addition, underwater sound and chemical pollution, food depletion and disturbance are continuous pressures on harbour porpoises. For ringed seals available breeding sites in ice lairs are expected to decrease with climate change.

To protect the harbour porpoise, in particular the Baltic Proper population, the aim is to minimize incidental by-catches in fishing gear to close to zero, as agreed in the Baltic Sea Action Plan, but there is a lack of data for proper assessments. The HELCOM Marine Protected Areas are important to protect harbour porpoise, particularly when relevant management measures are in place. ■

5.5. Waterbirds

The Baltic Sea is an important resting, feeding, moulting, breeding and wintering area for around 80 bird species. The waterbirds connect food webs in water with those on land, and by migration they also link the Baltic Sea with other marine regions. Many characteristic bird species have decreased over the last few decades, for example the pelagic feeding great black-backed gull, which scouts the sea surface for fish, and the velvet scoter, which feeds from the seafloor shallows. Other species have increased, the greylag goose, for example. Changes can be attributed to factors such as disruptions of food web structure, climate change and habitat alteration.

The Baltic Sea bird community is highly variable depending on the season. Although some of the bird species are present in the Baltic Sea area around the year, for example the herring gull (*Larus argentatus*), many species use the Baltic Sea only during specific seasons. Some species use the Baltic Sea as a wintering ground, for example the long-tailed duck (*Clangula hyemalis*), whereas others migrate to the area for breeding, such as the Arctic tern (*Sterna paradisaea*).

Many of the Baltic Sea waterbirds are predators, feeding mainly on fish, mussels or crustaceans, but they are also represented by scavengers, and by grazers feeding on vegetation.

There are also some differences between geographic areas. Whereas some of the assessed bird species occur all over the region, such as breeding common terns (*Sterna hirundo*) and wintering long-tailed ducks, others are restricted to smaller parts of the Baltic or only selected sites, for example breeding pied avocets and wintering Steller's eiders. Thus, when assessed at a finer geographic resolution the status differs across the region. The two core indicators related to the abundance of waterbirds during the breeding and the wintering seasons are currently calculated from land based survey data, whilst species in the open sea are not adequately assessed. Therefore, an overall assessment of waterbirds in the Baltic Sea has not been carried out, and coastal areas are the major focus of the assessment. Many open sea species are known to show strong declining trends in the Baltic Sea (Skov *et al.* 2011).

Smew swimming in the Baltic Sea.
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Indicators for assessing waterbirds

To capture the variety between seasons, the core indicators 'Abundance of waterbirds in the breeding season' and the 'Abundance of waterbirds in the wintering season' are used (Core indicator reports: HELCOM 2018as-at). At the Baltic Sea scale, the indicators assess the status of 29 breeding birds and 22 wintering birds respectively, with ten of the species being the same in both indicators. The species are chosen in order to represent both the overall species composition of waterbirds in the region, as well as to cover different species groups, including wading feeders, surface feeders, pelagic feeders, benthic feeders, and grazing feeders. Some species dominantly found in offshore areas lack long term data series and are currently not included in the core indicator assessments, particularly for the wintering season, since they only minimally overlap with the coastal area where monitoring is regularly carried out.

— The core indicators 'Abundance of waterbirds in the breeding season' and 'Abundance of waterbirds in the wintering season' evaluate status by relating an abundance index during the assessment period to a modern baseline (1991-2000). The indicators reflect good status when at least 75 % of the species considered at the given assessment scale deviate less than 30 % downwards from the baseline (20 % for species laying only one egg per year (HELCOM 2018as-at).

The indicators are assessed at two geographical scales. The integrated assessment of the two indicators is carried out for the entire Baltic Sea area, while each respective indicator is also assessed in seven assessment units consisting of aggregated sub-basins.

In addition, a HELCOM core indicator is under development on the number of drowned mammals and water birds caught in fishing gear (Boxes 5.4.1 and 5.5.1).

Assessment results for waterbirds

At the scale of the entire Baltic Sea, both the core indicators on waterbirds, representing the abundance of waterbirds in the breeding season and the wintering season, achieved the threshold value. It is however important to consider that this assessment does not encompass waterbirds in open sea.

At the smaller assessment scale, encompassing aggregated sub-basins, the core indicators reflect good status in the breeding season for waterbirds in the Belt group (Great Belt and the Sound) and the Bothnian group (Bothnian Bay, the Quark and the Bothnian Sea). Good status in the wintering season is seen in most of the region, excluding the Kattegat, Belt group and Åland group (Northern Baltic Proper and Åland Sea; Figure 5.5.1; HELCOM 2018as-at).

With respect to different groups of bird species, surface feeding and pelagic feeding birds have good status during both the breeding and wintering seasons at the whole Baltic Sea scale. Wading feeders do not achieve good status in the breeding season, and benthic feeders and grazing feeders not in the wintering season (Figure 5.5.1, first column; Tables 5.5.1-2; Figures 5.5.2-4).

When assessed at the smaller scale, the status evaluation differed regionally (Figure 5.5.1). In addition to defining the abundances of the involved species more clearly, assessments of waterbirds at smaller scales alters the number of species assessed within a feeding group in each case. In cases where a species has locally high abundance and/or where few species make up the feeding group, it is possible for all assessments at smaller scales to fail the assessment while the whole Baltic assessment achieves the respective threshold value, as seen for example benthic feeders in the breeding season (Figure 5.5.1; see Core indicator reports: HELCOM 2018as-at for details).

Among waterbirds breeding in the Baltic Sea, species with declining abundance belong to the group of benthic feeders (common eider and velvet scooter), surface feeders (great black-backed gull and common gull), grazing feeders (mute swan), ▸

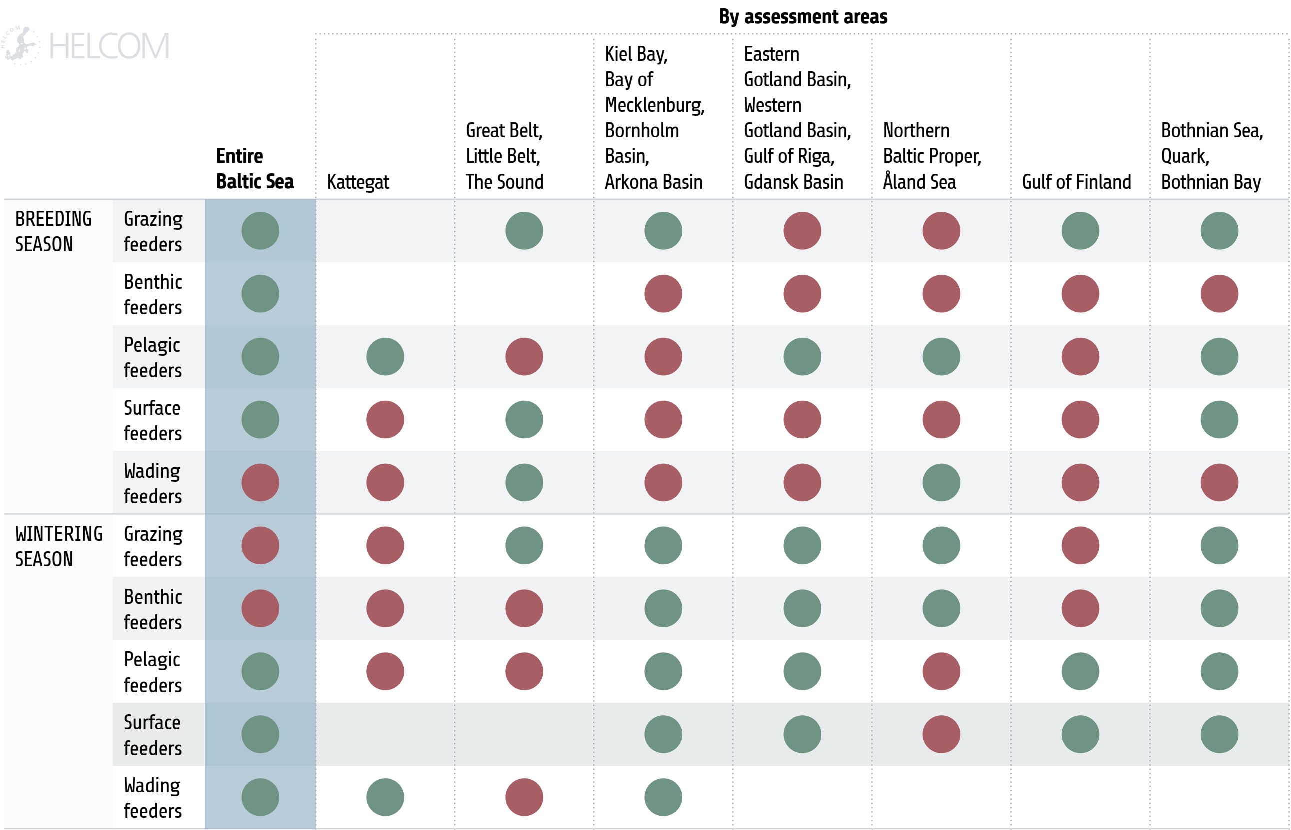

Figure 5.5.1.
Status of waterbirds by species groups at the whole Baltic Sea scale and aggregated assessment unit scale, based on results within the core indicators on abundance of waterbirds during the breeding and the wintering season. Status is evaluated based on the trends over time in the abundance of species within each of the groups. The assessment result for the entire Baltic Sea is shown in the first column. The following columns show the corresponding assessment results for different areas of the Baltic Sea. Green denotes that the species group passed the threshold value, and red that it failed. Since harmonised offshore monitoring was not possible to carry out for this assessment period waterbirds are assessed based predominantly on land-based surveys. Offshore species are thus not adequately assessed.

Table 5.5.1.
List of species included at the entire Baltic Sea scale in the core indicator 'Abundance of waterbirds in the breeding season'. Species groups not achieving good status according to the definition of the core indicators when applied at species group level, are highlighted in red. Species listed in Annex 1 of the Birds Directive are marked with an asterisk*. The column to the right shows the status of the same species according to the HELCOM Red List, which includes additionally thirteen species not included in the core indicators (HELCOM 2013b).

Species Group	Species	Scientific name	Trend 1991-2016	Threat status according to the HELCOM Red List
grazing feeders	mute swan	*Cygnus olor*	↓	
	greylag goose	*Anser anser*	↑	
benthic feeders	tufted duck	*Aythya fuligula*	↑	Near Threatened
	greater scaup	*Aythya marila*	?	Vulnerable
	common eider	*Somateria mollissima*	↓	Vulnerable
	velvet scoter	*Melanitta fusca*	↓	Vulnerable
pelagic feeders	goosander	*Mergus merganser*	↓	
	red-breasted merganser	*Mergus serrator*	→	
	great crested grebe	*Podiceps cristatus*	↑	
	great cormorant	*Phalacrocorax carbo*	→	
	razorbill	*Alca torda*	↑	
	common guillemot	*Uria aalge*	↑	
	black guillemot	*Cepphus grylle*	↑	Near Threatened
surface feeders	Arctic skua	*Stercorarius parasiticus*	→	
	common gull	*Larus canus*	↓	
	great black-backed gull	*Larus marinus*	↓	
	herring gull	*Larus argentatus*	→	
	lesser black-backed gull	*Larus fuscus*	→	Vulnerable
	little tern*	*Sternula albifrons*	→	
	common tern*	*Sterna hirundo*	↑	
	Arctic tern*	*Sterna paradisaea*	↑	
	Caspian tern	*Hydroprogne caspia*	→	Vulnerable
	sandwich tern	*Thalasseus sandvicensis*	↑	
wading feeders	common shelduck	*Tadorna tadorna*	→	
	Eurasian oystercatcher	*Haematopus ostralegus*	↑	
	pied avocet*	*Recurvirostra avosetta*	↓	
	ringed plover	*Charadrius hiaticula*	→	Near Threatened
	turnstone	*Arenaria interpres*	↓	Vulnerable
	dunlin*	*Calidris alpina*	↓	Endangered

pelagic feeders (goosander), and wading feeders (dunlin, pied avocet, and turnstone), when assessed at the whole Baltic Sea scale and during the period 1991-2016. Among waterbirds wintering in the Baltic Sea declining abundances are seen in species belonging to grazing feeders (Eurasian coot), pelagic feeders (goosander), and benthic feeders (common pochard, Steller's eider; see Table 5.5.1-2 for details and scientific names).

Waterbird species with relatively high abundance during the assessment years compared to the baseline[1] are the Arctic tern, common tern, sandwich tern, great crested grebe, common guillemot, and black guillemot, (assessed during the breeding season), and the Eurasian teal, black-headed gull, great cormorant, common goldeneye, and smew (wintering season). Low abundances relative to the baseline[2] are observed in great black-backed gull, velvet scoter, pied avocet, dunlin and turnstone (assessed during the breeding season). Among the wintering birds, low abundances are seen in common pochard, Bewick's swan, Eurasian coot and clearly so in Steller's eider.

It must be noted that important bird species have been omitted from the evaluation because they are not appropriately represented in the assessment data. Several species which spend the winter mainly in open sea areas have not been assessed, such as long-tailed duck, common scoter, velvet scoter, common eider, red-throated diver, black-throated diver, red-necked grebe, razorbill, black guillemot, common guillemot and Slavonian grebe. These are important representative species for the benthic and pelagic feeders. Hence, the core indicator results reflect only the status of waterbirds located in more coastal areas.

All bird species included in the core indicator-based assessment are also evaluated with regard to the EU Birds Directive (EC 2009). There may be differences in the results of these two processes, due to differences in methods and the spatial units considered. The HELCOM core indicator-based assessment is carried out at the whole Baltic Sea scale and for seven assessment units covering aggregated sub-basins and a regional threshold value, whereas the EU Birds Directive is bounded by national borders and uses different threshold values. At a smaller scale, changes in the relative abundance over time may differ due to local factors, such as loss of suitable habitat, competition and disturbance, or by enhancing factors such as habitat improvement and protection.

1 Index value >1.3 during assessment period compared with index value 1.0 for the baseline period.

2 Index value <0.7 during the assessment period compared with index value 1.0 for the baseline period.

Table 5.5.2.
List of species included at the entire Baltic Sea scale in the core indicator 'Abundance of waterbirds in the wintering season'. Species groups not achieving good status according to the definition of the core indicators when applied at species group level, are highlighted in red. The core indicator is based on counts along the coast, and does not include monitoring in open sea areas. Species listed in Annex 1 of the Birds Directive are marked with an asterisk*. The column to the right shows the status of the same species according to the HELCOM Red List (HELCOM 2013b). Note that the HELCOM Red List includes thirteen additional species not included in the core indicators.

Species Group	Species	Scientific name	Trend 1991-2016	Threat status according to the HELCOM Red List
grazing feeders	mute swan	*Cygnus olor*	→	
	whooper swan*	*Cygnus cygnus*	↑	
	Bewick's swan	*Cygnus bewickii*	?	
	Eurasian wigeon	*Anas penelope*	↑	
	mallard	*Anas platyrhynchos*	↑	
	northern pintail	*Anas acuta*	→	
	Eurasian coot	*Fulica atra*	↓	
benthic feeders	common pochard	*Aythya ferina*	↓	
	tufted duck	*Aythya fuligula*	→	
	greater scaup	*Aythya marila*	→	
	Steller's eider	*Polysticta stelleri*	↓	Endangered
	common goldeneye	*Bucephala clangula*	↑	
pelagic feeders	smew*	*Mergellus albellus*	↑	
	goosander	*Mergus merganser*	↓	
	red-breasted merganser	*Mergus serrator*	→	Vulnerable
	great crested grebe	*Podiceps cristatus*	↑	
	great cormorant	*Phalacrocorax carbo*	↑	
surface feeders	black-headed gull	*Larus ridibundus*	↑	
	common gull	*Larus canus*	→	
	great black-backed gull	*Larus marinus*	→	
	herring gull	*Larus argentatus*	→	
wading feeders	Eurasian Teal	*Anas crecca*	→	

Red-listed species

The red-listing provides additional information on the status of waterbirds in the Baltic Sea. Twenty-three out of fifty-eight bird species defined as breeding in the Baltic Sea are listed in the HELCOM Red List (HELCOM 2013b). The gull-billed tern (*Gelochelidon nilotica*) has been a regular breeding bird in the past but is now considered regionally extinct, and the Kentish plover (*Charadrius alexandrinus*) is categorised as critically endangered. Four species, the southern dunlin (*Calidris alpina schinzii*), the Terek sandpiper (*Xenus cinereus*), the Mediterranean gull (*Larus melanocephalus*) and the black-legged kittiwake (*Rissa tridactyla*), are classified as endangered. An additional eight species or subspecies are classified as vulnerable and nine as near threatened.

Sixteen out of forty-seven water bird species identified as wintering in the Baltic Sea are red-listed (HELCOM 2013b). The red-throated diver and the black-throated diver, are classified as critically endangered. Seven wintering bird species are categorised as endangered, including five species of sea ducks. Three species are classified as vulnerable and four near threatened.

The HELCOM Red List includes ten species that are also included in the core indicator for breeding birds, and two species that are included in the core indicator for wintering birds. In some instances, the core indicator evaluations may show a good status for a red-listed species. For example, the black guillemot (*Cepphus grylle*), tufted duck (*Aythya fuligula*), ringed plover (*Charadrius hiaticula*), greater scaup (*Aythya marila*), common eider (*Somateria mollissima*), Caspian tern (*Hydroprogne caspia*), and lesser black-backed gull (*Larus fuscus*) have a good status according to the core indicator for waterbirds during the breeding season, but are listed as 'vulnerable' by HELCOM (HELCOM 2013b) and this also applies for the red-breasted merganser (*Mergus serrator*) in the wintering season. Differences in the methodological approaches should be considered when making such comparisons. The core indicators are evaluated against a modern baseline and do not address the potential recovery of the species or overall population stability. Bird species are also assessed in other contexts, such as national red lists, which may show different results. Such inconsistencies between assessments may occur due to differences in the applied assessment periods, but may also reflect different population trends in different parts of the Baltic Sea. For example, the lesser black-backed gull (subspecies *Larus fuscus fuscus*) has decreased by around 40 % in Finland in 1991–2013 (Hario and Rintala 2016), while the core indicator shows a rather stable Baltic Sea scale population due to the increase of subspecies *Larus fuscus intermedius* in the western Baltic. ▸

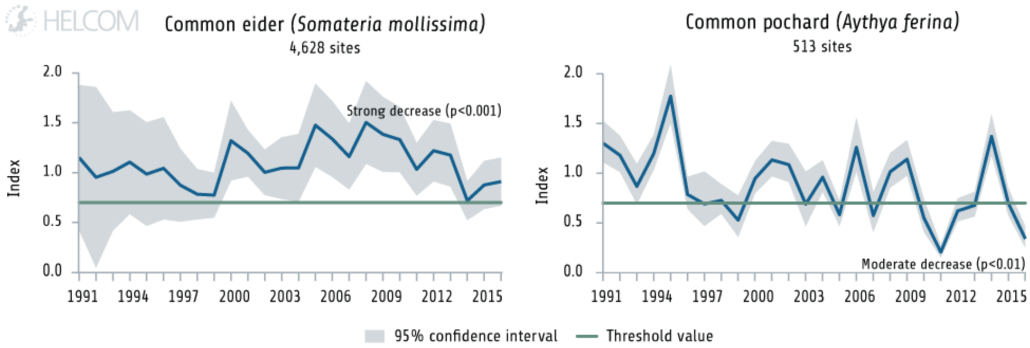

Figure 5.5.2.
Temporal development of the abundances of two benthic feeders; common eider (*Somateria mollissima*) in the breeding season and common pochard (*Aythya ferina*) in the wintering season at the whole Baltic Sea scale. Based on abundance index values during 1991–2016. Source: HELCOM (2018as–at).

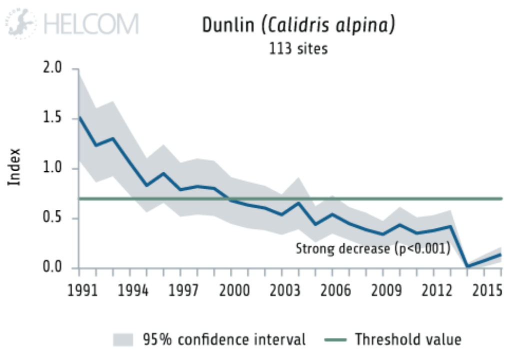

Figure 5.5.3.
Temporal development of the abundance of the wading feeder dunlin (*Calidris alpina*) in the breeding season at the whole Baltic Sea scale. Based on abundance index values during 1991–2016. Source: HELCOM (2018as).

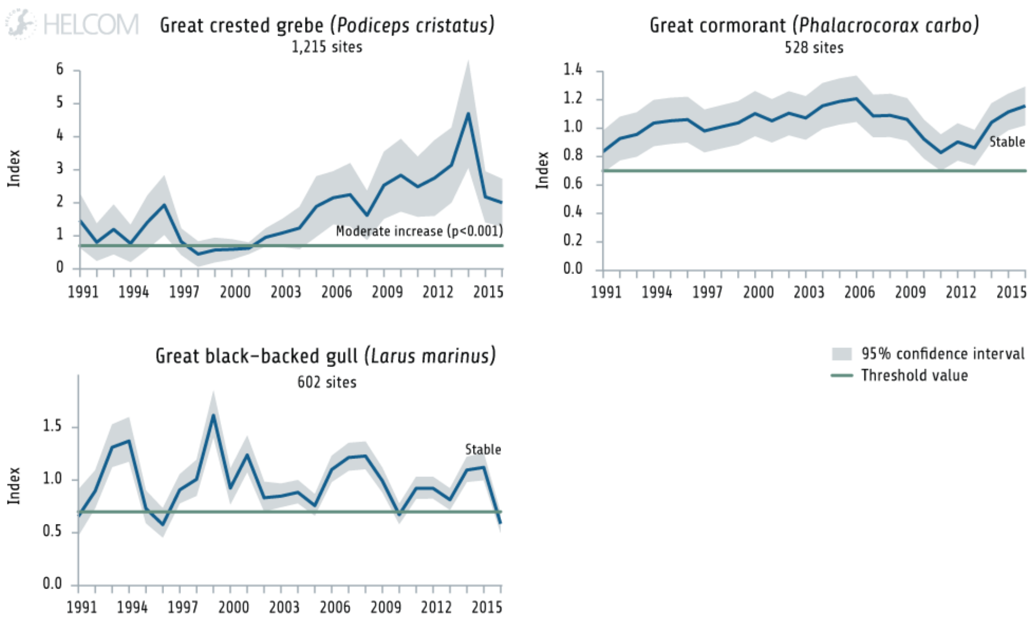

Figure 5.5.4.
Temporal development of the abundances of the pelagic feeders great crested grebe (*Podiceps cristatus*) and great cormorant (*Phalacrocorax carbo*) in the breeding season, and great black-backed gull (*Larus marinus*) in the wintering season at the whole Baltic Sea scale. Based on abundance index values during 1991–2016. Source: HELCOM (2018as–at).

Box 5.5.1.

Incidental by-catch of waterbirds in fishing gear

Drowning in fishing gear can be a strong pressure on populations of divers, grebes, cormorants, alcids, mergansers and ducks, especially in wintering areas with high densities of waterbirds. Diving waterbirds are especially vulnerable to being entangled in gill nets and other types of nets. Incidental by-catches also occur in other types of fishing gear, such as longlines and traps (ICES 2013b).

A rough estimate indicated that between 100,000 and 200,000 waterbirds drown annually in the North and Baltic Seas, of which the great majority drowns in the Baltic Sea (Žydelis *et al.* 2009, 2013, Bellebaum *et al.* 2012).

Beside the assessment of incidental by-catch, hunting must also be taken into account (See Chapter 4.6) because the total anthropogenic mortality has to be related to the population in order to assess its impact.

A HELCOM core indicator to assess the number of drowned mammals and waterbirds caught in fishing gear is undergoing further development (HELCOM 2018au).

Future perspectives

Waterbirds are widely dispersed and influenced by various human activities and pressures. Coastal developments, fishing, shipping, wind farms, recreation and hunting, are examples of human activities that may lead to disturbance, loss of habitat, alterations to the breeding and feeding environment, as well as mortality (Larsson and Tydén 2005, Žydelis *et al.* 2009, Petersen *et al.* 2011, Schwemmer *et al.* 2011). Many waterbird species are vulnerable to incidental by-catches in fishing gear (Box 5.5.1).

However, species react in different ways to the pressures, and changes in the environment, resulting also in effects on species composition and food web structure. High abundance of a bird species does not automatically indicate good status or sustainable human activities. For example, an increase in birds feeding on pelagic fish can reflect human induced disruption of the food web, such as overfishing of predatory fish leading to a higher abundance of the fish that these birds prefer to eat. On the other hand, the birds also influence other species by their feeding, and high numbers of a bird population may for example control abundances of mussels or fish.

Waterbirds are protected by the EU Birds Directive, requiring the conservation of habitats in a way that allows birds to breed, moult, migrate and overwinter (EC 2009). Species listed in Annex 1 of the EU Birds Directive and important habitats for migrating species are targeted for special protection measures. The HELCOM Marine Protected Areas are largely congruent with protected areas under the Birds Directives (See Chapter 7). In order to protect migrating birds in the Baltic Sea region, HELCOM has adopted Recommendation 34/E-1 'Safeguarding important bird habitats and migration routes in the Baltic Sea from any negative effects of wind and wave energy production at sea' (HELCOM 2013g). The recommendation has not been followed up yet. In addition, the conservation and sustainable use of migratory waterbird species is governed by the African-Eurasian Migratory Waterbird Agreement (AEWA), which is a legally-binding international treaty to which most Baltic Sea states are also Contracting Parties.

5.6. Summary and food web aspects

The biodiversity assessment shows that many species and habitats in the Baltic Sea have inadequate status. Only a few biodiversity core indicators achieved the threshold values in at least part of the Baltic Sea, and none of them achieved the threshold values in all assessed areas.

Summary for benthic and pelagic habitats

The integrated assessment of benthic habitats indicates good status in six out of thirteen assessed open sea areas, based on the available indicators and data. The assessment however only represents soft-bottom habitats, while the status of hard bottom areas is not assessed due to a current lack of indicators. In coastal areas, slightly above half of the assessed area show good status.

The integrated status of pelagic habitats indicates good status in the Kattegat, but not in any other open sea area. Pelagic habitats in the open sea are evaluated by core indicators representing phytoplankton biomass and the frequency of cyanobacterial blooms, and in six of the open sea sub-basins also by a core indicator on zooplankton. Coastal pelagic areas show good status in about one fifth of the assessed area.

The assessment based on HELCOM core indicators was supplemented with information from the most recent HELCOM Red List assessment (HELCOM 2013b). Altogether, fifty-one macroscopic species of benthic fauna are red-listed. However, not all species occurring in the marine region are evaluated. The list also includes eleven species of macroscopic plants and algae, out of 317 assessed.

A HELCOM threat assessment for biotopes and biotope complexes identifies seventeen biotope complexes as threatened, and 'aphotic muddy bottoms' are categorised as critically endangered. The evaluation represents a minimum estimate, based on available data. Eight out of ten assessed biotope complexes (comparable to 'habitats' as defined in Annex 1 of the EU Habitats Directive) are categorised as threatened in the Baltic Sea.

All species are dependent on each other and connected in the ecosystem.
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Summary for mobile species

The assessment of fish from a biodiversity perspective indicate good status in about half of the assessed coastal areas. The integrated status of pelagic fish in the open sea is assessed as not good in the southwestern Baltic Sea, the Gulf of Riga and the Gulf of Bothnia. Demersal fish do not show good status in any part of the Baltic Sea, reflecting a too high fishing pressure on both Western and Eastern Baltic cod stocks. The core indicators for the migrating fish species salmon and sea trout show inadequate status in about half of the areas where they are assessed.

Fourteen species of fish and lampreys, out of a total of around 230, are evaluated as threatened in the HELCOM Red List. The list of critically endangered fish species includes European eel and grayling, as well as the sharks porbeagle and spurdog in the Kattegat

Among the marine mammals, grey seal and ringed seal show inadequate status, and harbour seal shows good status only in the Kattegat. The abundance and distribution of several seal populations has, however, increased in recent time. Harbour porpoise is not as yet assessed by a core indicator, but according to the HELCOM Red List, both sub-populations occurring in the Baltic Sea are categorised as threatened (HELCOM 2013b).

The two core indicators for abundance of waterbirds during the breeding and the wintering season along the coastline both achieve their threshold values at the Baltic Sea scale, although the results as finer geographic resolution show differentiated results. An overall assessment of birds in the Baltic Sea is not possible, since birds in open sea areas are not included in the indicators. However, many bird species in open sea areas show strong Baltic-wide declines (Skov *et al.* 2011).

Food web aspects

Taken together, these results may also indicate the overall status of the food web, since all species are dependent on each other and connected in the ecosystem. Predatory species require a sufficient production of prey in order to maintain sustainable populations. From the top-down perspective, a deficiency of predators may lead to a reduced trophic regulation, with destabilisation of food web structure and function. Species at higher trophic levels may be particularly suitable indicators of food web status, due to this dual role, and since they are exposed to pressures both directly and via impacts that accumulate in the food web.

The ongoing decline in nutritional status of some fish populations is an important signal of ecosystem impacts, in addition to the results reflected by the core indicators. The condition and size structure of Eastern Baltic cod has declined sharply in recent years, likely reflecting large scale changes in the Baltic Sea ecosystem due to ongoing environmental pressures, and impacting, in turn, on the status of species in other parts of the food web. Potential explanations for the decline include overfishing, predation, and parasite infections, but many pressures are likely contributing. The widespread and increasing distribution of areas with low oxygen concentrations in the deep water is a particular concern, potentially affecting both pelagic and benthic productivity, and hence the basis for ecosystem productivity.

Similar changes may also be seen in other species groups. For example, the core indicator for grey seal nutritional status does not achieve the threshold value, and the nutritional status of sub-adult grey seals shows a declining trend. These changes remain to be understood but could be connected to populations approaching their carrying capacity.

Indicators representing the lower trophic levels of the food web are important as they may explain reasons behind any large scale changes. They are also critical in order to be able to detect potential changes at an early stage. The core indicator 'Zooplankton mean size and total stock' functions as a food web indicator by monitoring changes in both the abundance and size structure of primary consumers. In all sub-basins where the zooplankton indicator does not achieve the threshold value, this is due to a decrease in the proportion of large-sized taxa. Among primary producers, an indicator measuring the ratio between diatoms and dinoflagellates is tested in the Eastern Gotland Basin. Both these groups of phytoplankton are important food for higher trophic levels, but shifts in their relative abundance, attributed to eutrophication or climate change, may affect the nutrition of zooplankton and lead to subsequent changes in other parts of the food web.

The combined results suggest that conservation and management to restore biodiversity should increasingly include consideration of combined effects in the food web, as well as climate change. Climate-related changes in hydrology and seasonality are foreseen to affect species both directly, via effects on population growth and distribution, and indirectly via species interactions and changes in food availability.

Copepod (*Acartia tonsa*) zooplankton.
© Will Parson (CC BY 2.0)

Habitat quality

For some core indicators, the inadequate status is also linked to changes in the physical habitat. The overall availability and quality of breeding and feeding areas for species is often unknown on the regional scale. Particularly in coastal areas, a gradual deterioration due to construction, habitat disturbance or eutrophication is of concern. In addition, many Baltic rivers have lost their function as production areas for migrating fish species, due to damming of rivers, hydropower or dredging, exemplifying also the importance of interlinkages between marine areas and surrounding land.

Box 5.6.1.

Reduced welfare from changes in perennial vegetation and fish stocks

Deterioration of marine biodiversity may result in welfare losses to society (See Chapter 3). Although the effects may not be directly observable, people obtain benefits from knowing that the marine ecosystem and its species are thriving. The value for biodiversity is, for the most part, independent of the use of the marine environment, and more related to the knowledge that habitats and species exist and are in good health.

Improved biodiversity and marine health brings about increased economic benefits to citizens, which are lost if the state of the sea does not improve (cost of degradation). Some of these monetary benefits have been assessed in a stated preference choice experiment study carried out in Sweden, Finland and Lithuania in 2011, which elicited citizens' willingness to pay for improvements with regard to aspects related to marine biodiversity (Kosenius and Ollikainen 2015). The valuation study estimated the benefits from increasing the amount of healthy perennial vegetation (such as underwater meadows) and the size of fish stocks in the Finnish-Swedish archipelago and the Lithuanian coast from current to good status. The benefits were based on people's willingness to pay for these improvements.

As the study was conducted only in three countries, the benefit estimates had to be transferred to the six other Baltic Sea countries to arrive at a regional estimate. Thus, only the estimates for Finland, Lithuania and Sweden are based on original valuation studies and data collection, and the estimates for Denmark, Estonia, Germany, Latvia, Poland and Russia are based on value transfer. The transferred value estimates were corrected for differences in price and income levels between the countries. The Finnish benefit estimate was transferred to Denmark and Germany, and the Lithuanian estimate to Estonia, Latvia, Poland and Russia. The choice of which estimates to transfer, and where to, was made based on average income levels.

Figure B5.6.1 shows the estimates per person. The results suggest that citizens' welfare would increase by 1.8–2.6 billion euros annually in the Baltic Sea region, if the state of the perennial vegetation and fish stocks improved to a good status (See also Thematic assessment: HELCOM 2018A). It is worth noting that there is more uncertainty about these estimates compared to the estimates for eutrophication and recreation, as some of the values are based on benefit transfer.

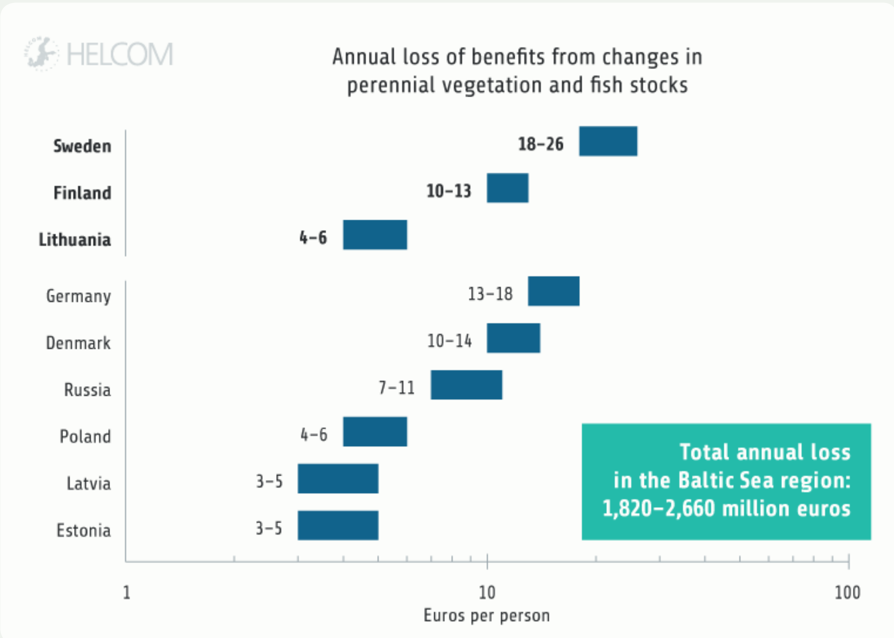


Figure B5.6.1.
Benefit losses related to perennial vegetation and fish stocks. Note that estimates for Finland, Lithuania and Sweden are based on original valuation studies and data collection, and estimates for the six other countries are based on value transfer from Finland (Denmark and Germany) and Lithuania (Estonia, Latvia, Poland and Russia). The range comes from the 95 % confidence intervals for the value estimates reported in the original study. Value estimates are in purchasing power parity adjusted 2015 euros.
Source: Kosenius and Ollikainen (2015).

6. Cumulative impacts on the marine environment

Human activities in the Baltic Sea and its catchment area create a variety of potential pressures. Cumulative impacts on species and habitats are caused by multiple pressures taken together. If each of the pressures is considered individually, they may appear to be at sustainable levels. However, when summed together, their total impact may be considerable if they take place in the same area, in particular when acting on sensitive habitats. The Baltic Sea Impact Index estimates the cumulative burden on the environment based on spatial information at a regional scale, showing higher impacts in coastal areas, which host more diverse benthic habitats, and in the southwest Baltic Sea, where human population density is higher and the narrow straits and shallow bays make the natural environment easily accessible to humans.

Offshore wind farm in the Øresund strait, Denmark.

Pressures from human activities can be broadly categorised into inputs of substances (including for example nutrients and hazardous substances), inputs of energy (underwater sound), biological pressures (including for example extraction of fish and disturbance to species), and physical pressures (physical loss and physical disturbance to the seabed). The pressures affect both the biotic and abiotic parts of the marine environment, but in the end they have impacts on species in different parts of the food web.

The spatial distribution of pressures and impacts in the Baltic Sea was evaluated using two methods: the Baltic Sea Pressure Index (BSPI) and the Baltic Sea Impact Index (BSII).

— The Baltic Sea Pressure Index evaluates the distribution of pressures and assesses where their current cumulative distribution is highest.
— The Baltic Sea Impact Index estimates the cumulative impacts in the Baltic Sea, by additionally using information on which species and habitats are likely to be present in an area.

6.1. Method overview

The assessment was based on information on the spatial distribution of human activities and pressures in the Baltic Sea during 2011–2016. The data represents a wide range of human activities and potential pressures of relevance to the region, based on the bulk list presented in Figure 3.1 (Chapter 3). In all, thirty-nine original data sets were aggregated into eighteen aggregated pressure layers representing levels at sea. The layers are described in more detail in the Thematic assessment (HELCOM 2018E). The Baltic Sea Pressure Index depicts the distribution of potential pressures in the Baltic Sea, based on these aggregated pressure layers. It should be noted, however, that the intensity of the pressures in relation to the impacts they may cause on the environment is typically not incorporated.

Additionally, thirty-six ecosystem component data layers, which represent the distribution of species and habitats, were included for assessing cumulative impacts using the Baltic Sea Impact Index (Thematic assessment: HELCOM 2018E). These data layers show ecosystem components in their current distribution, referring to the years 2011-2016. Hence, they do not include information on where species would occur if there were no pressures due to human activities. For example, the distribution of cod spawning areas is shown based on information on currently functional spawning areas, which have a clearly more limited distribution compared to the past (Köster *et al.* 2017). By this approach, the assessment focusses on identifying current potential impacts, given the existing status of species and habitats in the Baltic Sea, as assessed for selected pressures in Chapter 5.

The cumulative impact was estimated by combining the information on species and habitats with the information on the distribution of pressures, using estimates of the sensitivity of species and habitats to the different pressures. The sensitivity was estimated by sensitivity scores, which were obtained from a survey answered by over eighty selected experts representing marine research and management authorities in seven Baltic Sea countries. The results were evaluated for compatibility with a literature review study on physical loss and disturbance of benthic habitats, and assessed in relation to a self-evaluation of the experts on their confidence in their replies (Thematic assessment: HELCOM 2018E).

The Baltic Sea Impact Index evaluates in which areas human-induced pressures have potentially high or low cumulative impacts on the environment, relative to other areas. In reality, these impacts are often synergistic, so that the total effects of the pressures may be larger than their sum, and there may be positive or negative ecosystem feedbacks (Box 6.1). The current version of the BSII does not take these more complex linkages into account.

Confidence aspects

The assessments of cumulative pressures and impacts are both directly dependent on the quality of the underlying data layers. The aim has been to include spatial information on the Baltic Sea scale, so that the results will be comparable. The results give an estimation of potential pressures and impacts, created with the best available data. However, gaps and quality differences may occur in the underlying datasets. In some cases, it has not been possible to achieve data sets with full spatial coverage, but the layers have still been included in order to reflect the currently best available knowledge, rather than omitting this aspect. The completeness of data coverage for different geographical areas is shown on the side of each map.

The level of accuracy in detailed results needs to be evaluated on a case by case basis. While some maps provide information on a relatively detailed spatial scale, other layers are at present not detailed enough to be relevant at a more local scale, for example those showing species distributions.

The applied sensitivity scores are based on an expert survey, and the evidence base for linkages between human activities, pressures and impacts is to be addressed further in the future.

For more details, the underlying datasets and metadata can be viewed and downloaded from the HELCOM map and data service website. The assessment method is described in more detail in HELCOM (2018E), which also gives a collated view of the included data layers.

Container ship and white-tailed sea eagle.
© Cezary Korkosz

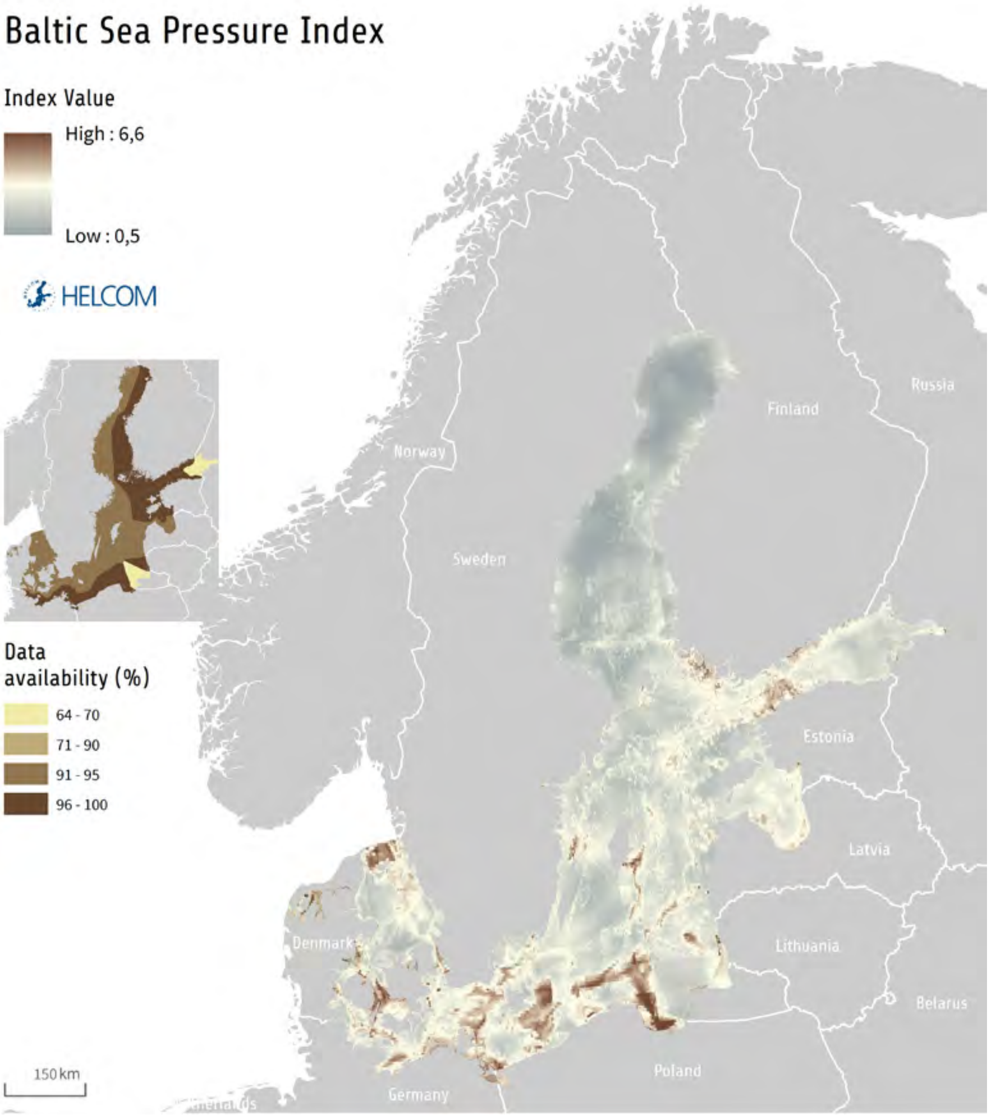


Figure 6.1.
The Baltic Sea Pressure Index shows spatial variation in potential cumulative pressure on the Baltic Sea, by combining data on several pressures together. The index is based on currently best available regional data, but spatial gaps occur in some underlying datasets, as identified in the smaller map.

6.2. Cumulative pressures on the Baltic Sea marine area

Pressures from human activities occur everywhere in the Baltic Sea, but are mainly concentrated near the coast and close to urban areas (Figure 6.1). The most widely distributed pressures at the regional scale are nutrients (including nitrogen and phosphorus), hazardous substances, non-indigenous species, and extraction of fish.

6.3. Cumulative impacts in the Baltic Sea marine area

The assessment of potential cumulative impacts indicates that there are great differences in the level of cumulative impacts between different areas of the Baltic Sea. The southwest Baltic Sea and many coastal areas experience higher potential cumulative impacts than the northern areas and many open sea areas (Figure 6.2). However in areas with

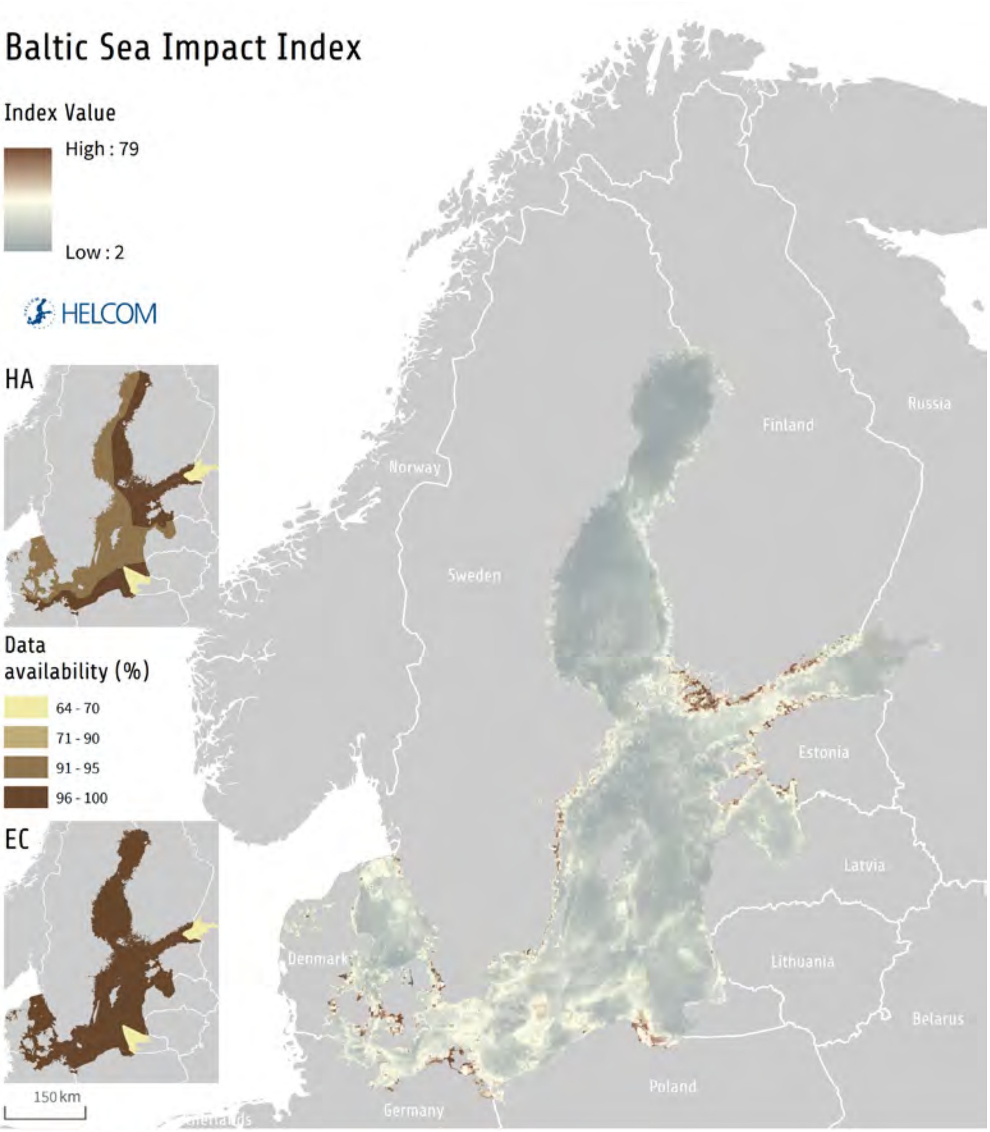


Figure 6.2.
Distribution of cumulative impact from human activities on the Baltic Sea environment, based on the Baltic Sea Impact Index. The index addresses the total added impact from pressures on species and habitats, focusing on spatial variation to identify areas subjected to potentially higher and lower impact. The analysis is based on currently best available regional data, but spatial gaps occur in some underlying datasets, as identified in the smaller map (EC=Ecosystem components layers, HA=human activities and pressures data sets).

poor data coverage the potential cumulative impacts may be underestimated.

Most of the identified impacts were attributed to nutrient concentrations and hazardous substances, followed by non-indigenous species, and the extraction of fish (Figure 6.3). Nutrient concentrations included phosphorus and nitrogen concentrations, and the theme representing the extraction of fish included cod, sprat and herring extraction (Thematic assessment; HELCOM 2018E). The results reflect that these are the pressures which are most widely distributed in the Baltic Sea, and to which many species and habitats are sensitive. Other pressures, such as oil slicks and spills, physical loss and physical disturbance, were associated with high sensitivity scores but had lower influence to the overall regional scale as they are not as widely distributed.

By considering how the spatial distribution of species and habitats overlap spatially with different pressures, the Baltic Sea Impact Index identifies the parts of the biological ecosystem that are potentially most impacted overall. The most widely impacted ecosystem components in the Baltic Sea were the deep water habitats and productive surface waters, the marine mammals (grey seal, harbour porpoise, ringed seal, and harbour seal), as well as cod (Figure 6.4). Relatively high impacts are seen in many coastal areas, which reflects that shallow habitats typical for these areas were assessed as sensitive to several pressures, and that more ecosystem components are represented in coastal areas than in the open sea.

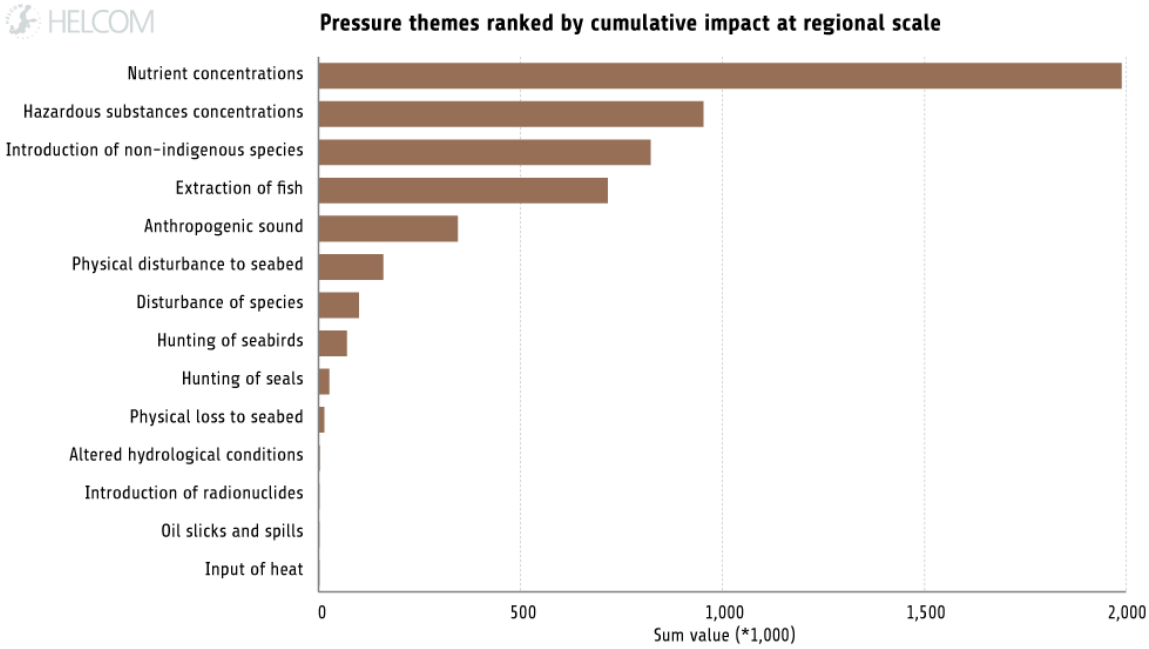


Figure 6.3.
Ranking of pressures themes attributed to cumulative impacts at regional scale in the Baltic Sea Impact Index. The 'Sum value' is calculated as the sum of impacts from each pressure on all studied ecosystem components at Baltic Sea scale. For further explanation to the pressures, see HELCOM (2018E).

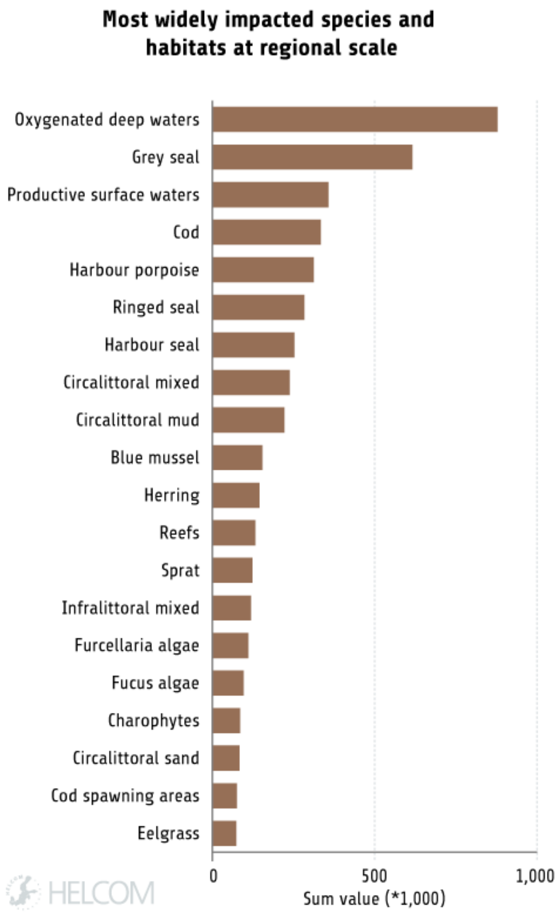


Figure 6.4.
List of most widely impacted ecosystem components (species or habitats), according to the Baltic Sea Impact Index. Note that only results for the twenty most impacted ecosystem components are shown. The 'Sum value' is calculated as the sum of impacts from all pressures on each ecosystem component.

6.4. Cumulative impacts on benthic habitats

A separate analysis was carried out for potential cumulative impacts on benthic habitats only, as these are particularly affected by physical pressures. In this case the evaluation was based on pressure layers representing physical loss and physical disturbance to the seabed, combined with information on the distribution of eight broad benthic habitat types and five habitat-forming species, which have been identified as relevant for the HELCOM area[1].

The evaluation suggests that benthic habitats are potentially impacted by loss and disturbance in all sub-basins of the Baltic Sea, but the highest estimates were found for coastal areas and in the southern Baltic Sea (Figure 6.5). The most impacted sub-basins were identified as the Sound, Bay of Mecklenburg, and the Kiel Bay (Figure 6.6). As the shallow waters usually host more diverse habitats, the impacts also accumulate more in coastal areas.

The top human activities causing cumulative impacts on benthic habitats, according to this assessment, are bottom trawling, shipping, recreational boating and sediment dispersal caused by various construction and dredging activities and depositing of dredged sediment (for more details, see Thematic Assessment: HELCOM 2018E).

1 Eight broad scale habitats (Circalittoral hard substrate, Circalittoral mixed substrate, Circalittoral mud, Circalittoral sand, Infralittoral hard substrate, Infralittoral mixed substrate, Infralittoral mud and Infralittoral sand) and five habitat forming species (*Furcellaria lumbricalis*, *Zostera marina*, *Mytilus edulis*, *Fucus* spp. and *Charophytes*).

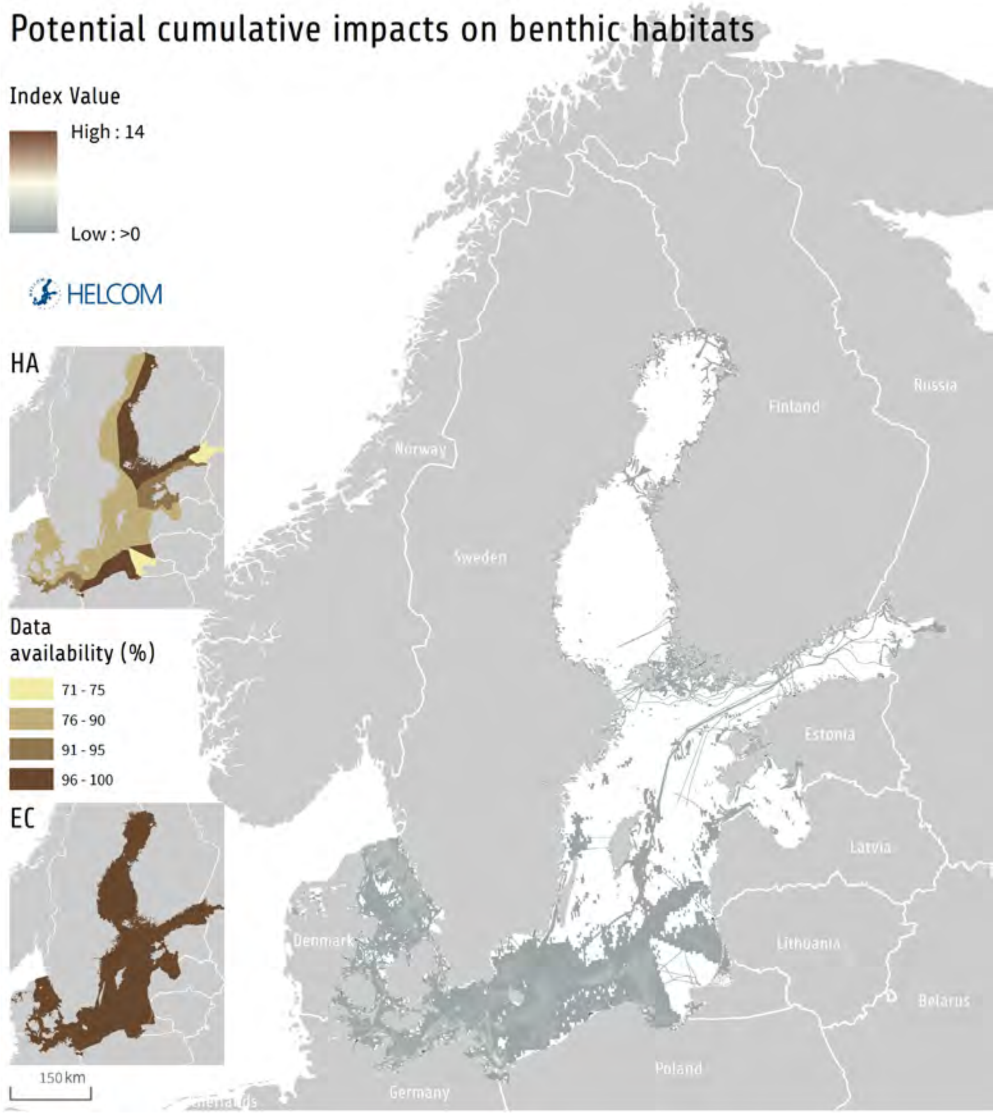


Figure 6.5.
Map of potential cumulative impacts on benthic habitats in the Baltic Sea. The cumulative impacts are calculated based on the method of the Baltic Sea Impact Index as the 'sum of impact', specifically for the two pressures physical loss and physical disturbance. Benthic habitats were represented by eight broad scale habitat types and five habitat forming species (*Furcellaria lumbricalis, Zostera marina, Mytilus edulis, Fucus* spp. and *Charophytes*). White color on the map indicates areas where impact is assessed as zero, due to absence of pressures or ecosystem components, or both. The analysis is based on currently best available regional data, but spatial gaps occur in some underlying datasets, as identified in the smaller map (EC=Ecosystem components layers, HA=human activities and pressures data sets).

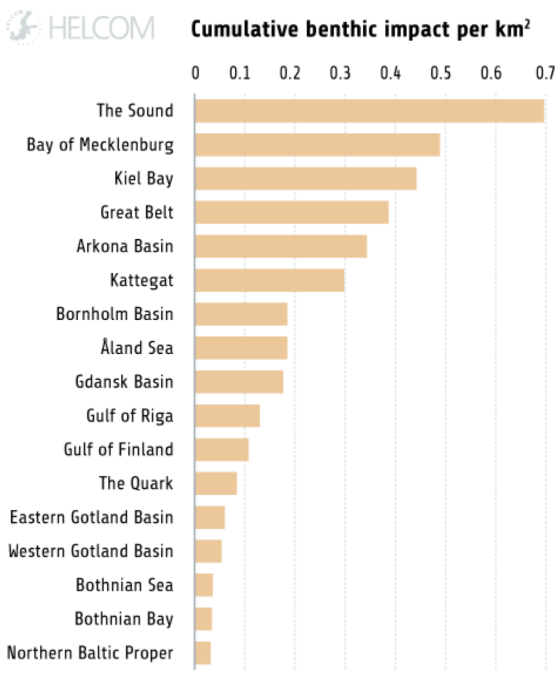


Figure 6.6.
Cumulative impacts on benthic habitats in the Baltic Sea sub-basins. The values are calculated as the summed impact from physical loss and physical disturbance on the studied benthic habitat types and habitat forming species, divided by the area of the sub-basin. The estimates are based on currently best available regional data, but spatial and temporal gaps may occur in underlying datasets.

Box 6.1.

How are species affected by human impacts

One human activity can cause many different pressures, and each of these pressures can affect organisms in various ways. The effects can also be hierarchically dependent. For example, the input of chemical substances can lead to reduced available energy of a species due to the energy exerted in combating the chemical. This can lead to reduced energy reserves for reproduction, resulting in negative population effects. Such cascading effects can also result in changes in community composition and biodiversity.

The Baltic Sea Impact Index uses sensitivity scores based on a regional scale expert survey in order to cover a broad range of topics in a similar way and makes use of existing expertise on the different ways in which pressures may impact the environment. The results can be further validated by a review of selected linkages, available in the literature.

Examples on how such pathways can be outlined systematically using a literature analysis tool are given below. The examples are shown for selected pressures affecting seagrasses and blue mussels, which are keystone species providing habitat for a huge number of other species which interact and are also dependent on one another.

Sea grasses

Major threats to seagrass result from nutrient inputs and habitat loss, the majority of which are from land such as from the oversupply of fertilisers or improperly treated waste water. The increased nutrient levels favour phytoplankton and epiphytes growing on seagrasses, leading to overgrowth and shading and finally to a reduced biomass of seagrass. This effect can be exacerbated by increased current velocities, caused for example by construction activities: snails, normally grazing on seagrass for epiphytes and thus, mitigating the overgrowth effect, are washed away and disappear. Deposit of dredged material in sea grass covered areas and dredging activities, bury and extract seagrass, respectively, and therefore have a direct impact. Additionally, re-suspension of sediments reduces light availability, leading to decreased photosynthesis and decreased growth. Some antifouling additives from ship coating reduce the photosynthetic efficiency of seagrass. Herbicides from agriculture may also affect seagrass and cause similar effects. Increased water temperatures caused by climate change not only affect growth and survival of seagrass but may also favour the spreading of pathogens, such as the potentially epidemic wasting disease which has been responsible for major seagrass declines in the past. Additional important pressures affecting seagrass meadows are for example oxygen depletion and increased sulphide concentrations, direct and indirect effects of fisheries, and acidification (Figure B.6.1.1).

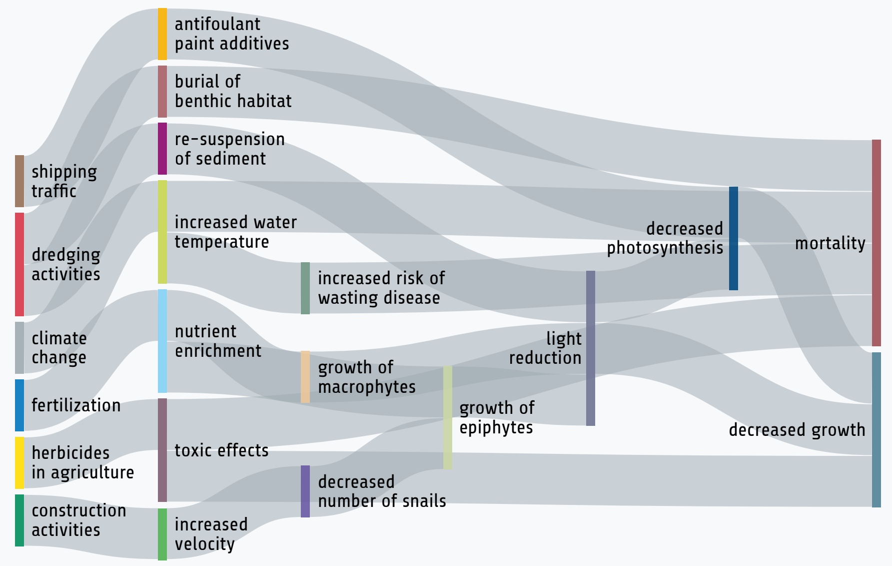


Figure B.6.1.1.
Effects of selected human activities on seagrass meadows. Based on systematic literature review using the LiACAT tool (HELCOM 2016f, Eilers *et al.* 2018).

Box 6.1. (continued)

Blue mussels

Blue mussels are sensitive to heavy metals and other pollution, since they are filter feeders and accumulate metals directly. Sources of contaminants are industries, land-based activities, air deposition, and activities at sea, such as harbours, shipping, industry, and oil spills. The defence mechanisms that are induced in the mussels are energetically costly for them, and alter heart rate and respiration. Additionally, physical condition is impaired, growth is reduced and mortality increases. The magnitude of these effects is dependent on environmental factors such as salinity, temperature and oxygen conditions. Changes in water temperature can be caused by local industrial heat sources or by climate change. In combination with acidification, effects on early development stages and on shell thickness have been observed. Moreover, shell growth and mortality are negatively affected by the interactive effects of reduced salinity and increased temperature. Seabed disturbance caused by fishing activities may lead to the decline of blue mussel, by removal of species and abrasion. The invasive species Crassostrea gigas is considered to compete with blue mussels and may alter the effects of anthropogenic pressures due to different tolerance levels towards the pressures (Figure B.6.1.2).

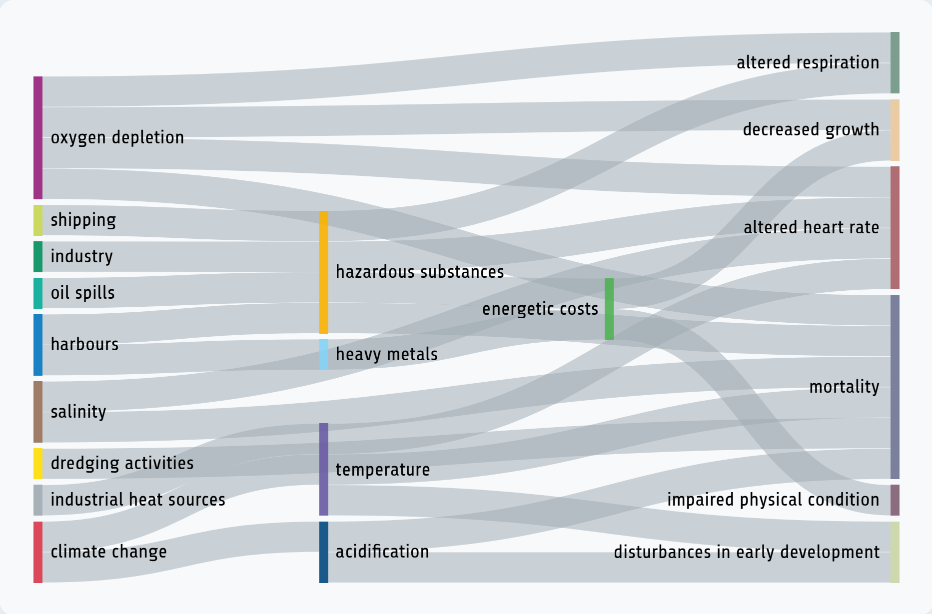


Figure B.6.1.2.
Effects of selected human activities on blue mussels to show the linkage framework. Based on systematic literature review using the LiACAT tool (HELCOM 2016f, Eilers *et al.* 2018).

Measures to improve the Baltic Sea environment are undertaken by many actors and at many levels; jointly at the regional level through HELCOM, by countries at national, county and local levels, and by initiatives in the private sector. Different types of measures are taken including technical improvements to minimise impact, economic and legislative measures, and measures directed towards raising awareness and incentives for changes in behaviour. In the Baltic Sea, where the transboundary aspects of environmental problems are highly evident, HELCOM plays a central role in coordinating the management objectives and their implementation in line with the Helsinki Convention.

A straight-forward conclusion from the results presented in this report is that the measures currently in operation have not been sufficient to reach a good overall environmental status in all areas of the Baltic Sea. More accurate estimates of foreseen effects of measures are needed, in order to evaluate if current measures are sufficient to reach good environmental status. Achievements gained via coordinated actions taken by HELCOM can however still be evaluated, as exemplified in this chapter.

7.1. Progress in achieving the objectives of the Baltic Sea Action Plan

The Baltic Sea Action Plan and the HELCOM Ministerial Declarations contain agreements on nearly 180 concrete actions for achieving the regionally agreed objectives (HELCOM 2007, 2010b, 2013a). A little more than half of those actions are carried out jointly in HELCOM, for example through the development of common management guidelines and 'HELCOM Recommendations' which are joint agreements on approaches or measures to address certain activities and pressures or areas of concern. Joint actions refer also to joint regional regulatory initiatives of the Contracting Parties in other intergovernmental contexts such as within the International Maritime Organization. To date, 126 HELCOM Recommendations are implemented to support a regionally coherent marine management. Other actions are implemented at the national level, for example through national legislation or national restoration activities.

By 2017, 68 % of the joint HELCOM actions had been carried out. Of the actions implemented at the national level, 23 % had been accomplished by all countries, and 62 % by some countries (Figure 7.1).

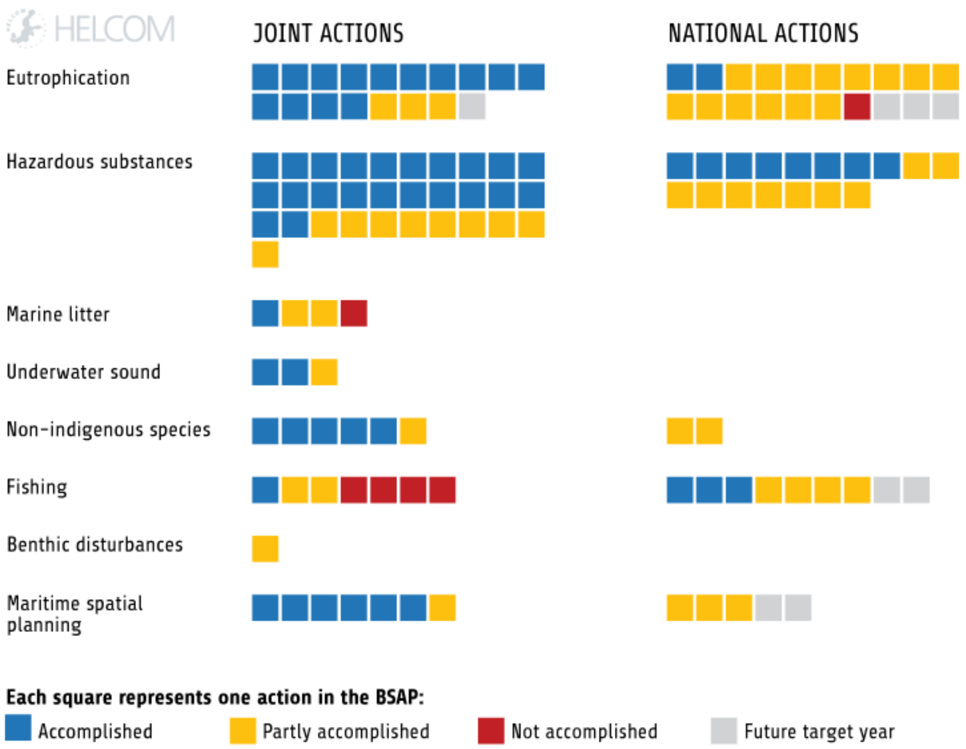


Figure 7.1.
Status of implementation of Baltic Sea Action Plan by 2017 – Pressures. Accomplishment of actions agreed under the Baltic Sea Action Plan and HELCOM Ministerial Declarations related to the reduction of pressures. Joint actions are those implemented together in HELCOM. For actions implemented nationally 'accomplished' signifies that the action has been implemented by all countries, 'partly accomplished' by some but not all countries, and 'not accomplished' that no country has implemented the action. Eight HELCOM actions related to financing and awareness are not included in this presentation.

Among the actions to reduce pressures, the lowest level of implementation is seen in relation to eutrophication (Figure 7.1). The overview gives a partly incomplete picture on actions related to benthic disturbances, marine litter and underwater sound, since HELCOM recommendations are currently not included in the follow-up of the implementation of the Baltic Sea Action Plan. For example, requirements are additionally in place concerning dredging and disposal of dredged material. In addition, the Regional Action Plan for Marine Litter from 2015 requires the countries to achieve significant reductions in marine litter by 2025 and includes a number of joint actions and voluntary national actions that are not addressed here. For underwater sound, HELCOM has focused on building knowledge and has, through the 2018 Ministerial Meeting, agreed to develop an action plan.

While there are few actions directly aimed at conserving habitats, in principle all actions addressing pressures on the Baltic Sea serve to improve the state of pelagic and benthic habitats, and importantly also the designation and management of marine protected areas (Figure 7.2). Among biological features, the fewest HELCOM actions are in place for waterbirds. Detailed information on the achievements and ongoing HELCOM activities to realise the agreement of the Baltic Sea Action Plan are included in the 2018 HELCOM report on implementation of the Baltic Sea Action Plan (HELCOM 2018au). HELCOM actions are not limited to concrete measures but include also other types of actions needed to support management towards the goals of the Baltic Sea Action Plan including monitoring, improving the knowledge base, and coming to an agreement on how to assess the state of the Baltic Sea (Figure 7.3). The joint indicators and assessment tools which form the base of this report are one example of the actions that have been worked on by HELCOM technical working groups and expert networks for a number of years.

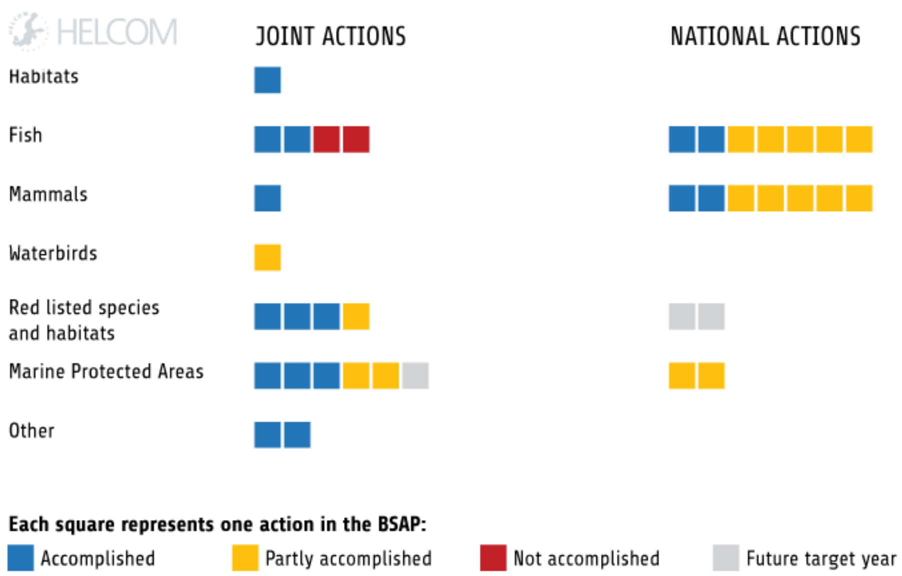


Figure 7.2
Status of implementation of Baltic Sea Action Plan by 2017 – Conservation. Accomplishment of actions agreed under the Baltic Sea Action Plan and HELCOM Ministerial Declarations related the conservation of species and habitats. Joint actions are those implemented together in HELCOM. For actions implemented nationally 'accomplished' signifies that the action has been implemented by all countries, 'partly accomplished' by some but not all countries, and 'not accomplished' that no country has implemented the action. Eight HELCOM actions related to financing and awareness are not included in this presentation.

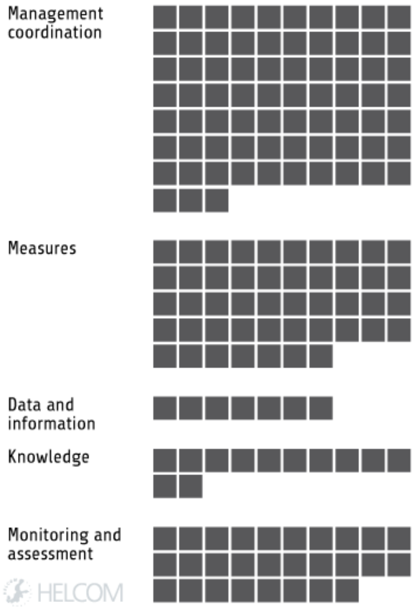


Figure 7.3.
Different types of HELCOM actions. The actions agreed in HELCOM are of various character. 'Measures' refers to actions that directly aim to reduce pressures or improve the state of the environment, through restoration activities for example. 'Management coordination' include development of joint principles for management of the marine environment, such as common management plans, guidelines, assessment tools, and classification systems. 'Monitoring and assessment' includes the development and implementation of monitoring programmes and the production of assessment reports. 'Knowledge' on particular topics is enhanced through targeted reviews and evaluations and the promotion of information sharing for example. Access to 'Data and information' is continuously improved to ensure support for decision making and conducting assessment. Both the follow-up of the implementation of the Baltic Sea Action Plan (HELCOM 2018au) and this report provide information for the Contracting Parties to consider the necessary further steps to reach a good environmental status for the Baltic Sea, as required both by HELCOM and, for those Contracting Parties being EU Member States, by the Marine Strategy Framework Directive.

7.2. Examples of achievements related to the Baltic Sea Action Plan

Eutrophication: Nutrient reduction targets

A key commitment in the Baltic Sea Action Plan is the agreement of reduction targets for input of nutrients, in order to combat the eutrophication of the Baltic Sea. This is the first regional agreement setting concrete Maximum Allowable Inputs to the Baltic Sea based on the best available scientific knowledge and communicating the necessary reductions to the individual coastal countries. The countries have flexibility regarding which measures they choose to utilise to meet their targets as long as they comply with the existing individual requirements and standards. In addition, certain reduction potential has been indicated for transboundary waterborne inputs of phosphorus and nitrogen originating from the upstream countries in the catchment areas as well as airborne nitrogen inputs from non-Contracting Parties and shipping, in line with the polluters-pay principle. HELCOM regularly assesses the progress in reaching the nutrient reduction targets. The achievements differ between countries. For total nitrogen, inputs were reduced to the level below the targets for the sub-basins Bothnian Sea, Danish Straits and Kattegat while, for instance, the phosphorus input to the Baltic Proper is still more than 50 % short of the reduction target (see also Figure 4.1.3).

Hazardous substances: Reduction of pollution hot spots

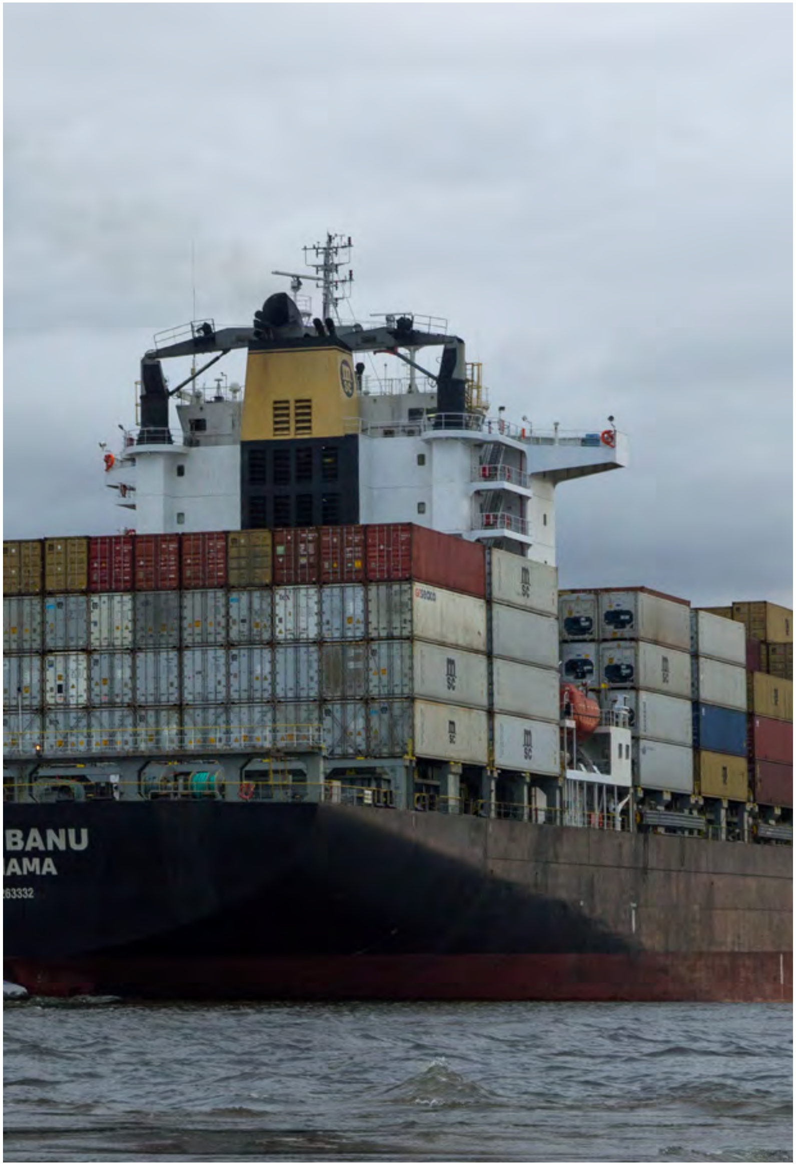
HELCOM's pollution hot spot programme was established in 1992, and resulted in the elimination of 41 industrial hot spots by 2013. The hot spots included sites affected by chemicals, cookery, fertilizer, combustion, food-processing, fish-farming, metal-processing, mining, pulp and paper, oil refinery, and metal smelter industries. While at least three pulp and paper mills and two food processing plants were closed down, the other sites had to comply with the requirements of relevant HELCOM Recommendations to be deleted from the list of hot spots. The status of compliance is evaluated by experts from HELCOM countries. Additionally, many industries are connected to municipal sewerage systems listed as municipal hot spots, out of which 54 were removed from the list by 2018.

The remaining 20 industrial hot spots and 23 municipal or combined municipal and industrial sites have been incorporated to the 2013 Ministerial Declaration, with a target year for deletion of 2016. Of these, one pulp and paper industry site and seven municipal or combined municipal and industrial sites have been removed from the list as of June 2017. Nineteen industrial hot-spots still exist in the Baltic Sea catchment area, including five pulp and paper industry plants, two hazardous waste landfills, a mining waste site, one chemical and one pharmaceutical industry, one power plant, one oil bunkering station, one oil refinery, and six other industries (metal and steel industries, for example).

Maritime activities: Nitrogen oxide emission control

In line with the 2010 HELCOM Ministerial Declaration, HELCOM countries have taken the initiative and prepared the necessary submissions within HELCOM to cut nitrogen oxide emissions from ships. The reduction will be achieved by designating the Baltic Sea as a nitrogen oxide emission control area (NECA) under the International Convention for the Prevention of Pollution from Ships (MARPOL). In 2017, a nitrogen oxide emission control area (NECA) for ships operating in the Baltic Sea and a similar control area in the North Sea were adopted under Annex VI of MARPOL. Both NECAs are expected to result in reduction of 22,000 tonnes of annual total nitrogen deposition to the Baltic Sea region compared to a scenario without Nitrogen oxide emission control areas (EMEP 2016). Out of the foreseen reduction, 7,000 tonnes is anticipated to be cut from direct deposition to the Baltic Sea surface, and the remaining 15,000 tonnes to be cut from deposition to the Baltic Sea catchment area. The NECA regulations are directed to new ships and do not address existing ships. Ships built in or after 2021 will have to use new technology, resulting in circa 80 % lower nitrogen oxide emissions. Hence, a period of fleet renewal for about two decades is expected before the regulation will show the effect described, even if emissions are cut earlier with every new ship. Parallel work to promote green shipping technology and the use of alternative fuels, such as liquefied natural gas, has been undertaken by HELCOM to enable reductions in air pollution from ships sooner.

Container ship in the Gulf of Finland.



Maritime activities: Reduction of sewage from passenger ships

In the Baltic Sea Action Plan, HELCOM countries agreed to develop regulations on ship sewage (covered by Annex IV of MARPOL) and on making a joint submission to the International Maritime Organization. The 2010 submission prepared within HELCOM led to amending Annex IV to enable special areas, and to not be limited to only addressing sanitary concerns of sewage, but also nutrient content. The proposal also led to the designation of the Baltic Sea as a special area.

As a result of the steps taken by HELCOM countries, the Baltic Sea is the first area in the world to receive the status of a special area for sewage from passenger ships, and to have this status adopted by the International Maritime Organization. After sufficient availability of port reception facilities for sewage was confirmed in 2016, the IMO decided that the regulation is to come into effect in June 2021 for all existing passenger ships (registered for twelve or more passengers). After this date, sewage discharges from passenger ships will only be allowed into port reception facilities, or alternatively at sea after treatment with advanced on-board sewage treatment plants which reduces the nutrient content of the sewage. For new passenger ships, the regulations come into effect from June 2019. For direct passages between St Petersburg and the North Sea, there is an extension until 1 June 2023.

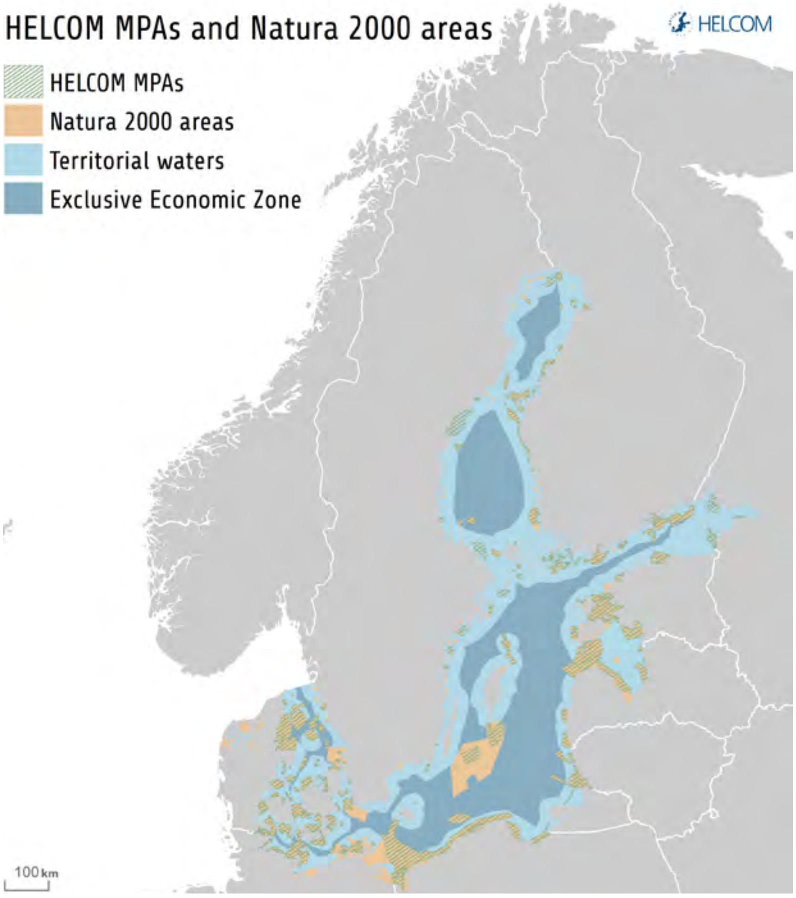


Figure 7.4.
Marine protected areas in the Baltic Sea. The Baltic Sea reached the target of conserving at least 10 % of coastal and marine areas, set by the United Nations Convention on Biological Diversity. Today the area protected by these marine protected areas (MPAs) has reached 12 %.

Biodiversity: Marine protected areas

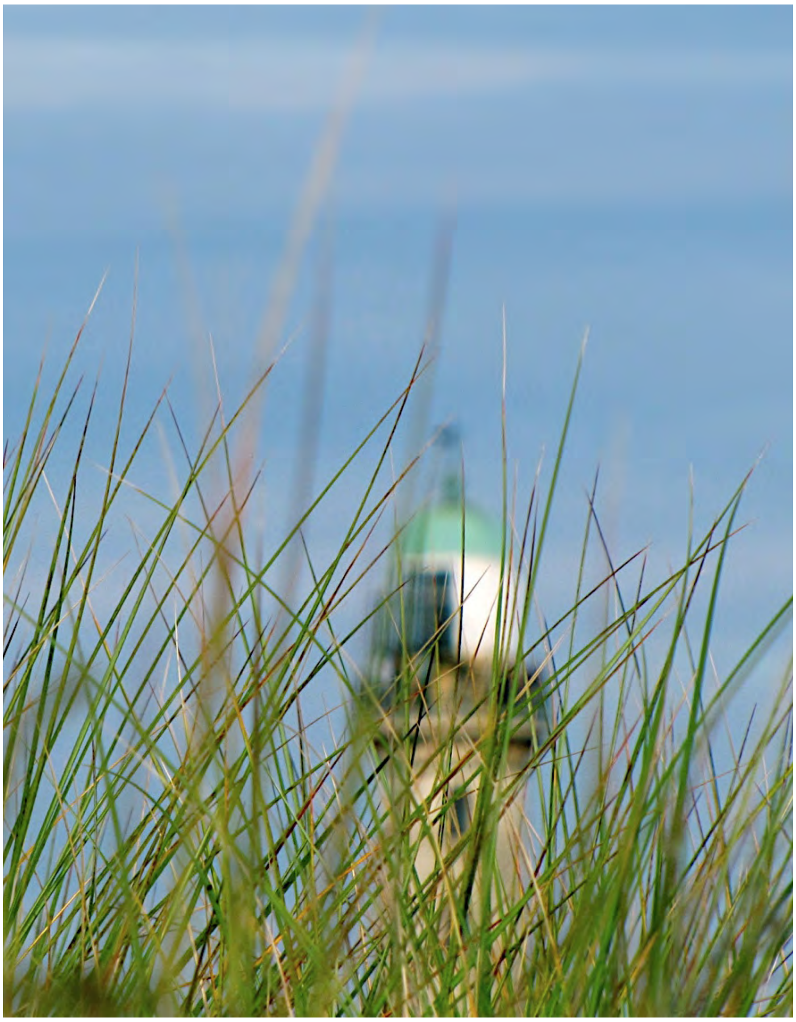
Spatial protection is central to the biodiversity agreements in the Baltic Sea Action Plan, and the designation of marine protected areas has been a key instrument for the protection of biodiversity in the Baltic Sea for more than thirty years. As the first marine region in the world in 2010, the Baltic Sea reached the target of conserving at least 10 % of coastal and marine areas set by the United Nations Convention on Biological Diversity. Today the area protected through marine protected areas has reached 12 % (Figure 7.4). The protection is however not evenly distributed between sub-basins or between coasts and open sea, and the aim remains to reach the target in all offshore sub-basins.

A specific aim for the HELCOM network of marine and coastal Baltic Sea protected areas (HELCOM MPAs) is to be 'ecologically coherent', meaning that a network of protected sites should be designed so that it delivers more benefits than individual areas. The HELCOM assessment of ecological coherence (HELCOM 2016b) showed that two of the evaluated aspects were at an acceptable level for supporting a coherent marine protected area network: the areal representation of different types of broad scale habitats and the replication of a set of indicative species and biotope complexes. However, the evaluation indicated that the connectivity, which measures how well the network supports the migration and dispersal of species is not yet optimised.

Management plans remain to be implemented in about 30 % of the marine protected areas. HELCOM is working towards the development of a method to assess the management effectiveness of HELCOM marine protected areas and the network. Such an assessment will be important to corroborate environmental positive effects and marine protected area management.

8. Conclusions and future outlook

The results in this State of the Baltic Sea report show that the environmental objectives of the Baltic Sea Action Plan are not likely to be reached by 2021. Continued and renewed efforts are needed to further reduce pressures, restore species and habitats to a healthy state, and to reach long term sustainability in the use of Baltic Sea resources. However, progress made so far shows that Baltic Sea regional collaboration gives results. The HELCOM Ministerial meeting of 2018 agreed to strengthen the implementation of the Action Plan and update it by 2021, and committed to enhancing cooperation and coherence among policies for delivering sustainable development goals. Key future collaboration themes for Baltic Sea countries include finalising the achievement of nutrient reduction targets and ending pollution, engaging in cross-sectorial approaches and adapting environmental management to climate change.



This second HELCOM holistic assessment shows that most fish, birds and marine mammals, as well as benthic and pelagic habitats of the Baltic Sea are still not in a healthy state. A deteriorated status is seen in different parts of the food web, comprising species which live in the open water column, in coastal areas, as well as those close to the seafloor. The impact is likely to influence the ecosystems' functioning, the resilience of the food web against further environmental changes and the prospects for socioeconomic benefits. Restoring the habitats of threatened species and improving the network of marine protected areas form an important backbone for improving this situation. In parallel, dedicated actions to reduce pressures are significant.

Major pressures on the Baltic Sea - eutrophication, hazardous substances, introduction of non-indigenous species, and effects of commercial fishing - were all at higher than sustainable levels during 2011-2016. These pressures were also the ones causing the most widespread impacts. Many species are affected by these pressures, and are potentially sensitive to them, directly or indirectly. For example, the effects of eutrophication on oxygen deficiency at the seafloor affect benthic fauna and extend via the Baltic Sea food web to zooplankton, and may ultimately influence food availability for fish, waterbirds and marine mammals.

On the other hand, many other pressures from human activities cause clearly evident effects at smaller spatial scales, such as activities causing loss of habitat or disturbances to the seafloor. Due to the multiple interactions in the ecosystem, many of the biodiversity indicators primarily reflect a response to total environmental pressure, rather than to individual ones. Thus, the roadmap towards healthy species and habitats involves several jointly contributing actions.

Lighthouse near Warnemünde, Germany.

8.1. Key priorities for a healthy Baltic Sea

Achieving nutrient reduction targets and ending pollution

The eutrophication status has changed only marginally since the previous HELCOM holistic assessment (HELCOM 2010a). At least 97 % of the open sea area is still eutrophied, based on an assessment of nutrient levels at sea, water quality and habitats, and about 12 % is assessed as being in the category of poorest eutrophication status. Even though nutrient inputs have been reduced substantially, their accumulation over decades and the long retention time of water in the Baltic Sea extend the time needed for recovery. Furthermore, agreed targets for Maximum Allowable Inputs are still exceeded in six out of seven sub-basins for phosphorus and in four out of seven sub-basins for nitrogen. Not all measures agreed on in the Baltic Sea Action Plan have been implemented yet, and nutrient resources are not optimally managed everywhere, showing that further potential to reduce nutrient input to the Baltic Sea exists.

Reaching the nutrient input reduction targets continues to be a priority in HELCOM work. Enhanced efforts will focus on developing a Baltic regional nutrient recycling strategy, cooperation with the agricultural sector as well as relevant river basin authorities. The key step in addressing nutrients that have accumulated in the seabed is improving the knowledge base on the nature and dynamics of internal nutrient reserves.

Barnacle shells on flotsam washed ashore near Usedom, Germany
@ Pascal Willuhn (CC BY 2.0)

Hazardous substances also remain a problem. Although inputs of some contaminants are decreasing, such as mercury and cadmium, concentrations of hazardous substances are still too high and several pollution hot spots remain. Several new types of substances, including pharmaceuticals, are reaching the sea, for instance through waste-water treatment plants, agricultural and industrial releases. The wide range of sources from which hazardous substances reach the Baltic Sea highlights the importance of coordinated and innovative management to address the causes. Further, increasing evidence on how the widespread use of plastic materials is affecting the sea has resulted in marine litter being identified as one of the priority areas for work in HELCOM.

Enhancing cross-sectorial approaches

The holistic assessment makes clear that several environmental objectives require a combination of measures and can only be achieved by engagement of all sectors impacting on, or being dependent on, the sea. The strong inter-linkages, for example between eutrophication, fisheries management and climate change impact in the Baltic Sea are highlighted here.

Fishing has historically imposed significant environmental impacts on the Baltic Sea. It remains a major pressure on several species, including cod in both the western and the eastern Baltic Sea, and also leads to associated food web impacts. At the same time, opportunities for fishing are dependent on having a good environmental status, as fish require suitable habitats and feeding conditions. Local fisheries are affected by decreasing fish resources, but also by conflict of interest with seals and certain sea birds. In addition, most Baltic Sea fish communities today are dominated by small-sized fish in comparison to historical records, suggesting that the fishable biomass could be considerably larger.

The impacts of fishing interact with those of eutrophication and other pressures. Numbers of large predatory fish have declined due to a combination of poor environmental conditions and high fishing pressure (for some stocks over recommended levels) whereas smaller prey species, such as herring and sprat, dominate the pelagic food web. The reduced role of predatory fish decreases ecosystem resilience, and reduces the natural resistance of the ecosystem, against the establishment of non-indigenous species for example, or the increase in species that benefit from eutrophication. Another case is the highly threatened European eel, which is affected by activities at sea, including fishing, but for which some land-based activities, such as the damming of migration routes in rivers, are a significant source of mortality.

Due to the ecosystem connections, coordinated management among sectors to mitigate and reduce environmental risks is required, to bring mutual benefits and support recovery of species and habitats. Looking both inside and outside of the Baltic Sea region, the benefits for the Baltic Sea of collaboration among countries, institutions and private initiatives are evident.

At the HELCOM Ministerial Meeting of 2018, HELCOM countries and the EU committed to a number of actions to enhance cooperation, policy coherence and coordination, in particular between marine environment, land-based activities, fisheries management measures, and maritime spatial planning (HELCOM 2018av). Baltic Sea countries will also work together in the implementation of the Ballast water management convention of the International Maritime Organization and will strengthen cooperation on ship hull fouling solutions, to prevent the introduction of non-indigenous species, and lower the use of hazardous substances in anti-fouling systems.

Adapting to climate change

Effects of climate changes are already evident in the Baltic Sea, and global warming is expected to lead to further hydrological changes in the near future. Most species in the Baltic Sea have their distribution limited by temperature and salinity conditions, and climate-related changes may lead to a considerable change in the occurrence of species. For example, a decrease in marine species is expected if salinity levels decrease further. Other projected changes include acidification, increased sea level, decreasing ice cover extent, and changed precipitation patterns, leading to altered composition of nutrients, and interactions with other pressures.

The climate-related changes should be considered in all aspects of management. For example, global warming is expected to amplify low levels of oxygen near the seabed, hence exacerbating eutrophication effects, and to affect the prospects for long-term sustainable resource use via effects on food web productivity. Meeting the nutrient reduction targets of HELCOM is important for mitigating these impacts.

Although many climate-related aspects call for further research and understanding, the vast existing knowledge can already be used in the planning of measures. Foreseen climate change impacts will be taken into account when updating the HELCOM Baltic Sea Action Plan. Priority areas include accounting for interactions between eutrophication and climate effects, strengthening the network of protected areas, and adhering to the United Nations Framework Convention on Climate Change and Paris Agreement for minimising further adverse effects. HELCOM will also work towards a better understanding of the role of the Baltic Sea in the global carbon cycle.

8.2. Are we moving in the right direction?

The results of the holistic assessment reflect that several HELCOM action areas lag behind in implementation, and only three years remain to reach the deadline of 2021 for the Baltic Sea Action Plan. However, we should also recall what the state the Baltic Sea environment could have looked like without the currently existing regional agreements. As a results of these, for example, we see that inputs of nutrients and several hazardous substances are decreasing, as well as the number and volume of illegal oil spills, and that several previously prevailing pollution hot spots have been removed.

Still, why is the status of the environment not better at this point? Many key pressures from human activities have been acting on the Baltic Sea during recent decades. Legacies such as nutrients and contaminants accumulated in sediments are buried only slowly and will still show unacceptable levels in the marine environment long after their inputs have ceased. Ecosystem models show that responses to nutrient reductions act on the time scale of decades, but that responses are underway and implementation of the eutrophication objectives of the Baltic Sea Action Plan will lead to an improved marine ecosystem. In addition, some measures are very recent, such as the designation of the Baltic Sea as a nitrogen oxide emission control area for shipping, and the entry into force of the Ballast water management convention, but benefits are expected in the near future.

The sufficiency of existing measures to improve the status of the marine environment has not yet been fully evaluated. This is partly due to knowledge gaps, and partly due to changes in the intensity and character of different pressures along with human development, highlighting the importance of regular follow-up on the implementation of actions and adapting policies based on the newest scientific knowledge.

The HELCOM 2018 Ministerial Meeting has given a mandate to Contracting Parties to update the Baltic Sea Action Plan by 2021 so that good environmental status can be reached, encompassing HELCOM's strategic goals and ecological objectives, and relevant ocean and water targets of the 2030 Agenda for Sustainable Development (HELCOM 2018av). The accomplishments of the 2007 Baltic Sea Action Plan and the three follow-up Ministerial Declaration commitments will be used as a basis for the update (HELCOM 2007, 2010b, 2013a, 2018av). In the next step, HELCOM will carry out an analysis of sufficiency of measures to reach HELCOM objectives and targets, in support of the selection of new joint and national actions. Transdisciplinary development of regional

- business-as-usual scenarios could help identify important management priorities when updating the HELCOM Baltic Sea Action Plan. The work would include foreseen ecological and socioeconomic development and different climate and global development scenarios, and consider management actions.

The holistic assessment and future HELCOM policy

The holistic assessment will underpin HELCOM policy also in the future. The State of the Baltic Sea report gives a comprehensive data-based assessment at Baltic Sea scale, covering or approaching the main themes to be considered in an ecosystem approach. The report summarises a significant improvement to regional monitoring and assessment since the implementation of the Baltic Sea Action Plan, and covers more aspects than ever seen before in the region (Box 8.1)

The report will provide a basis for identifying new actions in the updated Baltic Sea Action Plan. Additionally, the report has also been prepared in order to support EU countries within HELCOM in meeting the requirements of the EU Marine Strategy Framework Directive. The results may also contribute to global assessments, such as the second World Ocean Assessment, and support national and regional commitments towards the United Nations sustainable development goals. Agenda 2030 provides a global framework for this move, and HELCOM and Baltic Sea regional environmental work can provide one case study on how transnational environmental challenges can be tackled.

Box 8.1.
Achievements of the assessment

Over 30 indicators form the basis for the status assessment, reflecting key aspects of the health of the Baltic Sea ecosystem and providing a quantitative basis for status evaluation and management agreements. HELCOM will continue developing indicators for the purpose of assessment and policy evaluation for the next holistic assessment.

The HELCOM Integrated assessment tools for eutrophication, hazardous substances and biodiversity have been advanced for this assessment, and will be used and developed further in the future.

The assessment of cumulative impacts, using the Baltic Sea Impact Index, has improved considerably since its first regional use (HELCOM 2010a). 96 spatial data sets representing human activities, pressures and ecosystems components have been produced, and all the results are available for further use, including in maritime spatial planning.

The State of the Baltic Sea report has taken steps to further develop socio-economic aspects within the assessment framework, integrating the human aspect and providing a better basis for understanding benefits of environmental management. The coordinated regional economic and social assessments will be continued in HELCOM and developed to include mapping, valuation, and analysis of ecosystem services and natural capital accounting, taking advantage of improved methods and comparability of data.

Sunset in the Bothnian Bay near Isoniemi, Finland.

8.3. What does the future hold for the Baltic Sea?

The Baltic Sea region will be increasingly challenged by changes in climate, demography, and increasing demands for land use, food and energy provision in the catchment area. Looking at the cost of inaction, achieving a healthy Baltic Sea should be seen as an investment in the region's sustainable economic and social development.

The ability of societies around the Baltic Sea and its catchment to adapt to environmentally sustainable living is a key factor at all levels of governance. Opportunities for the Baltic Sea region are seen in knowledge and education, forming a basis for further ecological understanding, technical and social innovation, and a continued tradition for knowledge sharing, cooperation and interaction among institutes, organisations and local initiatives around the Baltic Sea, contributing to sustainable human activities and achieving a healthy Baltic Sea environment.

The process to develop the second HELCOM holistic assessment has contributed to a vast sharing and development of knowledge on the state of the Baltic Sea environment. There is a clearer picture than ever before of where we are, how things are connected, and what still needs to be done. The key aim for the future is to incorporate this new knowledge in the ecosystem-based management of the Baltic Sea, as well as into national, regional and global measures towards a sustainable future.

A peaceful Bothnian Sea.
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