4. What is impacting the status? How can we protect and restore the Baltic Sea and its biodiversity?

4.1. Pressures, types of measures and regulations

Measures to improve the Baltic Sea environment are implemented at many levels, from the subregional to the global. Nationally and at more local levels, people around the Baltic Sea carry out important work and take action to reduce pressures, conserve biodiversity or restore degraded ecosystems. The work is relevant to a range of initiatives, from the local scale to global agreements. Regional coordination in HELCOM helps identify key priorities for the Baltic Sea environment and identify actions that benefit from or require regional coordination in order to have the necessary effect.

The segments of the Baltic Sea Action Plan (BSAP) seek to reflect a combination of pressures that both stem from activities on land and relate to activities at sea (HELCOM 2021a). They identify regionally agreed steps required for HELCOM countries to reach shared objectives. Central goals related to the management of human activities and pressures in the plan are:

— *A Baltic Sea unaffected by hazardous substances and litter*

— *Environmentally sustainable sea-based activities*

— *A Baltic Sea unaffected by eutrophication*

Progress towards our shared vision for a healthy Baltic Sea ecosystem relies upon the successful implementation of actions included under all of the pressure-related BSAP segments. Furthermore, the three segments support each other: The interconnectedness of life in aquatic systems means that progress along any segment benefits the other segments, moving towards the same shared objectives.

The updated status assessment results for 2016-2021 highlight the significance of this work. Nutrient loads are decreasing, but most of the Baltic Sea is still affected by eutrophication, which is a key driver of ecosystem changes in many areas. Concentrations of certain hazardous substances are declining because of measures taken, but there are elevated levels of several contaminants, and there is a vast number of emerging substances of potential concern. Overfishing has had widespread impacts on fish stocks in pelagic, demersal and coastal systems, and it has also led to changes in the overall structure and function of the food web. Other pressures affecting the Baltic Sea environment include, inter alia, the introduction of non-indigenous species, marine litter, underwater noise, seafloor loss or disturbance, and the unintentional by-catch of birds and marine mammals. Stopping or reducing the negative impact of all of these pressures arecritical steps to reach a healthy Baltic Sea.

This chapter briefly presents the assessment results regarding pollution-related pressures (eutrophication, hazardous substances, marine litter, non-indigenous species and underwater noise), as well as pressures at sea (related to the extraction of fish, unintentional by-catch of marine mammals and birds, and seafloor loss and disturbance). In addition, the progress of work in HELCOM to develop marine protection and restoration is presented. All results are presented in summary, together with their main points of connection to species or habitats, climate change and the management objectives of the Baltic Sea Action Plan. Assessment results in full detail are presented in the respective thematic assessment reports (HELCOM 2023a-e).

4.2. Pollution

Pollution refers to pressures that spread through the marine ecosystem, where they can have major and widespread impacts. Eutrophication, hazardous substances, marine litter, underwater noise and the introduction of non-indigenous species add to the pressures exerted on the Baltic Sea ecosystem (Figure 4.4 and Box 4.1). These pressures originate from societal and economic activities, both terrestrial and maritime. For most of these pressures, reaching sustainable levels in the Baltic Sea is ultimately dependent on successful actions to restrict and limit their initial inputs, as subsequent remedial action is generally problematic, costly or impossible.

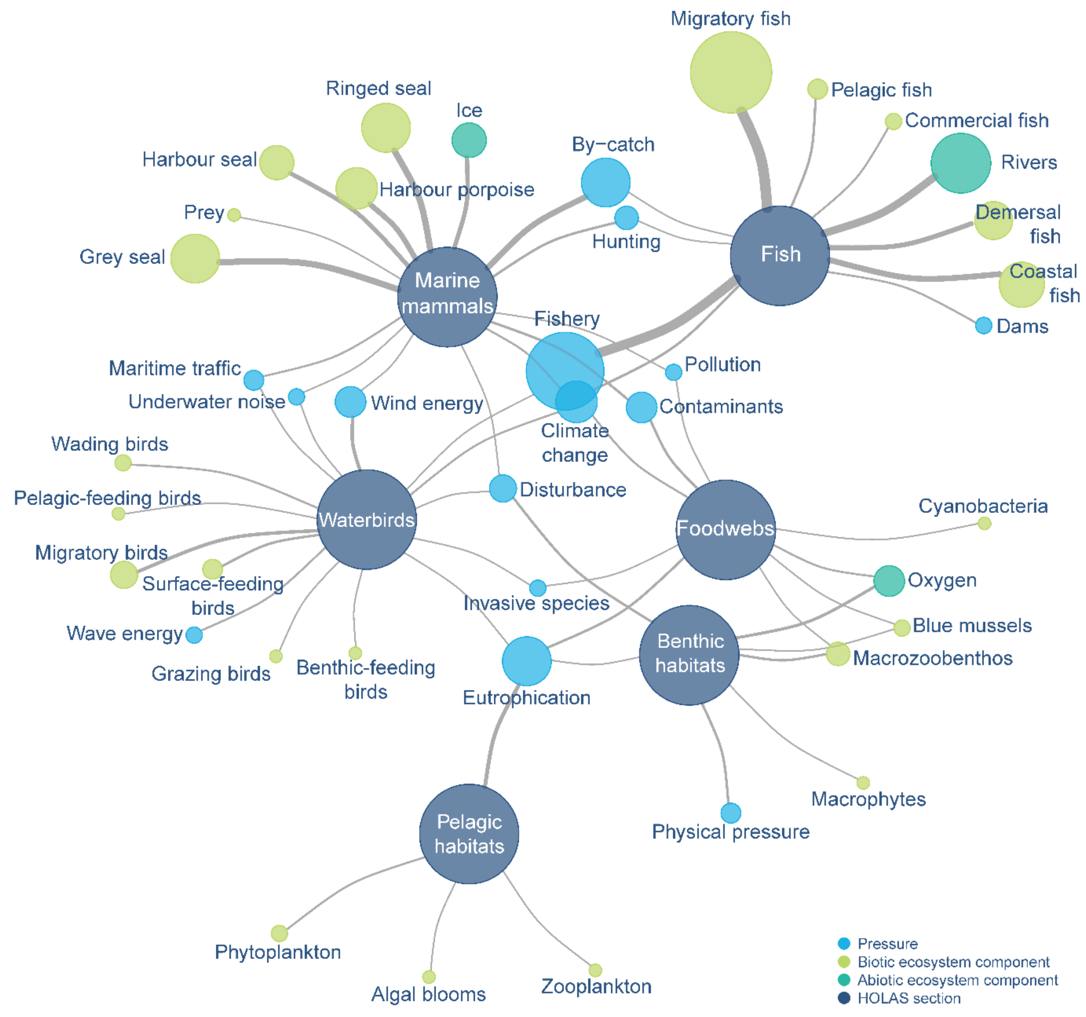

Figure 4.1. An overview of how the different ecosystem components mentioned in Chapter 3 are descriptively linked to different pressures, based on the HOLAS3 thematic assessment report on biodiversity (HELCOM 2023a). Each chapter in the thematic assessment is symbolised by a dark blue circle, and the other circles reflect the key elements (terms) used. The size of each circle loosely reflects how often the term is mentioned and should only be interpreted in this way. Similar terms are aggregated, so each circle includes both the term itself and all terms deemed to be synonymous (e.g. "eutrophication" includes "eutrophication" and associated terms such as "nutrient input" or "concentrations"). The width and length of the lines and the placement of the items is arbitrary. The image provides a simple visual representation of the topics and links covered, while simultaneously providing a gap analysis of where more information may be required in the future to increase the holistic nature of the evaluation (e.g. if the interaction between a certain pressure and an ecosystem component has not been well addressed). The overview was made using igraph.

Figure 4.2. Pollution enters the Baltic Sea from a mix of sources, including direct point sources, freshwater discharges, rivers and the atmosphere.

BOX 4.1.

The HELCOM thematic assessments of eutrophication, hazardous substances and other pollution

The HELCOM thematic assessment of eutrophication in 2016-2021 (HELCOM 2023b) addresses eutrophication in the Baltic Sea. It provides status assessment results for eutrophication indicators and their trends, as well as integrated assessment results using the HELCOM eutrophication assessment tool, HEAT. The results of the assessments are presented in summary in the current report and are given in full detail in the thematic assessment and its associated indicator fact sheets, which also describe the methods used.

The HELCOM thematic assessment of hazardous substances, marine litter, underwater noise and non-indigenous species in 2016-2021 (HELCOM 2023c) addresses other pollution-related pressures, and provides detailed assessment results and method descriptions for these topics. In addition to results based on the integrated HELCOM assessment tool CHASE (for hazardous substances), the report gives summaries of available indicator evaluations and descriptive knowledge of relevance. It also suggests various ways in which HELCOM assessments could be further improved in the future for the covered topics. For hazardous substances, the current assessments do not address all relevant policy requirements or cover all relevant ecological aspects. While a strong evaluation can be made based on the relatively few well-studied and well-monitored hazardous substances currently included in the assessment, there is a vast array of hazardous or potentially hazardous substances for which we have little information about their presence in the marine environment or their impacts.

The topics addressed in both reports are directly and primarily linked to human activities and have the potential to exert significant pressures on the Baltic Sea marine environment. They share the characteristic that the most effective way to address them is to prevent or limit their initial inputs. Once these pressures are in the marine environment, alleviating or remediating them is often very complex, difficult and costly compared with acting earlier. Different pressures have different scales of impact, but all cause or could cause significant negative effects on the ecosystem, and addressing all of them is of high importance for achieving our aim of a healthy Baltic Sea environment.

4.2.1 Eutrophication

The integrated assessment of eutrophication status shows that eutrophication is still a major problem in the Baltic Sea (Figure 4.3). There were no clear signs of recovery during 2016-2021 compared to the previous assessment period. Excess nutrient inputs to the marine environment increases phytoplankton development, which reduces light levels in the water, contributes to depleting oxygen reserves at the bottom, and triggers a series of other ecosystem changes (Box 4.2).

Inputs of nutrients to the Baltic Sea have decreased significantly but the target for maximum allowable inputs has not yet been achieved in all basins (Figures 4.4-4.5). For the whole Baltic Sea, the normalized total input of nitrogen was reduced by 12% and phosphorus by 28% between the reference period (1997-2003) and 2020 (HELCOM 2023f). The maximum allowable input (MAI) target for nitrogen was fulfilled in the Bothnian Bay, Bothnian Sea, Danish Straits and Kattegat. For the Baltic Proper and the Gulf of Finland, the MAI was exceeded, and results for the Gulf of Riga were statistically uncertain. The target for phosphorus was fulfilled in the Bothnian Bay, Bothnian Sea, Danish Straits and Kattegat. In the remaining sub-basins, the MAI was exceeded also for phosphorus.

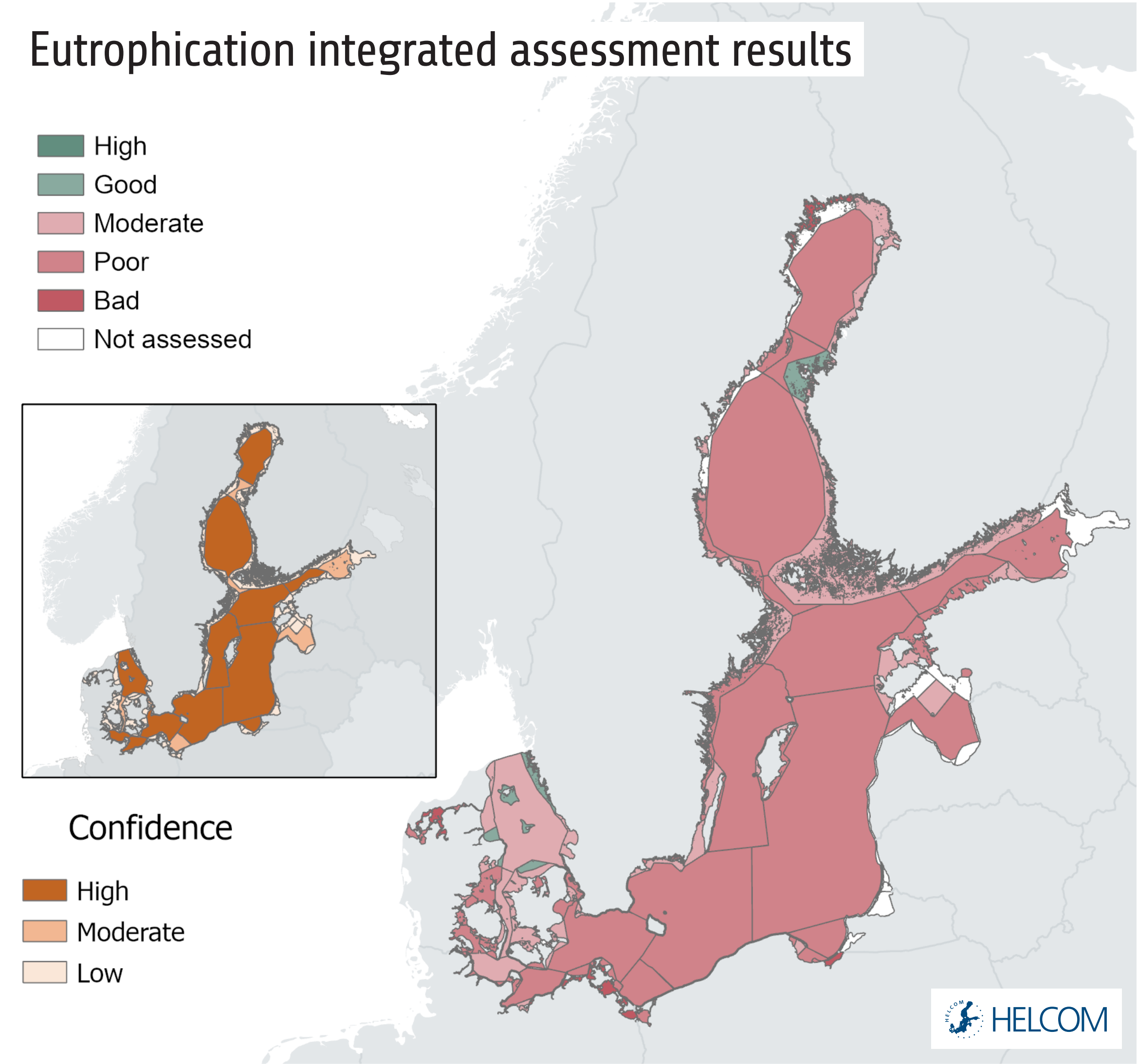

Figure 4.3. Summary of assessment results from the assessment of eutrophication. Source: HELCOM 2023b.

BOX 4.2.

What is eutrophication?

Eutrophication comes from the excessive input of nutrients into the marine system, leading to an increased supply of organic matter. Primary production by algae, plants and cyanobacteria is a key process at the base of the food web, providing energy for organisms higher in the food web. This primary production depends on the availability of nutrients, in particular nitrogen and phosphorus, but too high nutrient levels enhance primary production beyond what grazers in the food web can consume. Early symptoms of eutrophication are increased concentrations of chlorophyll in the water column and the growth of opportunistic algae. These lead to reduced water clarity and increased deposition of organic material to the seabed, which in turn increases oxygen consumption and may cause oxygen depletion. Long-lasting eutrophication can cause changes in species composition, when species that benefit from eutrophic conditions are favoured directly or through food web interactions, and vice versa.

The Baltic Sea Action Plan states the following ecological objective concerning eutrophication:

— A Baltic Sea unaffected by eutrophication

Countries around the Baltic Sea have a long-term commitment to reduce eutrophication in the Baltic Sea. A central tool is the Maximum Allowable Input, which gives the maximal inputs of waterborne and airborne nitrogen and phosphorus that can be allowed to Baltic Sea sub-basins while still achieving good status in terms of eutrophication.

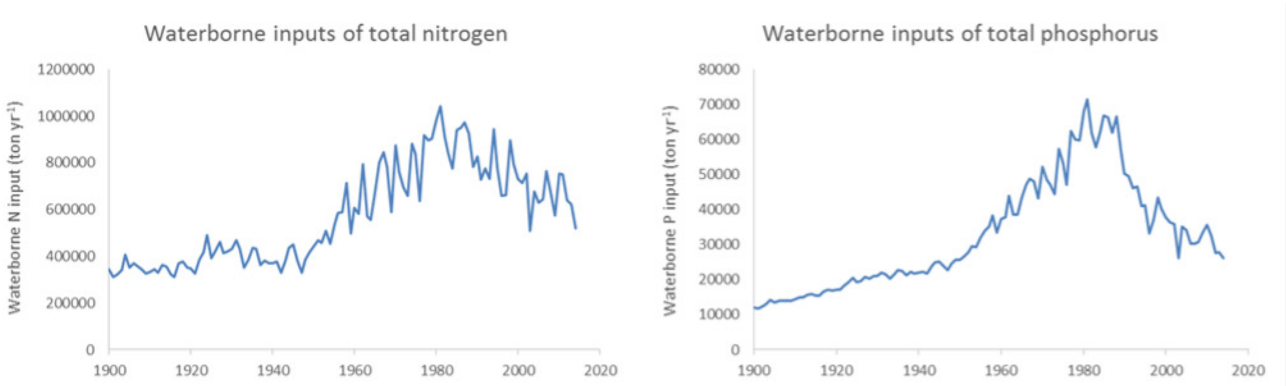

Figure 4.4. Temporal development of waterborne inputs of total nitrogen (left) and total phosphorus (right) to the Baltic Sea Source: HELCOM 2023b.

Figure 4.5. Inputs of nitrogen (left) and phosphorus (right) to the Baltic Sea sub-basins, as these are defined in the HELCOM pollution load compilation. BAS=whole Baltic Sea. The columns show trend-based estimates of total nitrogen and phosphorus inputs in 2020, in tons per year and including statistical uncertainty. The short blue lines show the maximum allowable inputs (MAI). Green indicates that the estimated inputs, including uncertainty, were lower than MAI, while red indicates that they exceeded MAI. Yellow indicates that the statistical uncertainty of the input data makes it not possible to determine whether MAI was fulfilled. Note that the scale of the y-axis differs between charts. Source: HELCOM 2023f.

Impacts of eutrophication in the Baltic Sea ecosystem

Eutrophication initially affects primary producers, and processes in the pelagic system are of key importance for how eutrophication symptoms develop. Widespread and lasting eutrophication can impair ecosystem functions through a combination of direct and indirect impacts on aspects such as species composition, food web dynamics and oxygen conditions (Carstensen *et al.* 2014). These impacts can have widespread effects across a broad range of habitats and species. In the Baltic Sea, eutrophication has been associated with changes in species composition in several key trophic groups, including primary producers, benthic fauna, coastal fish and sea birds. Over time, eutrophication has become a key driver of changes in the trophic state of the Baltic Sea ecosystem. The Baltic Sea has transformed from being a typical low productivity system in the 1920s to a high productivity system today, with the presence of insufficient oxygen conditions becoming a key mechanism and cause for concern (Tomczak *et al.* 2022, Rolff *et al.* 2022).

Eutrophication causes multiple adverse economic and societal effects. Factors such as decreased water clarity, more frequent cyanobacterial blooms, oxygen deficiency in bottom waters, changes in fish stocks and loss of marine biodiversity all decrease the environmental benefits from the Baltic Sea in terms of both use-related values and non-use values (Ahtiainen *et al.* 2016). Examples include increased costs of cleaning, reduced income from tourism, damage to fishing gear and lost fishing possibilities, increased travel costs to reach unaffected areas, and reduced cultural and historical values. Reaching good eutrophication status for the Baltic Sea is foreseen to increase human well-being significantly and bring economic benefits to society.

Sources of nutrient inputs

The majority of nutrient inputs to the Baltic Sea originate from human activities on land and at sea. Waterborne inputs enter via rivers and direct discharge from coastal areas. The main point sources of waterborne inputs are wastewater treatment plants (Figure 4.6), industries and aquaculture. The main diffuse sources are agriculture, managed forestry, scattered dwellings and storm water overflows. In addition, natural background sources contribute to the input.

The main sectors contributing to atmospheric inputs are energy production (combustion) and industry, as well as the transportation of oxidized nitrogen, and agriculture is also a source of reduced nitrogen. A large portion of the atmospheric inputs originate from sources outside the Baltic Sea region. Emissions from shipping in the Baltic and North Seas contribute significantly to atmospheric inputs of nitrogen.

Excess nutrients stored in bottom sediments can re-enter the water column and again enhance primary production. In oxygen-depleted areas, phosphorus can leak out and be used by cyanobacteria that can make use of inert nitrogen. Other habitats have a strong capacity to store and sequester nutrients, such as coastal habitats with rooted plants and long-lived macroalgae (HELCOM 2023d).

Regulations and needs

Minimizing the input of nutrients from human activities is a central management objective of the Baltic Sea Action Plan.

Regional targets for nutrient inputs are defined by the Maximum Allowable Inputs (MAI) and Nutrient Input Ceilings (NIC) in the Baltic Sea Action Plan. Fulfilling these targets for all sub-basins is a key prerequisite for achieving a Baltic Sea unaffected by eutrophication.

Reducing the agreed levels of nutrient inputs is expected to improve eutrophication status at sea, even though the responses at sea may take time (HELCOM ACTION 2021a). Model simulations indicate that significant improvements in eutrophication status can be expected roughly one or two decades after nutrient inputs are reduced to the target levels, and that it could take half a century or more to reach the environmental objectives. In coastal areas, the responses could be faster, if significant direct point sources are removed. This is probably also the case in the eastern part of the Gulf of Finland (HELCOM 2023f).

Measures to restore the natural functioning of Baltic Sea food webs are expected to enhance the natural capacity of the ecosystem to counterbalance eutrophication symptoms. Strengthening trophic control in the food web can curtail the overproduction of fast-growing filamentous algae, for example (see section 3.3).

Measures to strengthen coastal habitats with a strong capacity for nutrient uptake and storage, such as rooted plants and long-lived macroalgae, are expected to strengthen the ecosystem's natural capacity to sequester nutrients at sea.

Climate change is expected to worsen the negative impacts of eutrophication. Climate change effects could enhance algal blooms or oxygen consumption, for example.

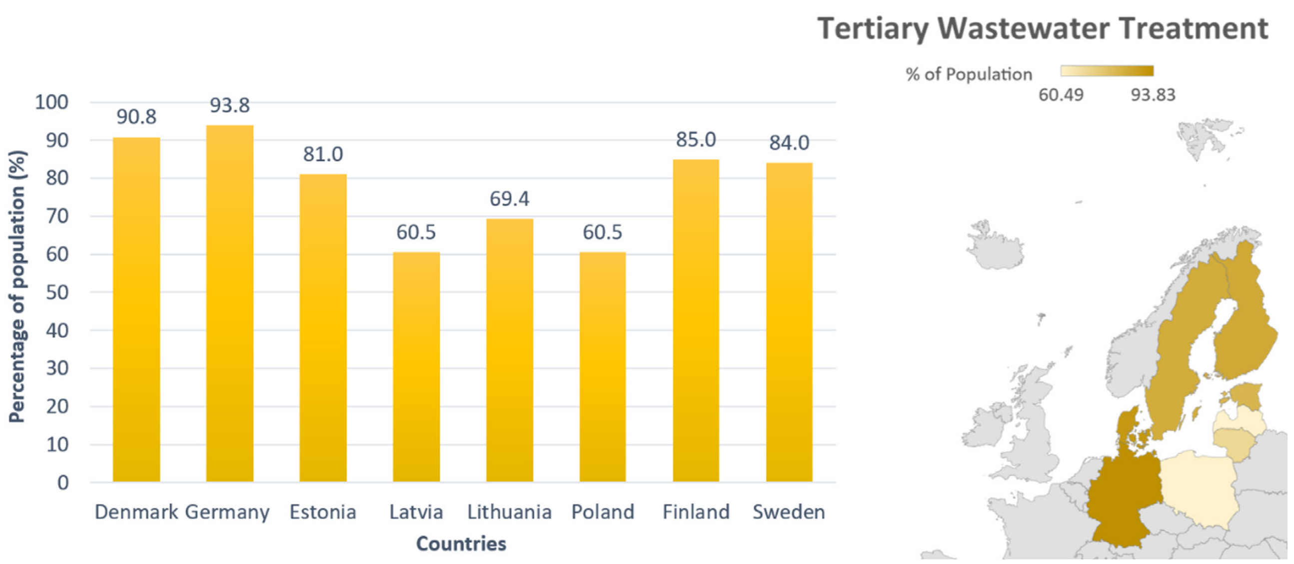

Figure 4.6. Various drivers determine the extent and efficiency of wastewater treatment in the Baltic Sea region, including political will, investment, regulations and the adoption of technology. Overall, 72% of the Baltic Sea catchment area population is connected to tertiary wastewater treatment plants (Eurostat 2022). The bar charts show the percentage of the total population connected to tertiary wastewater treatment plants in Baltic Sea countries in 2020. The chart does not include data from Russia or any non-HELCOM countries. Source: HELCOM 2023d.

4.2.2 Hazardous substances

The status of hazardous substances shows some signs of improvement during the assessment period, however it is still clearly not good (Figure 4.7). The integrated contamination status of the Baltic Sea remained above acceptable minimum levels during 2016-2021. The contamination status was assessed as either bad or poor in roughly 80% of the 57 assessed spatial units, including the majority of the open sea sub-basins. Only one assessment unit in the open sea had good status. The results partly reflect the prevailing monitoring regimes, because units achieving better status tend to be represented by fewer parameters being evaluated or key drivers of the overall status being absent.

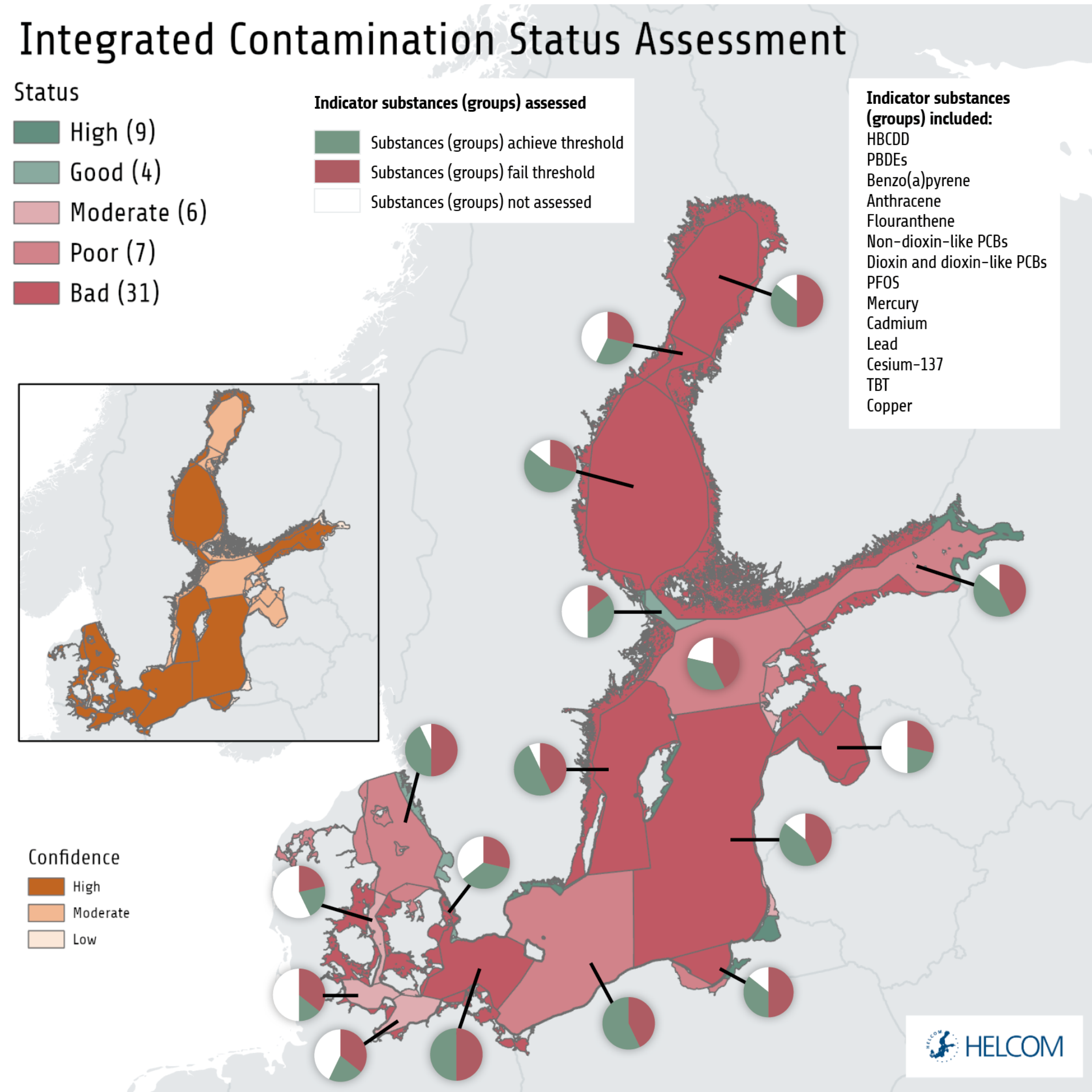

Figure 4.7. The integrated assessment of hazardous substances status in the Baltic Sea, assessed using the CHASE integrated assessment tool. The assessment shows that hazardous substances are a cause for concern in almost all assessed units, and those showing good status generally lack a full and adequate assessment. The integrated assessment is based on 11 core indicators. It integrates concentrations to threshold-derived values (contamination ratios) for fourteen individual hazardous substances or substance groups. The overall assessment is moderated by a parallel assessment of confidence (see inset map on the left) that can be considered an appraisal of the data coverage and assessment quality in any given assessment unit. Source: HELCOM 2023c.

Furthermore, only a small fraction of all potentially hazardous substances is measured and included in the indicator evaluations that make up the integrated assessment (Box 4.3).

There are some encouraging signs, however. Six open sea sub-basins have improved their status category since the previous assessment (HELCOM 2018), although they are still not in good status. Furthermore, at the level of individual monitoring stations, there are more substances with downward concentration trends than upward trends (Figure 4.8).

The assessment results are mostly driven by elevated concentrations of polybrominated diphenyl ethers (PBDEs) in biota, tributyltin (TBT) in sediments, mercury in biota, and copper in sediments. Cadmium concentrations in biota and sediments also contribute, as do lead concentrations in biota (Figure 4.9).

Monitoring and assessment currently focus on a relatively small number of priority substances which are known to have persistent and widespread negative impacts on the Baltic Sea environment. Work to address additional substances and develop a regional strategy for hazardous substances (towards BSAP action HL1) are ongoing in HELCOM. A pilot assessment shows that approaches to detect the biological effects of contaminants (signatures of exposure) and screening a wide array of substances could complement existing methods. An initial regional screening listed roughly 130 substances that regularly occur across the region, of which around 40 exceeded available environmental risk values. These substances include, for example, pharmaceuticals, industrial chemicals, personal-care products and tobacco/coffee-related contaminants, and they may require dedicated follow-up actions.

BOX 4.3.

What are hazardous substances?

Hazardous substances are synthetic or natural substances that enter the Baltic Sea at elevated concentrations because of human activities and can cause various types of damage to species and habitats in the ecosystem. Hazardous substances range from those that are highly visible in the form of oil-spills to others that can remain unnoticed until signs of detrimental impacts on the ecosystem or organisms become apparent. Many contaminants degrade slowly, and their impacts can magnify as they accumulate within aquatic food webs. Because hazardous substances are difficult or impossible to remove once they are in the system, the key measure is to limit the risk of their entry into the environment.

The Baltic Sea Action Plan has the following ecological objectives for hazardous substances:

- **Marine life is healthy**
- **Concentrations of hazardous substances are close to natural levels**
- **All sea food is safe to eat**
- **Minimal risk to humans and the environment from radioactivity**

Impacts of hazardous substances in the Baltic Sea ecosystem

Hazardous substances can have both direct and indirect harmful impacts on species, habitats, and the environment as a whole, and they remain among the most widespread and impactful pressures in the Baltic Sea today (HELCOM 2023c). Hazardous substances are often persistent, bioaccumulative and toxic. They affect the function or viability of biota when they occur at concentrations above safe limits. Many hazardous substances have the potential to interfere with biota even at very low levels. Furthermore, impacts from several contaminants can occur together (multiple mixture effects) or can coincide with other types of pressure, potentially enhancing and increasing the susceptibility of the system. Examples of impacts range from acute pollution events, such as oil spills to the slow accumulation of hazardous substances in top predators via biomagnification in the food web. Hazardous substances also affect the suitability of fish as food for humans and other animals.

Clear examples of hazardous substance leading to reproductive failure occurred recently in the history of the Baltic Sea. Widespread use of persistent organochlorines, such as DDT and PCBs, until the 1980s resulted in their spread into the Baltic Sea environment. They accumulated in the food web and severely reduced the fertility and population growth of ringed and grey seals, as well as the white-tailed eagle, all top predators in Baltic Sea food webs (Helle 1980, Helle *et al.* 1976, Bergmann 1999, Helander *et al.* 2008). There are also indications of a link between elevated organochlorine concentrations and lower pregnancy rates in harbour porpoises (Murphy *et al.* 2010). At the point when impacts are detected on top predators, such as marine mammals, the road to recovery is often long and complex. However, because certain persistent chemicals accumulate in the food web, new emerging pollutants that are below detection limits in other biota may be detected in the tissues of top predators, giving an early warning signal.

Sources of hazardous substances

Hazardous substances enter the Baltic Sea through various pathways. Key sources of hazardous substances include wastewater treatment plants, rivers, atmospheric deposition, redispersal of substances from dredged material (or other dumped material, such as dumped munitions) and discharge from maritime activities. Certain direct inputs also occur (or have occurred), such as in relation to biofouling treatment using TBT or copper. More examples are presented in the HELCOM (2023c).

Wastewater treatment plants are a key point source of contaminants to the Baltic Sea. Households and industries in the Baltic

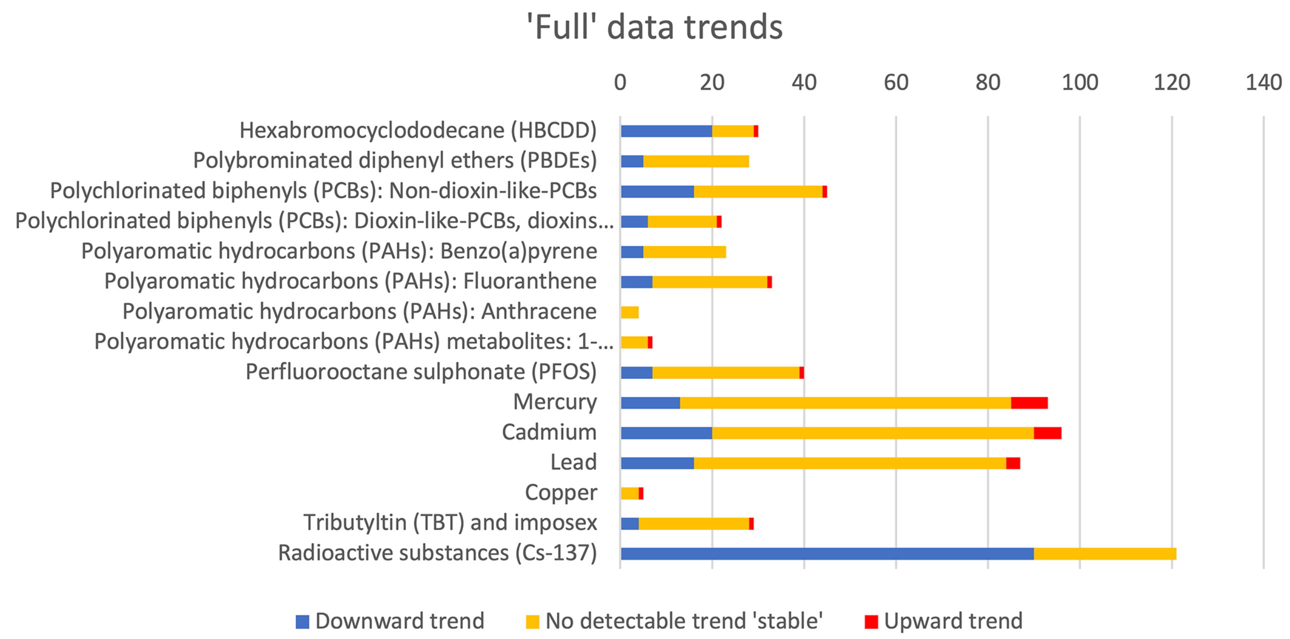

Figure 4.8. Trends in indicator substances or substance groups based on stations where "full" data series were available (i.e. longer-term data series with more than three years of data). The number of stations with suitable time series data available (horizontal axis) is divided into trend categories. Downward trends reflect a decrease in concentrations (i.e. improving status), whereas the opposite is true for upward trends, and other stations show no detectable trend ("stable" concentrations). Source: HELCOM 2023c.

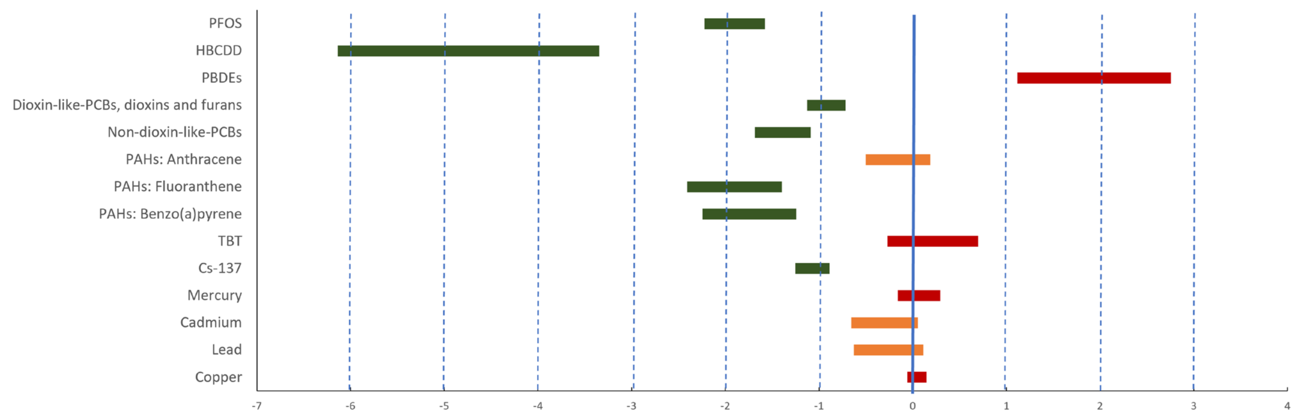

Figure 4.9. The range of contamination ratios of the evaluated hazardous substances. The ratios are the observed concentration value divided by the threshold value, based on the mean concentrations for the assessment period 2016–2021. The horizontal bars show the range of contamination ratios from the 20th to 75th percentile for each substance on a log-transformed scale. Red bars indicate that the median value fails the threshold value, which is indicated by the solid blue line. Orange bars represent a situation where the median value achieves the threshold value but not some of the stations (in the 75th percentile). The figure is based on the coastal and open sea data used in the integrated assessment. Source: HELCOM 2023c.

Sea catchment area are generally well connected to wastewater treatment systems, which results in a large number of hazardous or potentially hazardous substances occurring at elevated concentrations in their sludge and effluent. Some substances are depleted or transformed in the wastewater treatment process, while others remain relatively unaffected (HELCOM 2021). Phenolic substances appear to be frequently occurring, based on available measurements, although they generally are at levels below current environmental quality standards. Polyfluoroalkyl substances (PFASs), in particular PFOS and PFOA, are detected regularly, and many are not removed. Pharmaceuticals have also been shown to remain relatively unaffected by wastewater treatment processes, and levels exceed current environmental quality standards (HELCOM 2021).

Information on riverine and atmospheric sources are available for a few selected priority substances (HELCOM 2021). Data for the period 2015-2017 suggest that inputs of cadmium come mainly through rivers, while mercury and lead are predominantly introduced through atmospheric deposition. The total amount of input differs markedly between the substances, with 27, 5.3 and 356 tonnes per year being recorded for cadmium, mercury and lead, respectively. Only a small amount is estimated to come from point sources. Atmospheric deposition of these substances has generally declined since the 1990s (HELCOM 2020e and HELCOM 2021). The volume and location of dredged material in the Baltic Sea varies between years (e.g. HELCOM 2020b). For example, around nine million tonnes were deposited at 106 sites in 2020, with a little over half of this material being from capital dredging and the rest from maintenance dredging. Around seven million tonnes came from harbours and river estuaries, and most of the dredged material was deposited at locations offshore. Levels of mercury, lead, copper, tributyltin and polycyclic aromatic hydrocarbons in the dredged material were similar to or lower than corresponding values recorded in 2014 or before. However, cadmium levels had increased.

Maritime activities, such as shipping, can emit hazardous substances through spills of oil or other substances. Operational discharges from the cleaning systems of ships are a significant source. With the use of exhaust gas cleaning systems (scrubbers), hazardous substances are released with the discharge of scrubber waters, as well as in grey and bilge waters and through the smokestack. In 2021, the total volume of discharge water from exhaust gas cleaning systems was roughly 286 million cubic metres, mainly from open loop systems. For example, open loop scrubber systems are estimated to generate as much as 8.5% of the total Baltic Sea load of the polyaromatic hydrocarbon anthracene (Ytreberg *et al.*, 2022). Discharges from these activities are increasing.

Regulations and needs

Minimizing the input and impact of hazardous substances from human activities is a key goal of the Baltic Sea Action Plan.

Management objectives relating to hazardous substances are to minimize their input from sea-based activities, enforce international regulations, achieve no illegal discharges and have safe maritime traffic without accidental pollution.

Hazardous substances that enter the aquatic environment often remain for a long time, and their impacts accumulate in the food web. Removing a contaminant once it is present at sea is far more complex and costly than preventing its release, and in several cases is impossible. Furthermore, many substances are persistent and have long recovery times even after their input has been stopped.

Finding measures to reduce or prevent the input of hazardous substances at the source is significantly more achievable and cost-effective than dealing with them once they are already present in the environment.

The complexity of human activities and regulatory levels associated with environmental contaminants makes management response and policy implementation for hazardous substances a significant challenge that warrants strategic development in itself.

Climate change is expected to have significant effects on the Baltic Sea, but there is currently no regional overview of how climate change interacts with hazardous substances (HELCOM and Baltic Earth 2021). A number of direct climate change effects are likely to affect hazardous substances, such as water temperature, atmospheric circulation, solar radiation, acidification, stratification, precipitation, river runoff and sediment transportation. Among indirect effects, factors such as changes in oxygen concentration, microbial processes, non-indigenous species and ecosystem functions could affect the presence and impact of hazardous substances in the Baltic Sea ecosystem (HELCOM 2023c).

4.2.3 Marine litter

The status of marine litter in the Baltic Sea is currently evaluated based on beach litter and litter on the seafloor (Figure 4.10, Box 4.4).

The HELCOM threshold value for beach litter is 20 litter items per 100 metres of beach. During 2016-2021, eleven out of the sixteen sub-basins that could be assessed were above this limit and did not reach good status. The subbasins with highest median values were the Sound (313 litter items per 100 m), the Gulf of Riga (156 items) and the Eastern Gotland Basin (96 items). The sub-basins achieving good status for beach litter were Kiel Bay, the Bay of Mecklenburg, the Gdansk Basin and the Western Gotland Basin. The Quark had a median value below the threshold value, but the result was evaluated as uncertain due to limited data. Plastic litter, including single-use items, was the most common litter category, accounting for between 32 and 93% of the total number of litter items (Figure 4.12). Several sub-basins showed a decrease in the total litter count over time, which correlates with a decrease in the count of single-use plastics and plastic litter items.

Data about litter on the seafloor is collected in connection with fish surveys using trawls and is available for some sub-basins (Figure 4.11). Litter in the categories “plastic” and “other” increased during the evaluation period, and these categories thus fail the preliminary threshold value, which is “no significant increase” from 2015 to 2021 in weight, number or probability of catching litter. The category “fisheries-related litter” achieved the threshold when measured in number per square kilometre but not when measured in weight. The remaining categories,

BOX 4.4.

What is marine litter?

Marine litter comes from a vast range of human sources and reaches different marine compartments. Beach litter is monitored worldwide as a proxy of human impacts on the ecosystem. Information on the amount of litter can indicate general levels of potential harm to marine biota and ecosystems, as well as societal losses in the form of aesthetic values, economic costs and hazards to human health. Litter that has accumulated on the seafloor is equally relevant and can have significant impacts on organisms at sea. Evaluation of litter types and categories helps us understand the sources of marine pollution and assess the efficiency of environmental management measures.

The Baltic Sea Action Plan states the following ecological objective for marine litter:

— No harm to marine life from litter.

Figure 4.10. The impact of marine litter on the marine environment is closely linked to human behaviour.

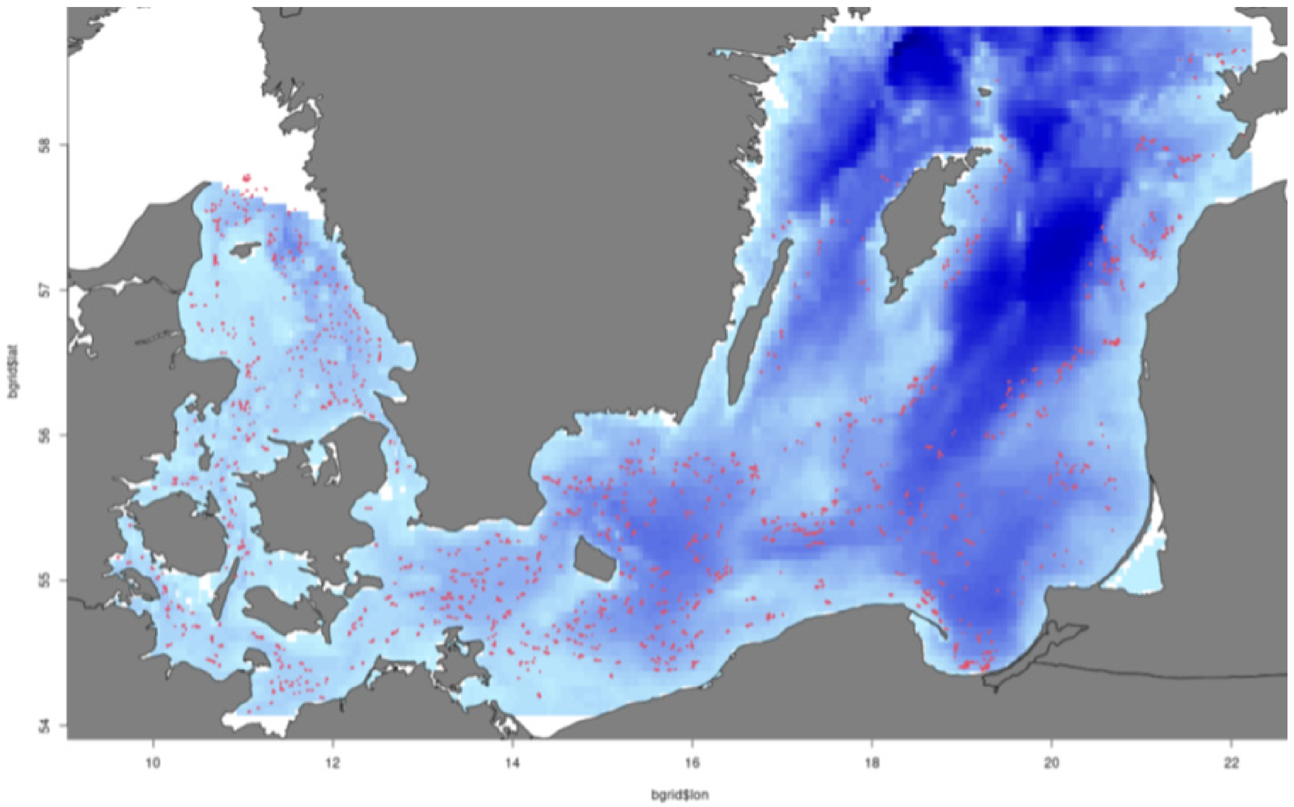

Figure 4.11. Sampling locations of sea-floor litter (red) and depth (shades of blue, darker indicating deeper). Note that deep locations and the north and north-eastern parts of the Baltic are not currently sampled, and that the depth map is not aligned with HELCOM assessment unit borders. Sampling of sea-floor litter was started in 2011, by its inclusion in the Baltic Sea International Trawl Survey, but litter categories and sample codes were not fully standardised until 2015. Source: HELCOM 2023c.

"glass", "metal", "natural", "rubber" and "single use plastics", showed no significant increase in weight or number per square kilometre during the evaluation period.

Work is needed to develop these evaluations further, along with evaluations of microlitter and the impacts of litter on biota (HELCOM 2023c).

Impacts of marine litter in the Baltic Sea ecosystem

Litter may cause harm to animals when they ingest it, either by clogging or injuring their digestive tract or by causing contamination. Another major impact is animals becoming entangled and trapped in lost fishing gear or packaging material. Litter on the seafloor can result in anoxia in the underlying sediments, which alters the biogeochemistry and the benthic community structure (Goldberg 1994). Certain litter types, such as glass bottles and tin cans, may provide substrates for the attachment of sessile biota (Mordecai *et al.* 2011, Moret-Ferguson *et al.* 2010, Pace *et al.* 2007). Heavy plastic items may become colonized by bacteria or loaded with sediments and sink to the seafloor, where they can persist for centuries (Thompson 2006, Derraik 2002, Ye & Andrady 1991). Large plastic items can pose a risk of obstruction or harm to animals, and they leak smaller particles that pose risks to organisms. Litter containing hazardous substances can act as a source of contamination and thereby contribute to chemical impacts on the ecosystem. Marine litter has a socioeconomic impact through the costs associated with cleaning it up, damage to or loss of fishing gear, obstruction of motors and harm to tourism and recreation (Newman *et al.* 2015).

Sources of marine litter

Marine litter comes from both land and sea-based sources. The types of litter from land are often closely linked with consumer behaviour, such as recreational and tourism activities leaving behind plastic bags, left-overs from beach picnics or cigarette butts. Other land-based sources are riverine inputs and inputs from storm-water overflow. Important sea-based sources are ship-generated waste, such as lost or abandoned fishing gear, foamed plastic or lost fish traps. Beach litter monitoring thus reflects both littering trends along the coastline and litter transported over long distances.

The seafloor is a sink for marine litter, and litter items on the seafloor originate from both maritime activities (e.g. fishing or shipping) and land (Galgani *et al.* 2010, Galgani *et al.* 2015, Pham *et al.* 2014). Lost fishing gear, known as ghost nets, continue trapping marine animals for a long time. Both passive fishing gear, such as traps and nets, and trawls are often lost or discarded. The extent of lost fishing gear in the Baltic Sea is not known, but some examples are available. In 2011, WWF Poland, together with fishermen, scientists and divers, retrieved six tonnes of ghost nets from the Baltic seafloor and two wrecks over 24-days. In 2014, a ghost net project conducted on Rügen by the Ozeaneum Stralsund, archeOmare, the Drosos foundation and WWF Germany removed around 4 tonnes of ghost nets from two wrecks (HELCOM 2023c).

Figure 4.12. Lost fishing gear can end up on land, but most often it remains in the sea where it can continue trapping marine animals for a long time.

Regulations and needs

HELCOM countries have agreed in the Baltic Sea Action Plan to prevent the generation of waste and its input to the sea, including microplastics, and to significantly reduce amounts of litter on shorelines and in the sea.

The implementation of the 2021 HELCOM Regional Action Plan on Marine Litter should enable the achievement of the management objectives for marine litter in the Baltic Sea Action Plan. However, there is a need for better geographical coverage in monitoring to evaluate the effect of current actions on marine litter and to define additional ones, if necessary.

Researchers in the fields of climate and marine litter have put forward that commitments against plastic littering in the sea can also increase interest in solving issues related to climate change (Ford *et al.* 2022). The connections between climate change and plastic pollution in the oceans include the fact that plastic contributes to greenhouse gas emissions both throughout its life cycle and as litter in the sea, and that climate change and plastic pollution both occur in all environments. Climate change could worsen the spread of plastic pollution, because litter abundance on coastlines is influenced by water currents and prevailing wind conditions, and rivers are pathways for litter from inland. Changes in precipitation and floods, as well as oceanographic changes, could thus alter litter abundance and the deposition of litter.

4.2.4 Non-indigenous species

Thirteen non-indigenous or cryptogenic species appeared for the first time in the Baltic Sea during the assessment period 2016-2021 (Figure 4.14, Box 4.5). The threshold value for good environmental status is no new introductions of non-indigenous species through human activities at the scale of the whole Baltic Sea during the assessment period. Good status for non-indigenous species was therefore not achieved.

The new introductions were recorded in the Kattegat, the Great Belt, Kiel Bay, the Bay of Mecklenburg, the Bornholm Basin, the Gulf of Gdansk, the Archipelago Sea and the Gulf of Finland.

The indicator only considers new human-mediated introductions. Spreading within the Baltic Sea by natural means, such as by migration or aided by water currents, is not part of this indicator.

The trend in the arrival of new non-indigenous or cryptogenic species increased sharply in the second half of the last century and has not shown any signs of decreasing since then (Figure 4.13).

The number of new introductions was higher during the current assessment period (13) than in the previous one (12 introductions in 2011-2016). However, this comparison is complicated by the fact there were significant additional reports provided for the previous assessment period that were not directly included in the that assessment.

BOX 4.5.

What are 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. Non-indigenous species have the potential to cause harm in their new environments through their interactions with naturally occurring species or human activities.

The Baltic Sea Action Plan states the following ecological objective for non-indigenous species:

— No introductions of non-indigenous species

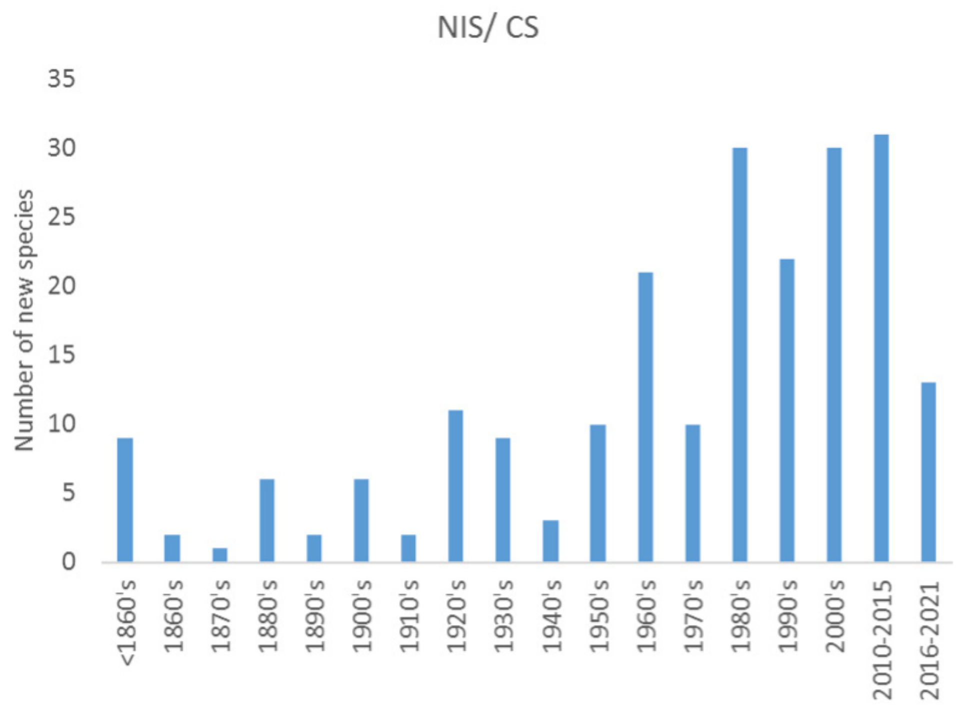

Figure 4.13. The number of non-indigenous species (NIS) introduced to the Baltic Sea over time. The bars indicate the number of new introduced species per time period. Note that the lengths of the last two time periods differ from the others, covering intervals of six instead of ten years. There is a discrepancy between the statistics presented in this figure and the assessment results presented in the text because of retrospective reporting of many new non-indigenous species after the publication of the previous holistic assessment (HELCOM 2018). The threshold value for good status is 0 new introductions. Data are from the Information system on aquatic non-indigenous and cryptogenic species (AquaNIS). Source: HELCOM 2023c.

Impacts of non-indigenous species in the Baltic Sea ecosystem

Non-indigenous species that spread into and become established in the Baltic Sea may harm the natural marine environment. For example, the round goby (*Neogobius melanostomus*), a bottom-dwelling invasive fish originating from the Black Sea and the Caspian Sea, was first observed in the Baltic Sea in 1990. After a few years of low abundance, the species increased dramatically and is now a dominant species in many areas of the Baltic Sea, with the capacity to change interactions in the benthic food web (Kotta *et al.* 2016), and it is still expanding its range in the Baltic Sea.

Overall, non-indigenous species have caused ecological, economic and public health impacts globally (Ruiz *et al.*, 1997, Mack *et al.* 2000, Lockwood *et al.* 2007, Ojaveer and Kotta 2015). Non-indigenous species can induce considerable changes in the structure and dynamics of marine ecosystems. Economic impacts range from financial losses in fisheries to expenses to industries for cleaning intake or outflow pipes and structures from fouling (Black 2001, Williams *et al.* 2010). Public health impacts may also arise from the introduction of pathogens or toxic algae.

The impacts of non-indigenous species can be unpredictable and may be large, especially when they co-occur with other pressures. However, not all non-indigenous species are invasive, spread widely or 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 to help implement measures at an early stage (Katsanevakis *et al.* 2014). An evaluation of current cumulative negative impacts on marine biodiversity caused by non-indigenous species in the Baltic Sea, based on the Cumulative IMPact of ALien species (CIMPAL) index, is depicted in Figure 4.15. However, our knowledge is very limited for the majority (60%) of wide-spread non-indigenous species in the Baltic Sea (Ojaveer *et al.* 2021).

Sources for the introduction of new non-indigenous species

Maritime transport is the main pathway for the introduction of new non-indigenous species. Harbours and ports are hotspots for both the new introduction of non-indigenous species and their establishment, as they are sites where ships are stationary for extended periods. Harbours and ports also offer suitable places for species to settle, in shallow water or modified habitats (Lehtiniemi *et al.* 2015).

Figure 4.14. The round goby (*Neogobius melanostomus*) is an example of a non-indigenous species that has taken a major role in the Baltic Sea food web, leading to impacts on several other species.

Regulations and needs

The management objective for non-indigenous species under the Baltic Sea Action Plan is "no introductions of non-indigenous species".

Preventative measures are key to limiting non-indigenous species, as the eradication of already established non-indigenous species is difficult and cost-intensive and has generally proven not to be feasible in aquatic environments (Sambrook *et al.* 2014). There are no records of the eradication of established non-indigenous species in the Baltic Sea. Management should therefore primarily aim to prevent further introductions and to minimize the negative effects of the non-indigenous species that have already been introduced. Further monitoring and evaluation of the establishment, risk and potential harm caused by non-indigenous species in the Baltic Sea is also needed.

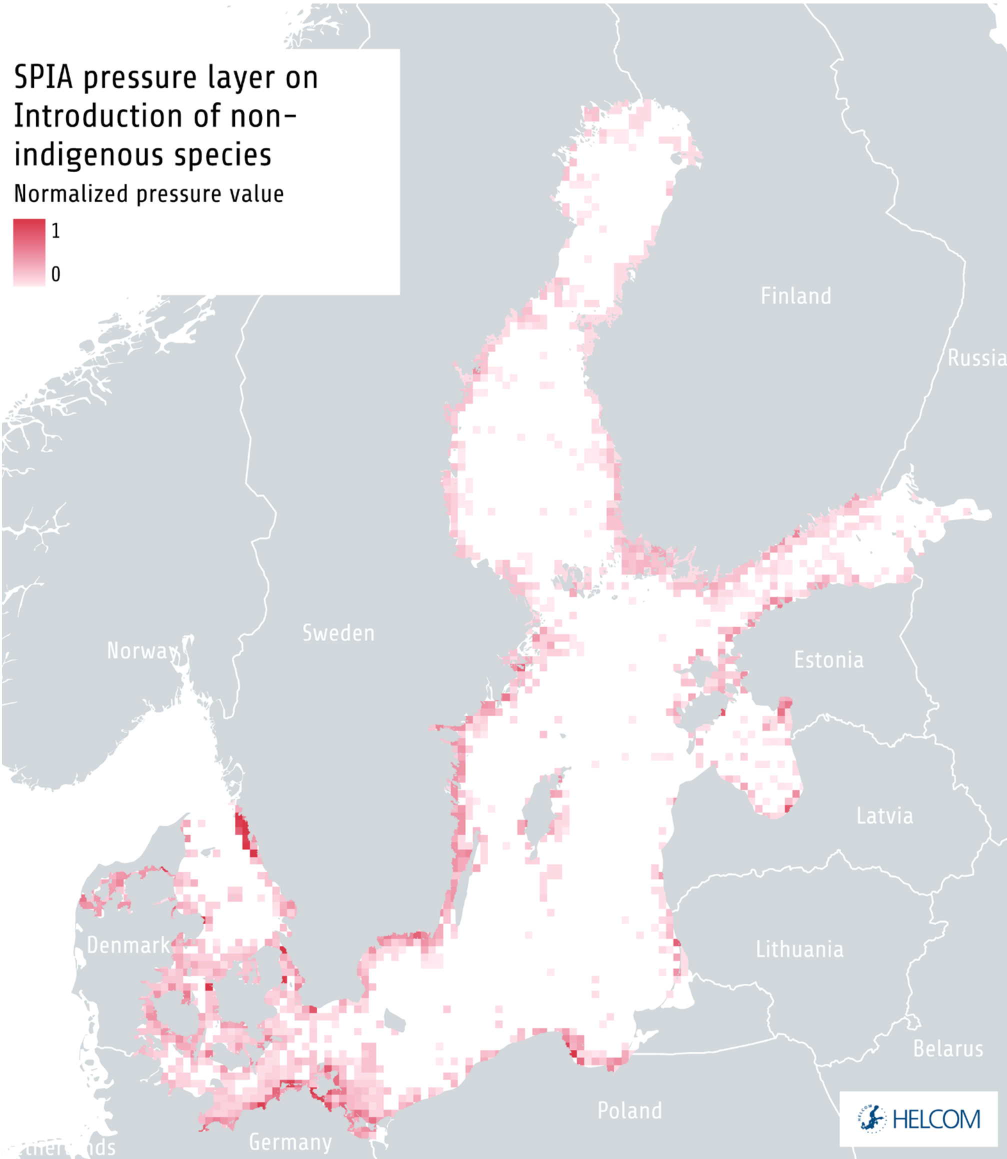

Figure 4.15. Non-indigenous species impacts in the Baltic Sea, as presented in HELCOM (2023e). The layer indicates the cumulative negative impacts on marine biodiversity caused by non-indigenous species based on the index CIMPAL (Cumulative IMPact of ALien species (Katsanevakis et al. 2016). The map shows the normalized pressure values, with increased colour intensity indicating higher pressure. Source: HELCOM 2023e.

4.2.5 Underwater noise

Continuous noise was evaluated for the first time in HELCOM during the current assessment period, by addressing the proportion of the Baltic Sea area exceeding noise levels that may cause adverse biological effects (Box 4.6). The evaluation results indicate a good status of continuous underwater noise in all areas of the Baltic Sea with respect to the risk of behavioural disturbance in fish or marine mammals. With respect to the risk that human-induced noise masks natural sounds, the evaluation indicates good status for marine mammals in all of the Baltic Sea but not good status for fish in 9 out of 17 assessment units. Several aspects of the evaluation method are still under development.

Continuous underwater noise shows considerable variation in space and time (Figure 4.16). Noise levels are clearly higher in shipping lanes than elsewhere in the Baltic Sea, and noise is more widespread in winter than in summer.

BOX 4.6.

What is underwater noise?

Underwater noise measures the contribution of human activities to the sound environment under the sea surface. Both continuous and impulsive noise occur, and the two types vary in their properties and in how they affect aquatic animals. Continuous noise is constant, fluctuating or varying slowly over time, while impulsive noise has a short duration and a fast pulse rise time.

The Baltic Sea Action Plan states the following ecological objective for underwater noise:

- **No or minimal harm to marine life from man-made noise.**

The status of continuous noise is evaluated in relation to the hearing frequencies of fish and marine mammals, at 125 and 500 Hz decidecade bands, respectively. The risk of behavioural disturbance is evaluated based on the median total sound pressure level, and the risk of masking natural sounds is evaluated based on the median excess of a species-specific level. Impulsive noise is evaluated based on the occurrence of impulsive noise-producing events, such as explosions, reported to the regional HELCOM/OSPAR noise registry hosted by ICES (ICES 2015). The distribution of sound was compared to the distribution of harbour porpoises in the Baltic Sea to get a preliminary view of the overlap between sound and the occurrence of harbour porpoises.

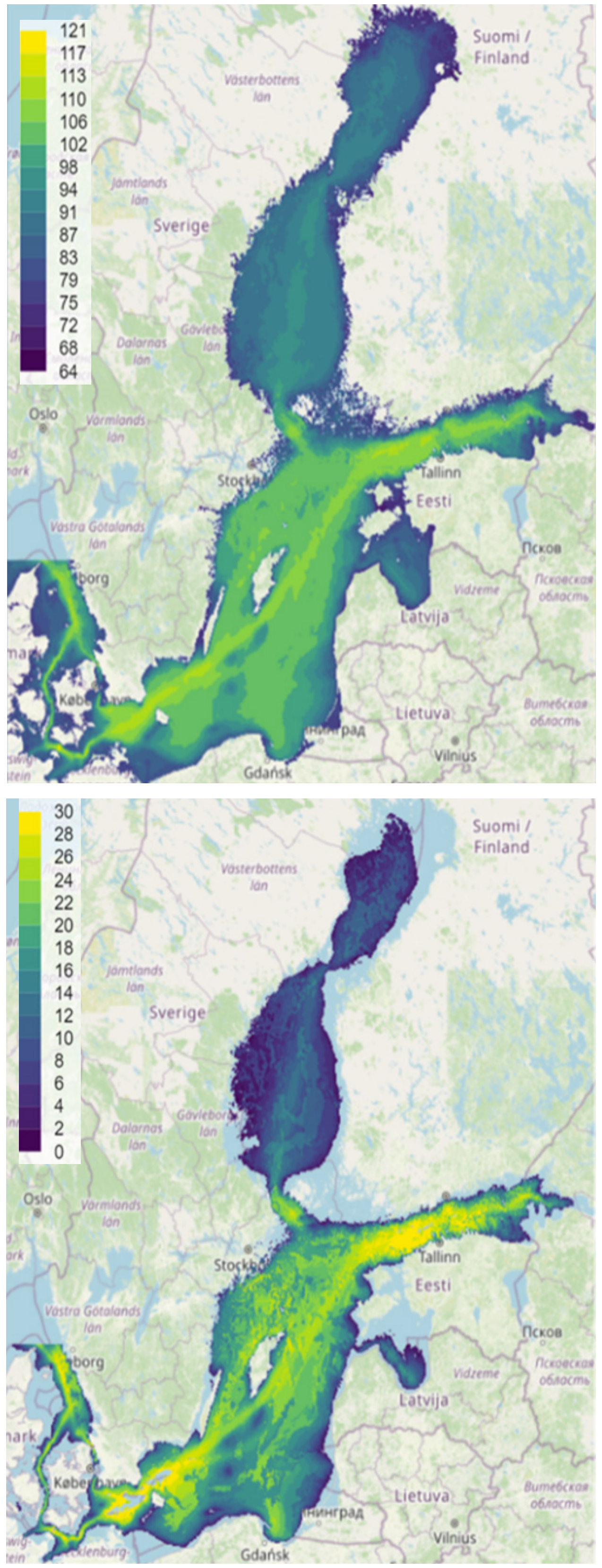

Figure 4.16. Illustration of continuous underwater noise in the Baltic Sea. The upper map shows the median sound pressure level for the third octave band 125 Hz in March 2028, and the map below shows the median excess level for the same. The maps represents the time of the year with the most favourable conditions for the transmission of anthropogenic noise in the Baltic Sea. Source: HELCOM 2023c.

Additionally, the potential effect of continuous noise on mobile species was addressed by combining the HELCOM SPIA pressure layer representing input of continuous noise with information on the distribution of fifteenmobile species and their habitats (HELCOM 2023e). According to the obtained results, the highest average potential effect of continuous underwater noise occurs in the south-western Baltic Sea, where all ships entering or leaving the inner parts of the sea pass through a rather narrow area, compressing the traffic. The Arkona basin is also a hotspot for the occurrence of mobile species, intensifying the impact of this area (Figure 4.17).

Preliminary evaluations of reported impulsive noise indicate that there was enough undisturbed habitat for harbour porpoises in the Baltic Sea to avoid the impacts of low- and mid-frequency impulsive sounds during the assessment period. The area of habitat exposed and disturbed remained clearly below 10% of its HELCOM area habitat per day, based on the occurrence of impulsive noise-producing activities reported by Contracting Parties (Figure 4.18).

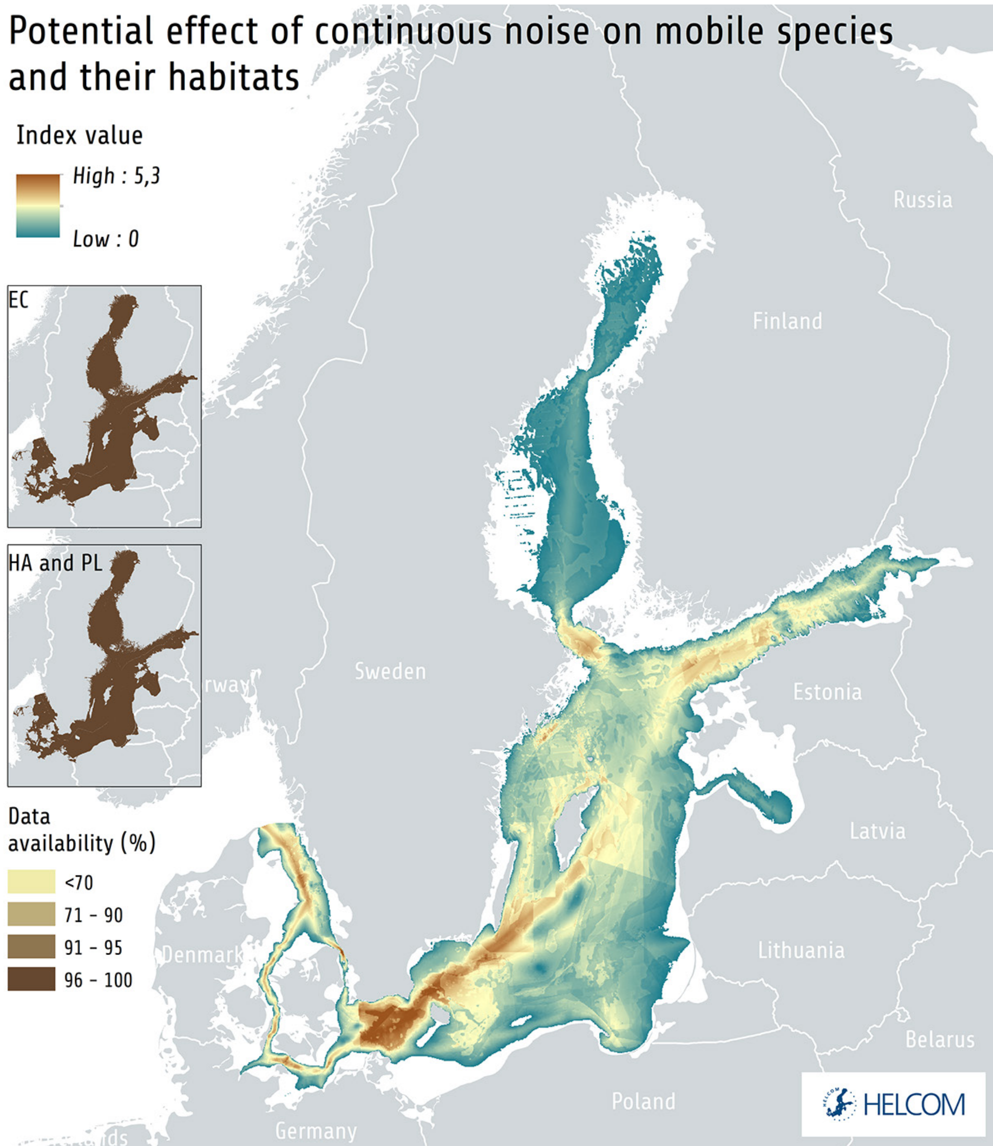

Figure 4.17. Areas with potentially highest impact from continuous underwater noise on mobile species. The map is based on the HELCOM pressure layer on inputs of continuous noise combined with information on the distribution of fifteen mobile species and their habitats (HELCOM 2023e). The highest average potential impact occurs in the south-western Baltic Sea, where all ships entering or leaving the Baltic Sea pass through a rather narrow area. The Arkona basin is also a hotspot for the occurrence of mobile species, which increases the potential impact. Source: HELCOM 2023e.

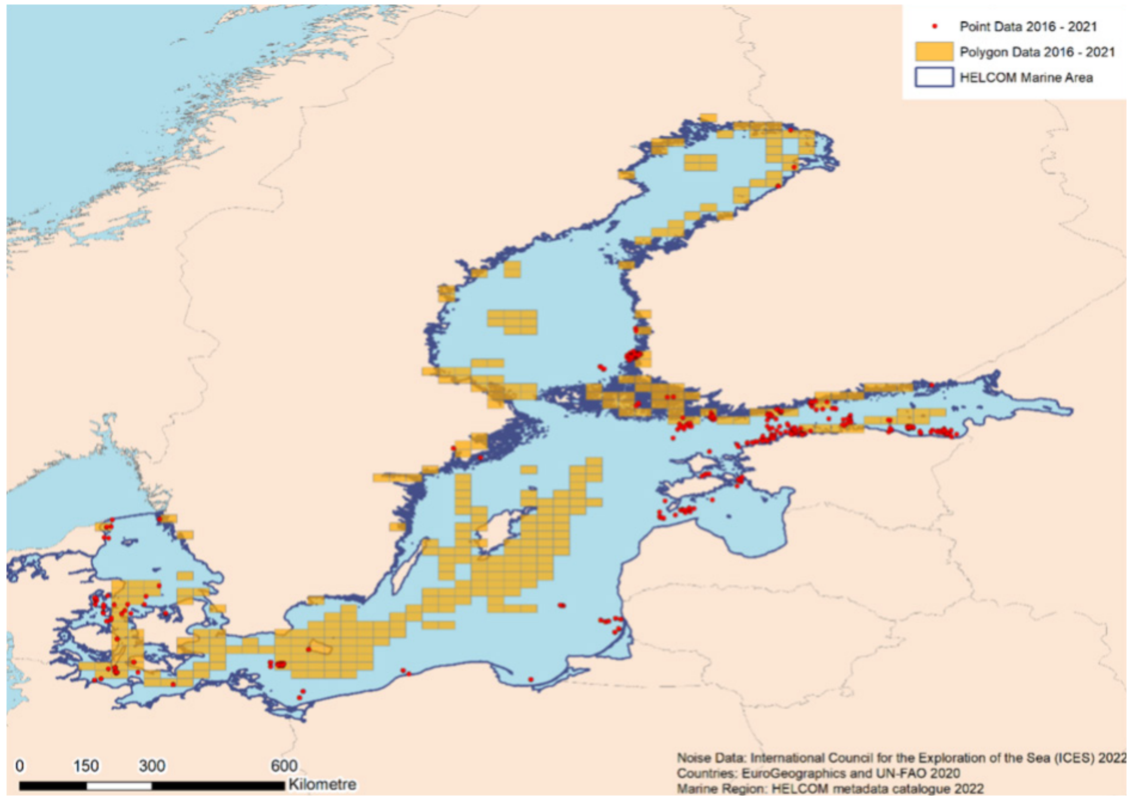

Figure 4.18. Impulsive noise activities reported for the period 2016 – 2021 in the HELCOM area. Data are from the HELCOM noise registry (ICES 2015). Source: HELCOM 2023c.

Impacts of underwater noise in the Baltic Sea ecosystem

Noise can affect aquatic life in several ways. Continuous noise at certain frequencies and high intensity can mask the natural acoustic communication of animals and decrease their ability to hear biologically relevant sounds, such as sounds involved in locating prey. It can also disturb their natural behaviour.

Although loud impulsive noises do not persist, they can nevertheless induce a range of impacts depending on their intensity. Certain levels of impulsive noise can cause biological disturbance by inducing stress and behavioural changes in, for example, fish and marine mammals (Wysocki *et al.* 2006, Santully *et al.* 1999), particularly in harbour porpoises (e.g. Madsen *et al.* 2006, Brandt *et al.* 2009, Tougaard *et al.* 2009, Tougaard *et al.* 2012, Dähne *et al.* 2013) but also in harbour seals (e.g. Jacobs and Terhune 2002, Gordon *et al.* 2015, Kastelein *et al.* 2015). Such disturbances may deter animals from an area or prevent them from carrying out normal feeding or reproductive behaviour. At higher levels, noise can have an impact on an animal's auditory system, leading to temporarily or permanently impaired hearing (Lucke *et al.* 2009, Finneran 2015). Very high levels of impulsive noise can lead to further physiological injury or death.

Sources of underwater noise in the Baltic Sea

Continuous noise in the Baltic Sea comes mainly from maritime transport. Other sources of continuous noise include fishing vessels, energy installations, leisure boats and dredging. Noise from ships sailing at service speed is primarily from their engine and propeller, with secondary components being machinery and the movement of the hull through the water. Sound waves propagate efficiently in water, so sounds from point sources are heard much farther away than in air.

The most intense sources of loud impulsive noise are explosions, pile driving, seismic exploration and low frequency sonar. Unless mitigation measures are used to reduce the propagation of impulsive noise, activities such as explosions and piling may have effects at vast distances from the source. For example, impulsive noise input from pile driving activities was shown to induce avoidance reactions and thus disturbance to harbour porpoises at a distance of 25 km (Dähne *et al.* 2013). Effective mitigation measures exist to significantly reduce the effect distance and to temporarily deter animals from the remaining impacted area.

Regulations and needs

Reducing noise to levels that do not adversely affect marine life is a key management objective of the Baltic Sea Action Plan.

The envisaged revised International Maritime Organization Guidelines for the reduction of underwater noise from commercial shipping to address adverse impacts on marine life and the HELCOM Regional Action Plan on Underwater Noise are expected to lead to the achievement of this objective. However, compulsory regulations will likely be needed to achieve a significant reduction in underwater noise from shipping.

Furthermore, as spatial and temporal threshold values for underwater noise have just been adopted at the EU level, formal discussions and agreements are still needed about how these should be applied with respect to, for example, spatial assessment units, habitat size and sound levels that result in biologically adverse negative effects.

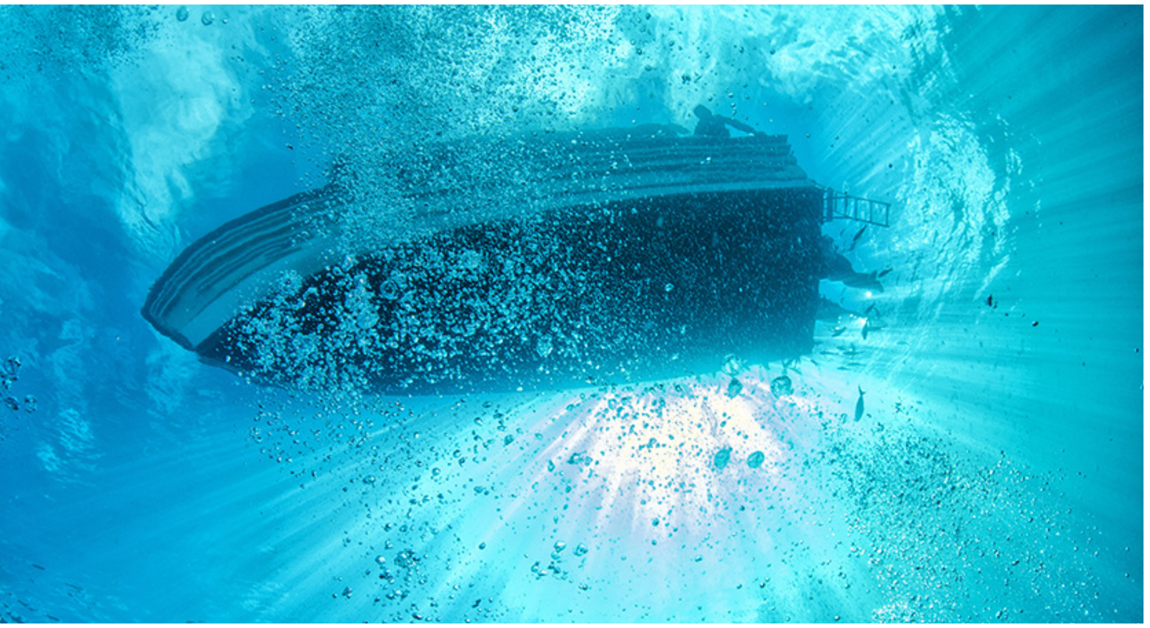

Figure 4.19. Contoinuous noise comes from boats and vessels of all sizes.

4.3. Pressures from activities at sea

Several pressures on the Baltic Sea derive from our direct use of the sea and its resources. Extractive pressures are associated with fishing, hunting and the extraction of materials from the seabed, such as sand and minerals. Physical pressures come from activities such as dredging, bottom trawling and marine construction.

The assessment results for pressures stemming from sea-based activities are presented here for the extraction of fish, unintentional by-catches, hunting of birds and mammals, and sea-floor loss and disturbance. More detailed results can be found in the HELCOM thematic assessment of biodiversity status (HELCOM 2023a) and its underlying indicator reports.

As these pressures are extractive or lead to physical alterations of the seabed, they have direct impacts on the affected species and habitats. Careful planning and regulation of the activities is needed to ensure sustainable use.

4.3.1 Extraction of fish

The status assessment of fish presented in Chapter 3 integrates the status of fishing pressure in the evaluation of commercially important fish stocks (Box 4.7). Out of fifteen commercial stocks that could be fully evaluated, only four showed good status on average during 2016-2021 (Figures 4.20-4.21). Stocks showing good status with respect to both fishing pressure and stock size were plaice in the Baltic Sea, herring in the Gulf of Riga and the Gulf of Bothnia, and vendace in the Swedish part of the Bothnian Bay, although the latter two stocks showed a decreasing trend in stock size.

Looking specifically at fishing pressure, threshold values were not achieved for eight of the seventeen stocks that could be evaluated for this indicator; these were four pelagic and four demersal stocks. Threshold values for stock size was not achieved for two pelagic stocks, four demersal stocks and eel (Table 4.1).

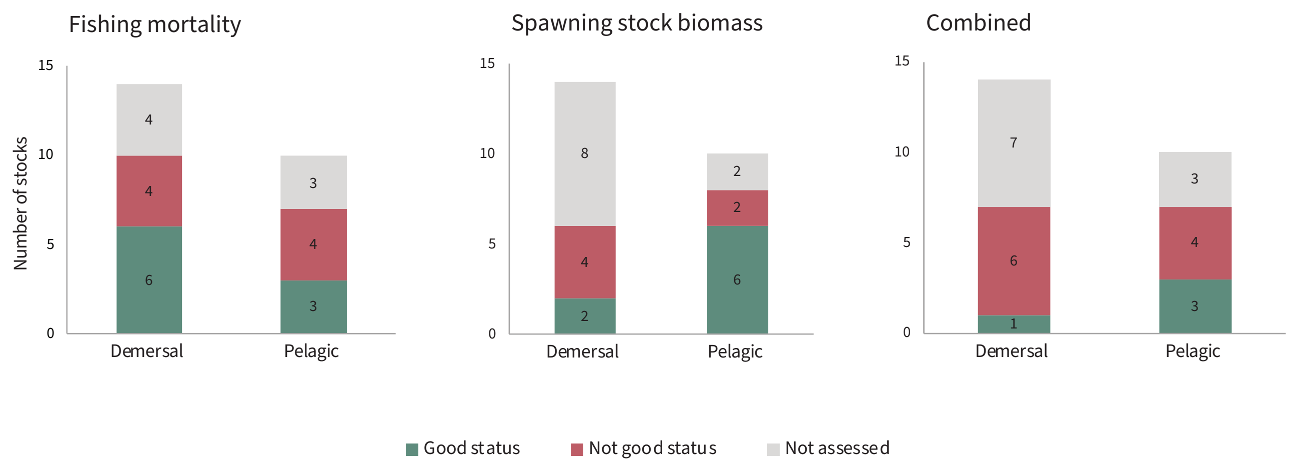

Figure 4.20. Number of pelagic and demersal commercial fish stocks in good and not good status with respect to fishing mortality (left), stock size (spawning stock biomass, middle), and both aspects combined (right). The colours denote whether the average value during 2016–2021 achieved (green) or failed (red) the 2021 threshold value. The number of fish stocks not assessed in each case is indicated in grey.