HOLAS III

Biodiversity

Thematic assessment 2016–2021

Baltic Marine Environment Protection Commission

THIRD HELCOM HOLISTIC ASSESSMENT OF THE BALTIC SEA 2016–2021

HOLAS 3

Biodiversity

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Contents

What is HELCOM?

Preface

By their nature, many environmental problems transcend political, legal and other anthropogenic boundaries, and thus cannot be adequately solved by individual countries alone. Regional Seas Conventions (RSCs) such as the Convention on the Protection of the Marine Environment of the Baltic Sea Area establish legal frameworks for necessary transboundary cooperation.

The Helsinki Commission (HELCOM) is an intergovernmental body composed of the Baltic Sea coastal states and the EU, and functions as the governing body of the Convention on the Protection of the Marine Environment of the Baltic Sea Area. HELCOM functions as a regional platform for cooperation with a broad spatial and sectoral reach, working with biodiversity and protection, shipping, fisheries management, maritime spatial planning (MSP), pressures from land and sea-based activities and regional governance. Furthermore, HELCOM has a wide vertical and horizontal scope, with established structures for transboundary cooperation within and across levels of organization, ranging across technical experts, authorities, managers and national ministries. HELCOM is also an established provider of infrastructure to support both regional and national work, including functioning as the natural regional data hub and tool developer as well as providing concrete support for regional assessments, ensuring that regional coherence and an ecologically valid perspective is maintained.

Benefits of cooperation at the regional level:

— Benefitting from the expertise of others;
— Sharing of knowledge, information and resources;
— Improved effectiveness of measures due to regional coherence and mutually enforcing or synergistic actions;
— Action is taken at the ecologically relevant scale, i.e. the scale at which the environment functions.

HELCOM is...

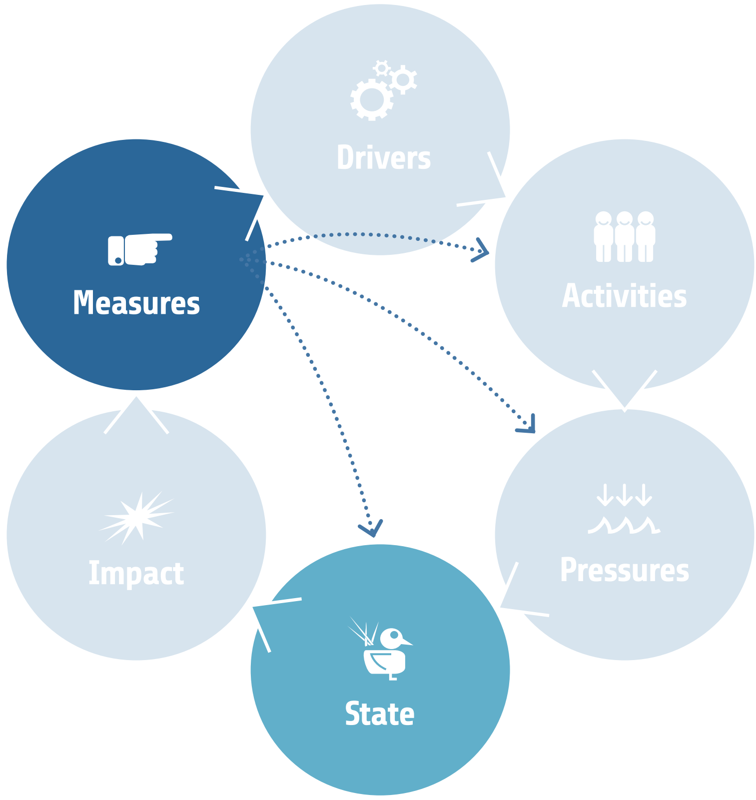

Figure P1. Conceptual overview of the management framework HELCOM works within.

Our activities at sea and on land cause pressures on the marine environment which in turn, to varying degrees, negatively impacts the ecosystem on which we all depend for our survival. These impacts cumulate and cascade through the ecosystem and eventually return to impact our wellbeing and that of society as a whole.

To limit the negative impact of our activities to within what the ecosystem can tolerate, we must understand what effects our actions have and then use that information to manage the activities which are causing negative impact. This is done through establishing well-founded and ecologically relevant targets and objectives to work towards and then taking concrete measures to ensure we reach them. Figure 0.1 shows the conceptual management framework HELCOM works within, and within which the holistic assessment is made. This is a regional version of the more common Driver-Activites-Pressures-Impacts-Response (DAPSIR) framework, which has been modified to fit the work under HELCOM.

Measures to improve the Baltic Sea environment are undertaken by many actors and at many levels, jointly at the global level, regionally at Baltic Sea level through HELCOM, by countries at national, county and local levels, and by initiatives in the private and public sector. The measures also differ in type, 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.

In order to allow the tracking, and to get a comprehensive and accurate overview of progress towards set objectives and targets, as well as to see if our measures are working and sufficient, assessments need to be conducted. In order to better understand the ecosystem and our relationship with it, and to ultimately improve the environmental status of the sea, we need to map activities which affect the marine environment, analyse what effects these activities have and how strong these effects are, and assess what this means for the ecosystem.

When using assessment to track progress of measures and management, and identify possible gaps or barriers, this needs to be done in two ways. On the one hand, we need to assess the level of implementation of the agreed measures, i.e. has the agreed action actually been taken and to what degree. This tells us about possible implementation gaps and can help to identify unforeseen barriers or challenges that need to be addressed. In HELCOM this is achieved through regular reporting and the use of the HELCOM Explorer tool. On the other hand, we need to understand and track the actual effects that the implemented measures have on the marine environment. This helps us understand if the measures which have been put in place are sufficient to limit the negative impact of our activities. Where the measures turn out to not be sufficient, the knowledge we gain from the assessments enables us to identify new or improved measures, which can be more targeted, resource efficient and/or adaptive.

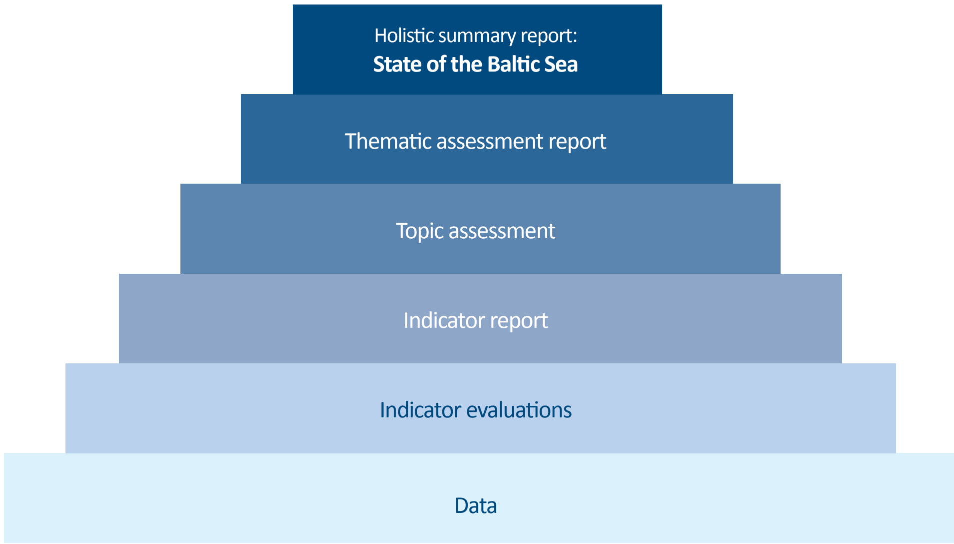

Figure P2. The structure and process of the HELCOM holistic assessment. Within the assessment structure, highly detailed results are progressively aggregated, allowing anyone to explore the results at whatever scale is most relevant to them and culminating in the overall summary report on the State of the Baltic Sea.

Assessments also help us understand what pressures and measures need to be addressed at what level. Our activities cause various types of pressures, the impact of which can vary spatially and temporally. However, because of how dynamic the marine environment is, the majority of pressures in the marine environment have transboundary impacts. For measures and management to be effective it therefore has to be implemented at an appropriate level and this often means that implementation need to be regional, i.e. the scale at which they need to be addressed in order to be effective goes beyond the national borders of one specific country.

HOLAS

The Holistic Assessment of the Status of the Baltic Sea (HOLAS) is a reoccurring, transboundary, cross-sectoral assessment which looks at the effect of our activities and measures on the status of the environment. The assessment is a product of HELCOM. The HOLAS assessment covers, or approaches, the main themes to be considered when taking an ecosystem approach to management and provides regular updates on the environmental situation in the Baltic Sea. Each report captures a 'moment' in the dynamic life history of the Baltic Sea. The report highlights a broad range of aspects under the overarching themes of the state of the ecosystem, environmental pressures and human well-being and contributes to a vast sharing and development of knowledge both within and across topics. The focus of the assessment is to show results of relevance at the regional scale and large-scale patterns across and between geographic areas in the Baltic Sea. Each assessment provides a clearer picture of where we are, how things are connected, and what needs to be done.

The holistic assessment also specifically enables tracking progress towards the implementation of the 2021 Baltic Sea Action Plan (HELCOM 2021) goals and objectives and functions as a regional contribution to the reporting under the Marine Strategy Framework Directive (MSFD)(EU 2008). The results of the assessment underpin HELCOM policy and the information from the assessment is incorporated in the ecosystem-based management of the Baltic Sea, as well as guiding measures nationally, regionally and globally.

The HELCOM holistic assessment is a multi-layered product (Figure P.2). Within the assessment structure, highly detailed results are progressively aggregated, allowing anyone to explore the results at whatever scale is most relevant to them and culminating in the overall summary report on the State of the Baltic Sea.

Data

The collection, reporting and collation of national monitoring data at the Baltic Sea level forms the basis of the assessment. The data is spatially presented using a defined assessment unit system dividing the Baltic Sea into assessment units representing different levels of detail, in a regionally agreed nested system. The data then feed into regionally agreed evaluation and assessment methods. This allows us to explore trends over time, spatial aspects, as well as results, in order to indicate potential future developments and geographic areas of key importance for the assessed themes.

Indicators

HELCOM core indicators have been developed to assess the status of selected elements of biodiversity and human-induced pressures on the Baltic Sea and thus support measuring the progress towards regionally agreed targets and objectives. The core indicators are selected according to a set of principles including ecological and policy relevance, measurability with monitoring data and linkage to anthropogenic pressures (HELCOM 2020a). The observed status of HELCOM indicators is measured in relation to a regionally agreed threshold value specific to each indicator, and in many cases at the level of individual areas in the Baltic Sea. The majority of the indicators are evaluated using data from regionally coordinated monitoring under the auspice of HELCOM and reported by the Contracting Parties to the Convention. The status of an indicator is expressed as failing or achieving the threshold value. Hence, the results indicate whether status is good or not according to each of the core indicators. HELCOM core indicators make up the most detailed level of results, presented in the dedicated indicator reports (https://indicators.helcom.fi).

Thematic assessments

A basic criterion for HELCOM core indicators is that they are quantitative and that their underlying monitoring data and evaluation approaches are comparable across the Baltic Sea. This is to ensure that they are suited for integrated assessment. Integrated assessments are assessments where the quantitative information from indicator evaluations or other data, as well as qualitative information, is combined by topic, to produce a broader, more holistic overview of the situation for that specific topic and, subsequently, for the theme under which that topic is included. The integrated assessments are made using the BEAT (biodiversity), HEAT (eutrophication) and CHASE (hazardous substances) assessment tools, as well as the Spatial Pressures and Impacts Assessment tool, developed for this purpose by HELCOM. In addition to presenting whether status is good or not, the integrated assessment results also indicate the distance to good status. Distance to good status is shown by the use of five assessment result categories; out of which two represent different levels of good status and three different levels of not good status.

Quantitative integrated results can then be further combined with qualitative assessment results (where quantifiable information is not available) and contextual information to form five thematic assessments, each with their own report (biodiversity, eutrophication, hazardous substances, marine litter, underwater noise and non-indigenous species, spatial distribution of pressures and impacts as well as social and economic analyses). This report represents a thematic assessment and covers the theme biodiversity.

The overall aim of a thematic assessment is to present what the results of the various assessments related to the theme of biodiversity are, how they have been produced as well as their rationale, all within the relevant policy and scientific frameworks. Confidence in the assessments is presented together with the results to ensure transparency and facilitate their use. The thematic assessment reports are an integral part of the overall Status of the Baltic Sea assessment but also function as stand-alone reports. The reports are more technical in nature than the summary report, as they are intended to give details to the assessments, explaining underlying data and indicators to the extent that is needed to ensure that the HOLAS 3 assessment is transparent and repeatable.

Summary report

The main aim, and the added value, of the Summary Report lies in the possibility to link the information from the topical and thematic assessments together and thus highlight the holistic aspects of the assessment for each topic. With this in mind the Summary Report focuses on presenting the results and looking more in depth at why we are seeing these results, i.e., presenting the results of the thematic assessments by topic but linking and combining these topical results with the information and input from the other assessments/sources to provide context and analysis.

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Summary

Biodiversity loss driven by human activities is identified among the biggest current global threats to humanity, through effects on ecosystems and the functioning of foodwebs. On the other hand, restored and properly protected marine ecosystems can bring substantial health, societal and economic benefits. A HELCOM core vision for biodiversity is a healthy Baltic Sea environment with diverse biological components functioning in balance, resulting in good ecological status. Through the actions included in the 2021 Baltic Sea Action Plan (HELCOM 2021a), HELCOM Contracting Parties have declared their firm determination to ensure the possibility of self-regeneration of the marine environment, preservation of its ecological balance, and to take all appropriate measures to conserve natural habitats and biological diversity and to protect the ecological processes of the Baltic Sea by 2030 at the latest.

The thematic assessment of biodiversity status of the Baltic Sea, as part of the holistic assessment of the ecosystem health of the Baltic Sea in 2016-2021 (HOLAS 3), presents results from status assessments relating to the biodiversity segment, based on HELCOM indicators, integrated assessments and regionally agreed data. Results are presented in short below, and in full detail in the respective eleven topical chapters of the report and its associated annexes.

Overall, for most assessment elements, the spatial coverage has improved in the current assessment period (2016-2021) compared to that of HOLAS II (2011-2016), several new indicators have been included, and new topics have been introduced. For the first time, it is was possible to qualitatively compare trends for indicator and assessment results across assessment periods. However, further work is needed to fill remaining gaps in spatial coverage, improve the precision and coverage of HELCOM indicactors, and strengthen the relevance of the biodiversity assessment in line with future requirement for supporting ecosystem-based management, and following up on the implementation of measures. The results clearly show the need of continued and improved coordinated measures for the Baltic Sea environment. For the HELCOM biodiversity indicators, there are cases of inadequate status across the full spatial extent of the Baltic Sea and in all levels of the foodweb. Only a few core indicators have acceptable levels in parts of the region, and none in all assessed areas. The deteriorated status is of immediate concern regarding the affected species or ecosystem components, but through the links within the food web, they also lead to impacts on the ecosystem as a whole.

1. **PELAGIC HABITATS,** including phytoplankton and zooplankton, do not have good status in any of the fourteen assessed open sea sub-basins. The most deteriorated status occurred from the northern Baltic proper up to the Bothnian Bay, and the situation has worsened in the Bothnian Bay. The mean size of zooplankton has increased in some of these areas, which is positive, but the status of phytoplankton is not good. Four out of thirteen assessed coastal areas have good status for phytoplankton. No assessed open sea or coastal areas have good status when also taking the eutrophication indicators into account, representing an unchanged situation since HOLAS II with respect to eutrophication pressure on pelagic habitats. Climate change is expected to affect pelagic habitats further, for both phytoplankton and zooplankton. However, the function and role of the different species of the pelagic system is in need of further knowledge.

2. **BENTHIC HABITATS** were evaluated regarding the aspects of soft-bottom macrofauna, shallow-water oxygen, oxygen debt and cumulative impact from physical pressures. Large part of benthic habitatsin the Baltic Proper and the Sounds do not have good status, while the status is good in most of the Gulf of Bothnia. Good status for oxygen debt is not achieved in any of these areas. Oxygen debt below the halocline has increased in all basins since the early 1900s, especially in the Baltic Proper. The increase has been very steep between the previous and current assessment periods. The cumulative impact-risk from physical pressures is generally highest in the southern Baltic Sea and in the Kattegat, which are pressures with wide spatial extent, such as bottom trawling. Oxygen depletion is an indirect effect of eutrophication having an indirect link to anthropogenic pressures, through increased anthropogenic nutrient loads and subsequent increase of organic matter sedimentation. In addition to effects of eutrophication, benthic biotopes in the Baltic Sea are negatively affected by several human activities causing physical disturbance to the seafloor, for example bottom trawling fishery, extraction and disposal of sediments, and constructions.

3. **FOR FISH,** only four commercial fish stocks show good status, out of the fifteen stocks that could be fully evaluated. Three stocks have declined in status since HOLAS II, one stock has improved, and the status remains unchanged for eight stocks assessed in both periods. The integrated status of coastal fish using HELCOM indicators is good in two out of twenty-two assessed coastal areas. For migrating species, salmon (*Salmo salar*) stocks in the northern Baltic rivers have improved, many rivers further south are far from good status. The European eel (*Anguilla Anguilla*) remains critically endangered. Evaluation of fish age and size structure is imperative for a sufficient confidence in the assessment. Changes over time in fish age/size structure are included descriptively, for the first time, but regional work should continue to develop assessment approaches in relation to definitions of good environmental status. Overfishing and several other concurrently acting pressures affect the status of fish. Continued deterioration of essential recruitment areas is a concern in coastal areas and river mouths. In the open sea, the currently most important spawning area for Eastern Baltic cod (*Gadus morhua*) is only a fraction of its historical area due to oxygen deficiency.

4. **FOR WATERBIRDS**, the overall status is not good, although there is some variability for waterbirds within different feeding behaviour. Benthic feeders and waders do not have good status in any part of the region, while surface-feeders have good status in the Gulf of Bothnia. Pelagic feeders are in good status in several sub-basins. Grazing feeders fail to reach the threshold value for good status in Kattegat, the Northern Baltic Proper, and the Åland Sea. Many characteristic bird species have decreased over the last few decades, for example the pelagic feeding great black-backed gull (*Larus marinus)* and the velvet scoter (*Melanitta fusca*). Other species have increased, such as the greylag goose (*Anser anser*). Changes can be attributed to factors such as disruptions of foodweb structure, climate change and habitat alteration.

5. **MARINE MAMMALS** are overall not in good status. Several seal populations have too low abundance and reduced distribution compared to the definitions of good environmental status. Grey seal (*Halichoerus grypus*) and harbour seal (*Phoca vitulina*) are increasing in some areas, but population growth rates are evaluated as too low and both reproductive and nutritional status are below the threshold values for good status. Data quality for abundance of ringed seals (*Pusa hispida*) in the Bothnian Bay has decreased due to behavioural change possibly attributed to a warming climate. The status of harbour porpoise (*Phocoena phocoena*) is not good for any of the Baltic Sea populations, with regard to both abundance and distribution and based on a qualitative evaluation. The overall assessment for seals indicates a generally deteriorating trend since HOLAS II, and the integrated status has changes from good to bad in the Kattegatt, reflecting changes in the status of harbour seal.

6. **FOOD WEBS** are fundamental for ecosystem functioning and the delivery of ecosystem services. Further, foodweb knowledge is essential for informing sustainable and effective management of pressures and biodiversity components, highlighting the relevance of foodweb status assessments. Currently available data and knowledge could only support qualitative assessments of Baltic Sea foodwebs, however, and achieving systematic, quantitative assessments of foodweb status should be a priority for future work. Available evidence suggests that major changes in the abundance and biomass of species, driven by human pressures such as extraction of fish and input of nutrients, have been associated with corresponding changes in Baltic Sea foodwebs, and several examples of foodweb disruptions and putative tipping points give cause for concern. Proposed HELCOM ways forward to achieve future quantitative evaluations of foodweb status, improved and harmonised assessment methods are presented.

7. **FISHERIES BY-CATCHES** impact on pelagic- and benthic-feeding waterbirds. Impacts from bycatch on waterbirds occur widely, but due to the lack of monitoring a quantification and an assessment of consequences for the populations were not possible. For pelagic and benthic feeders, all areas from Kattegat to Eastern Gotland Basin fail the threshold value for good status with regards to by-catches. Marine mammals show poor status for all populations of harbour porpoise and the three seal species examined. By-catches were assessed quantitatively for the first time, but information from literature suggests no change in status category since the previuos assessment.

8. **THREATENED SPECIES** were most recently evaluated by HELCOM according to the IUCN Red List criteria in 2013. In all, 4% of the 1750 evaluated species were at that time regarded as in danger of becoming extinct in the Baltic Sea. Three species were found to be already regionally extinct in the HELCOM area: two fish, American Atlantic sturgeon (*Acipenser oxyrinchus*) and the common skate (*Dipturus batis*), and one bird, the gull-billed tern (*Gelochelidon nilotica*). Among the 173 taxa assessed, 8 were categorised as critically endangered. 18 taxa were categorized as endangered, 43 as vulnerable, 36 as near threatened, and 37 as data deficient. The red list is planned to be updated by HELCOM in 2024.

9. **THE THREAT STATUS OF HABITATS AND BIOTOPES** in the Baltic Sea is currently in review process in HELCOM, to be included in an updated Red list of Baltic Sea habitats and biotopes by the end of 2024. In the latest HELCOM Red List of underwater biotopes, habitats and biotope complexes of 2013, approximately a quarter of assessed biotopes were red listed, while 73% were classified as least concern. Of biotopes classified by the HELCOM Underwater Biotope and habitat classification system, 59 (28%) were red-listed. The proportion of red listed biotopes was the highest among the benthic aphotic biotopes, compared to the photic or the pelagic zone.

10. **THE BALTIC NETWORK OF MARINE PROTECTED AREAS (MPAS)** currently covers 16.5% of the Baltic Sea. National marine protected areas have been instruments for protection of the Baltic Sea for decades and the first HELCOM MPAs were designated already in 1994. Following adoption of the 2007 Baltic Sea Action Plan (BSAP), the share of protected areas increased to 10.3 percent, making the Baltic Sea the first marine region in the world to reach the target of conserving at least 10 percent of coastal and marine areas, set by the UN Convention on Biological Diversity. Significant increase in spatial coverage is expected in the future.

11. **RESTORATION** in and of the marine environment is an emerging topic in the Baltic Sea. As marine restoration in the Baltic Sea is largely in its infancy, spatially restricted development work is ongoing in some areas, e.g. eel grass restoration in the Kattegatt and restorarion of coastal lagoons in the Bothnian Bay (SwAM 2021, HELCOM ACTION 2021a, Saarinen 2019), and there is no consistent source of information on effort, success rates or trends of restoration in the region. The importance of restortation is likely to increase due to both ecological, management and policy related changes.

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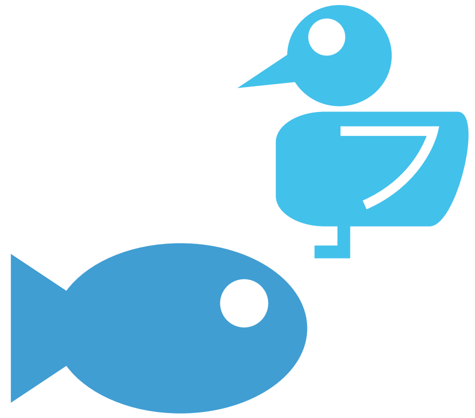

1. Introduction

1.1. Biodiversity in the Baltic Sea

The Baltic Sea is one of the largest brackish water areas in the world, with a surface area of 420,000 square kilometers. The drainage area of the Baltic Sea is about four times larger than its surface area and inhabited by around 85 million people. 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 can improve oxygen conditions in the deeper waters. 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 1.1). 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.

The species diversity in the Baltic Sea is rather low partly because the brackish water in the Baltic Sea imposes physiological stress on both marine and freshwater organisms and partly because geologically the sea is young. There are several examples of genetic adaptation and diversification in the region as a result of

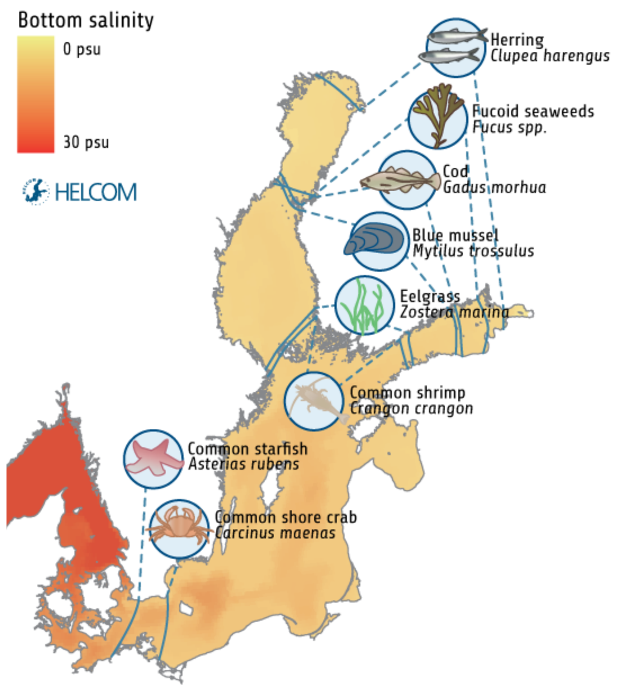

Figure 1.1. The Baltic Sea is characterised by brackish water, and by gradually decreasing salinity from its entrance in the southwest to the inner parts. These conditions also affect the distribution of species. The left figure shows the salinity in different areas of the Baltic Sea and the inner distribution limits of some species of marine origin (cod (Gadus morhua) and herring (Clupea harengus): according to Natural Resources Institute Finland (2017); other species: Furman et al. (2014) and Finnish Environment Institute (2017). (Source: HELCOM 2018a).

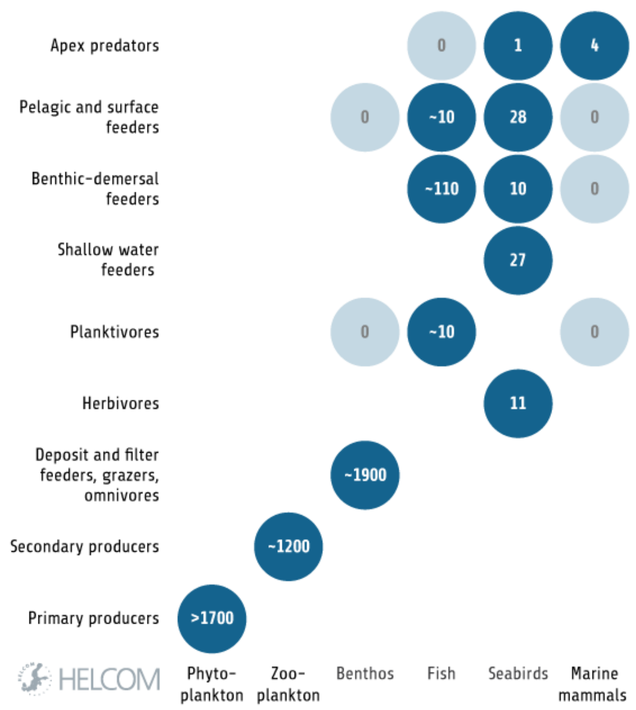

Figure 1.2. Estimated numbers of species in the Baltic Sea. Light blue fields indicate species groups which do not occur in the Baltic Sea, although they are typical to marine waters in general. The numbers are shown in relation to functional groups on the vertical axis and by taxonomy on the horizontal axis. Data sources for phytoplankton and zooplankton: Ojaveer et al. (2010); benthic fauna: HELCOM (2012); fish: HELCOM (2012); birds: ICES (2016a). 'Fish' includes species classified as regularly or temporarily occurring by HELCOM (2012) and are biologically classified based on Fishbase (2017). For marine mammals all three seal species, as well as harbour porpoise is included but Eurasian otter (Lutra lutra) was not included in the original overview. (Source: HELCOM 2018a).

the physiological stress (Johannesson and André 2006). 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 different salinity phases, including both freshwater and marine/brackish water phases (Harf *et al.* 2011). The recent configuration 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). This all influences the number, and composition, of species occurring in the Baltic Sea.

The Baltic Sea has around 5,000 known species, out of which just over 3,000 are macro species, meaning that they are species that are visible to the naked eye (HELCOM 2020b; Figures 1.2, 1.3). The clear majority of these are benthic invertebrates. A substantial pro-

Box 1. What is biodiversity?

Biological diversity, or biodiversity, encompasses the variety of life, how species live together and depend on one another. Biodiversity is used to refer to the variability among living organisms and the ecological complexes of which they are part; this includes diversity within species, among species, and of ecosystems. It also refers to the variation in genetic, phenotypic, phylogenetic, and functional attributes, as well as changes in abundance and distribution over time and space within and among species, biological communities and ecosystems. In the Baltic Sea, this means that biodiversity refers to the species in the region, how they interact and affect each other and how they interact with their environment to make biotopes, i.e. the combination of a or a group of species and their non-living habitat. Every living thing on the planet, including us humans, is involved in complex networks of interdependent relationships we refer to as ecosystems. In a simplified way, biodiversity functions as the building blocks of these systems, with each individual gene, species, each community of species, or function forming a building block. These building blocks come together to create the living part of the environment in the Baltic Sea.

Just as with normal building blocks, for biodiversity the more different building blocks there are, the more different systems can be built and those systems can be bigger and more complex. The Baltic Sea is exceptional, there is no other sea like it in the world and this applies to its biodiversity as well. Thousands of species, and millions of genes, create the unique ecosystem that is the Baltic Sea and jointly structure and maintain it. While it might sound like a lot, in reality this actually represent comparatively few building blocks in relation to most areas around the world. This makes the Baltic Sea simultaneously very important and very vulnerable.

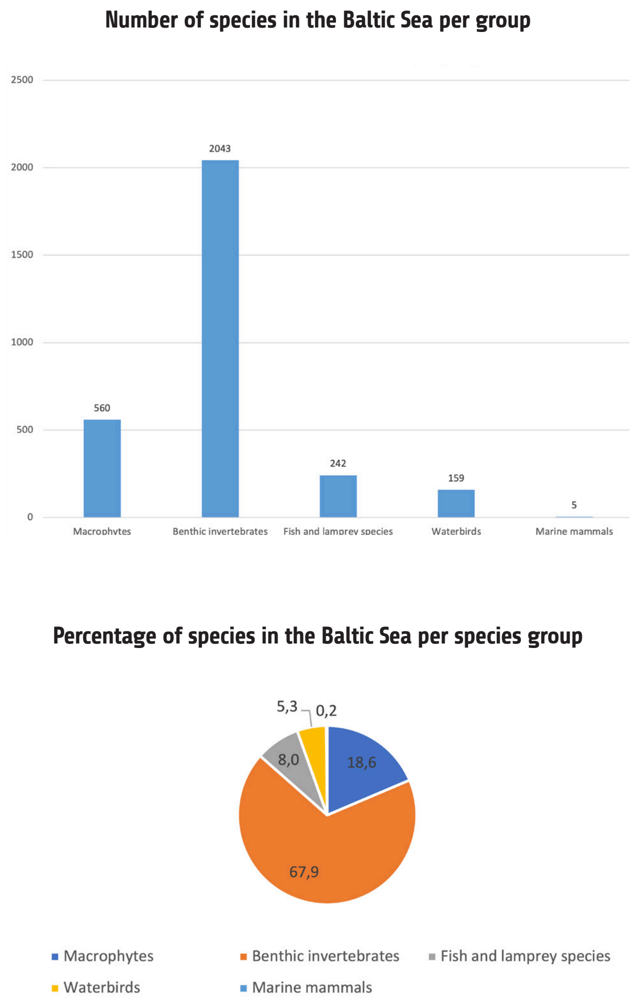

Figure 1.3. Number species in each macro-species group found in the Baltic Sea and proportion of species group as part of Baltic Sea biodiversity. (Source: HELCOM 2020b).

portion of the remaining macro-species are macrophytes, including macroalgae, vascular plants and bryophytes, followed by fish. Phytoplankton diversity includes the currently known planktonic microalgae and cyanobacteria in the Baltic Sea. Diversity of other bacteria except for cyanobacteria is not included.

Clear geographical differences are evident for all species groups, with the number of species decreasing along a south to north gradient (HELCOM 2020b) (an example presenting macro-species can be found in Figure 1.4). 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. Most of the marine species that are present 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. 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 foodweb where marine and freshwater species coexist and interact (HELCOM 2018a). This trend is natural and a result

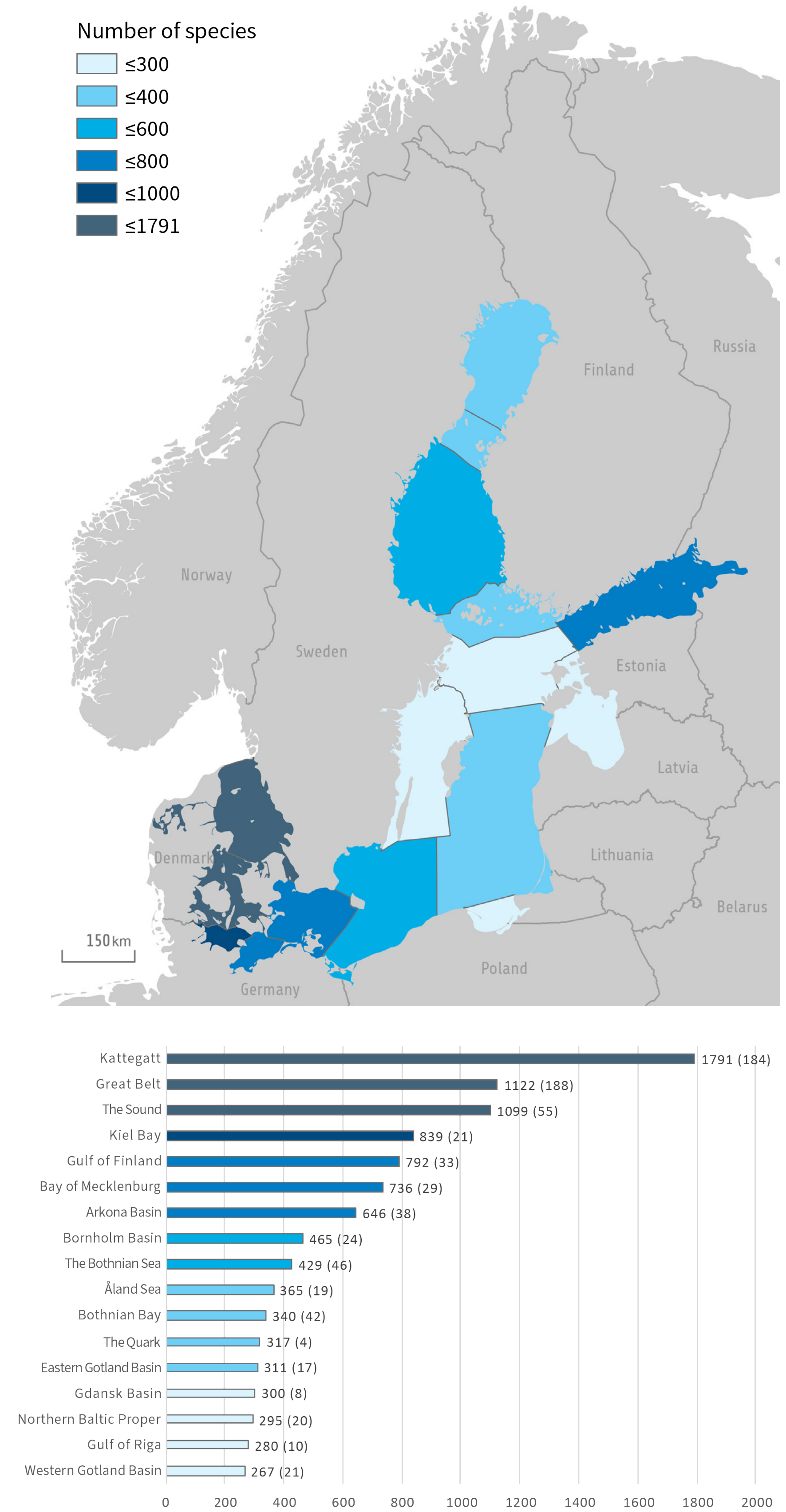

Figure 1.4. Number of macro-species in each sub-basin of the Baltic Sea. (Source: HELCOM 2020b).

of the Baltic Sea's unique salinity gradient and high variability in habitat type. While the Baltic Sea may not be comparatively species rich, the two aspects presented above actually give the Baltic Sea a greater biodiversity and variety of plant and animal life than might be expected. In addition, the species that have adapted to Baltic Sea conditions often appear in relatively high abundance.

As many of the species live on the edge of their tolerance of variation in their living environment, any changes can cause the abundance of the species to alter radically. Accordingly, the structure of the communities and the biodiversity in a region of the Baltic Sea run the risk to change significantly due to even a small change in the environmental conditions (HELCOM 2009).

1.2. Importance of biodiversity for ecosystem health

Biodiversity status is a key indicator of the health of an ecosystem, as biodiversity is essential for the natural processes that support all life. A maintained good state of biodiversity is central for the functioning of healthy ecosystems, to ensure their resilience and productivity, as well as their capacity to adapt to any future environmental changes. Further, we humans, as an integral part of the natural world, are entirely dependent on nature for our survival. People in the Baltic Sea region as well as worldwide depend on biodiversity in their daily lives, in ways that are not always directly apparent or appreciated.

Complexity is an inherent property of viable natural ecosystems, supported by biodiversity.

Each unit and level of biodiversity fulfils a multitude of necessary functions in the complex networks constituting ecosystems. Without a wide range of animals, microorganisms, plants and algae, and populations thereof, we cannot have the healthy ecosystems that we rely on.

In spite of its ecological, cultural and economic importance, biodiversity is however still being degraded and lost in the Baltic Sea region, and the importance of functioning ecosystems for human well-being is too often underestimated, or not fully recognized in planning and decision-making.

1.3. The role of biodiversity in Baltic Sea management

Societal needs, through human activities, cause many pressures on natural marine ecosystems that lead to changes in state (Borja & Dauer 2008), by interfering with environmental status from the local or species scale through to wider geographical scales and entire biological communities and ecosystems (Adams 2005, Österblom *et al.* 2017). The impacts affect the ability of marine systems to maintain ecological functions, but also impairs their capacity to produce ecosystem services in support of human wellbeing (Beaumont *et al.* 2007, Micheli *et al.* 2013, Bryhn *et al.* 2020).

Efforts to manage biodiversity directly have, however, rarely yielded desired outcomes in the past. Due to complex interactions within ecosystems, such actions often result in unexpected and even undesired consequences. However, managing the multiple human activities and pressures influencing the status of ecosystem components is central for supporting biodiversity, through both direct and indirect linkages. Ecosystem-based management, applying an integrated perspective that encompasses the central role of biodiversity in maintaining long-term sustainable ecosystems, is a key tool to achieve a sustainable management of human activities under such conditions (Box 2). Adaptive management (Figure 1.5) can, further, be a particularly good approach when optimal target conditions are unclear, or under changing external environmental conditions, such as under climate change. Adaptive management assumes an iterative approach by which managers work toward agreed biodiversity or ecological goals while simultaneously monitoring and studying the effects and impacts of previous management measures. Hence, adaptive management relies on hypothesis-testing to inform decisions about the preferred management measures in the next stage and, thus, enables revising management goals in light of new information.

It can, however, be challenging to identify what impacts our activities are causing and on what part of the ecosystem, due to the complexity of natural systems. Each biodiversity component in reality can be connected to hundreds of others. To get an idea of which pressures entail the greatest risk for impact on biodiversity, and at what geographical scale, we need to know where and how the pressures and the biodiversity components interact, and what impact these pressures have on their status. This is where an assessment such as HOLAS comes in. Even if the HOLAS biodiversity assessment only touches upon a part of what can be understood under the umbrella of biodiversity, the large amount of data available for the Baltic Sea (HELCOM 2010, 2018b, 2022a, 2023a), give a fairly good understanding of the main pressures on the Baltic Sea, where pressures mainly occur, if they are widespread or local, and what the status of key ecosystem components is in these areas.

Generally, the more pressures that coincide, the higher is the risk for impacts on biodiversity. While management traditionally looks at the pressures individually, there is a clear need for improved understanding of how pressures act and affect a biodiversity component together. The need for stronger action and management of human activities is all the more acute as climate change clearly enhances the risks for marine and coastal ecosystem biodiversity loss (IPCC 2019).

Further, biodiversity loss driven by human activities is among the biggest threats humanity is facing in the next decade (World Economic Forum 2020).

The World Health Organisation (WHO) acknowledges that human health ultimately depends upon ecosystem products and services, and that these are necessary for good human health and productive livelihoods. Biodiversity loss can have significant direct impacts on human wellbeing if ecosystem services are no longer adequate to meet societal needs. Changes in the provision of ecosystem services affect livelihoods both directly and indirectly, through for example impacts on health, incomes, demographic patterns and risks for conflicts. These aspects are also explored in more detail in the Thematic Assessment Report on Economic and Social Analyses (HELCOM 2023b).

On the other hand, restored and properly protected marine ecosystems can bring substantial health, societal and economic benefits to coastal communities (Balmford *et al.* 2002).

Box 2. What is the ecosystem approach?

The ecosystem approach is a form of environmental governance that places ecosystem dynamics at the heart of environmental policy making. The ecosystem approach grounds policy making in a scientific understanding of the environment, viewing an ecosystem is a functional unit or complex of relations in which living organisms which interact with one another and with their physical environment, forming a dynamic yet broadly stable system. The approach places focus on the structure and functioning of the unit as a whole and highlights the fundamental interdependence of the components within it. Each species fulfills certain functions within an ecosystem and depends on interactions with the other components. An important implication is that the degradation of one element of the ecosystem or the reduction of one species could modify the whole ecosystem and subsequently damage other components (or species). In policy-making terms, this translates into the necessity to develop comprehensive integrated policies that protect the ecosystem as a whole by ensuring that none of its components are overexploited or depleted beyond renewable levels.

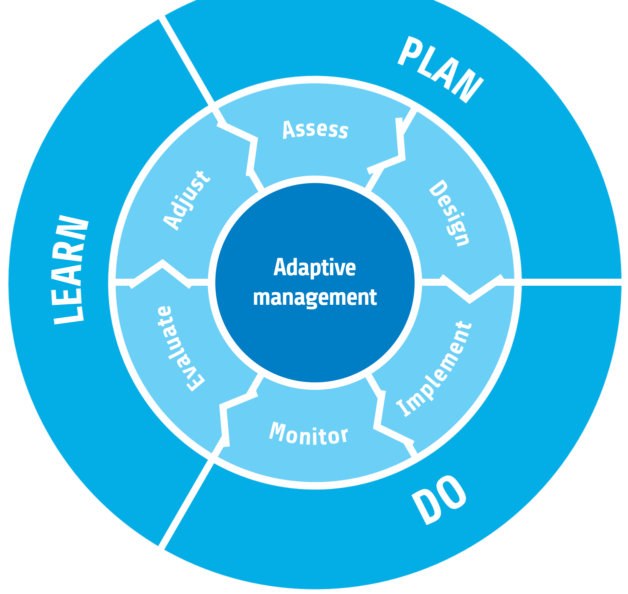

Figure 1.5. Conceptual overview of the adaptive management cycle.

1.4. Biodiversity measures in HELCOM and the Baltic Sea Action Plan

A HELCOM core vision for biodiversity is a healthy Baltic Sea environment with diverse biological components functioning in balance, resulting in good ecological status. Through the actions included in the 2021 Baltic Sea Action Plan (BSAP) the HELCOM Contracting Parties have declared their firm determination to assure the ecological restoration of the Baltic Sea, ensuring the possibility of self-regeneration of the marine environment and preservation of its ecological balance. They have agreed that each country individually, as well as where needed jointly, take all appropriate measures to conserve natural habitats and biological diversity and to protect the ecological processes of the Baltic Sea.

The ultimate goal of the BSAP with respect to biodiversity and ecosystems is that the Baltic Sea ecosystem is healthy and resilient.

This is described through HELCOM's mutually supportive and interlinked ecological objectives of attaining:

— Viable populations of all native species;
— Natural distribution, occurrence and quality of habitats and associated communities;
— Functional, healthy, and resilient foodwebs.

These objectives have been chosen as a representation of the desired state of the environment. A healthy and resilient ecosystem is one which can maintain its species and communities over time, despite external stress. This includes populations with age and spatial distributions corresponding to their natural limits, and key ecosystem functions and processes that are naturally upheld, in an interacting network of species and habitats. A prerequisite to securing the vitality and long-term survival of species and populations is ensuring an adequate quality, distribution and occurrence of natural habitats that can support the communities they host. Each of these key elements strengthen the functionality, health and resilience of the foodwebs, ultimately safeguarding the integrity and long-term sustainability of the ecosystem as a whole.

In order to reach this desired state, the following management objectives are identified for biodiversity:

— Effectively managed and ecologically coherent network of marine protected areas;
— Minimize disturbance of species, their habitats and migration routes from human activities;
— Human induced mortality, including hunting, fishing, and incidental bycatch, does not threaten the viability of marine life;
— Effective and coordinated conservation plans and measures for threatened species, habitats, biotopes, and biotope complexes;
— Reduce or prevent human pressures that lead to imbalance in the foodweb.

The management objectives of the biodiversity segment target both protection and restoration

Achieving the goal and objectives under the biodiversity segment requires management of human activities and the resulting pressures. Thus, an achievement of the goals and objectives of the biodiversity segment is strongly linked to the successful implementation of actions under all other segments.

Table 1.1. Outline of for what 2021 BSAP segment and actions this topic is relevant.

Code	Action
B25	Map ecosystem services and the present and potential spatial distribution of key ecosystem components, including habitat forming species such as bladder wrack, eelgrass, blue mussel and stoneworts Baltic-wide, by 2025.
B26	Protect key ecosystem components including habitat forming species by 2030, by: — assessing the state of, and threats to these key ecosystem components by 2023 — implement effective and relevant threat mitigation measures based on the threat and state assessments, including restricting human activities associated with causing physical loss or disturbance, by 2030 — identifying suitable measures and types of habitats, biotopes and key ecosystem components for passive or active restoration by 2025 and implementing programmes for restoration as outlined in the HELCOM Restoration Action plan by 2030.
B27	By 2025 develop and by 2026 start implementing a HELCOM Action Plan for habitat and biotope restoration, including qualitative and quantitative regional targets, a prioritized list of actions, and an associated implementation toolbox outlining best practices and methods for restoration in the Baltic Sea region.
B28	Update the HELCOM Red List Assessments by 2024, including identifying the main individual and cumulative pressures and underlying human activities affecting the red listed biotopes and habitats.
B29	By 2025 develop, and by 2027 implement, and ensure compliance with, ecologically relevant conservation plans or other relevant programmes or measures, limiting direct and indirect pressures stemming from human activities for threatened and declining biotopes and habitats
B30	Develop tools for and regularly assess the effectiveness of other conservation measures for habitats and biotopes besides marine protected areas (MPAs), with the first assessment to be done by 2025, as well as assess the effect on biotopes and habitats through risk and status assessments by 2029.
B31	Identify by 2022 data needs for spatial pressure and impact assessment of human activities, including cumulative impacts, and implement by 2024 at the latest methods for mapping and assessment of adverse effects on the ecosystem of human activities in the Baltic Sea region.
B32	Update the HELCOM Underwater biotope and habitat (HUB) classification where gaps have been identified by 2024, and by 2025 develop a fully functioning translation matrix between HUB, Marine Strategy Framework Directive (MSFD) broad habitat types, Habitats Directive habitats and the European Nature Information System (EUNIS), in co-operation with the European Marine Observation and Data network (EMODnet).
S64	Enforce and implement by 2025, in line with the update of the marine protected area (MPA) management guidelines, effective management plans and/or conservation measures to not allow destructive and exploitative activities related to the seabed that may compromise the conservation objectives of MPAs.
S65	By 2026 implement a common approach to address and where possible minimize the loss of and disturbance to seabed habitats caused by human activities.
S66	Regularly update and improve the HELCOM Recommendation and Guideline for handling dredged material at sea using the best available knowledge to minimize environmental impact of these activities further developing Best Environmental Practice (BEP) and Best Available Technique (BAT) for dredging and depositing operations.
S67	Define the characteristics of benthic habitats, develop core indicators and undertake an integrated assessment of the status of benthic habitats, including their structure, function, distribution and extent of loss, no later than 2023, leading to the identification of measures to reduce adverse effects where needed. Work should be done in close cooperation with work undertaken by Contracting Parties in other relevant fora, taking into account activities in EU Technical Group on seabed habitats and sea-floor integrity (TG Seabed), and considering the ICES advice on a sea-floor assessment process.
S68	Develop a map service for lost and disturbed habitats under the HELCOM Map and Data Service by 2024

In addition to the Baltic Sea Action Plan, a number of HELCOM Recommendations directly target conservation and improving biodiversity status:

— 15/1 PROTECTION OF THE COASTAL STRIP
— 16/3 PRESERVATION OF NATURAL COASTAL DYNAMICS
— 17/2 PROTECTION OF HARBOUR PORPOISE IN THE BALTIC SEA AREA
— 19/2 PROTECTION AND IMPROVEMENT OF THE WILD SALMON*) (Salmo salar L.) POPULATIONS IN THE BALTIC SEA AREA
— 27-28-CONSERVATION OF SEALS IN THE BALTIC SEA AREA
— 32-33-1 CONSERVATION OF BALTIC SALMON (SALMO SALAR) AND SEA TROUT (SALMO TRUTTA) POPULATIONS BY THE RESTORATION OF THEIR RIVER HABITATS AND MANAGEMENT OF RIVER FISHERIES
— 34E/1 SAFEGUARDING IMPORTANT BIRD HABITATS AND MIGRATION ROUTES IN THE BALTIC SEA FROM NEGATIVE EFFECTS OF WIND AND WAVE ENERGY PRODUCTION AT SEA
— 35/1 SYSTEM OF COASTAL AND MARINE BALTIC SEA PROTECTED AREAS (HELCOM MPAs)
— 37/2 CONSERVATION OF BALTIC SEA SPECIES CATEGORIZED AS THREATENED ACCORDING TO THE 2013 HELCOM RED LIST
— 40/1 CONSERVATION AND PROTECTION OF MARINE AND COASTAL BIOTOPES, HABITATS AND BIOTOPE COMPLEXES CATEGORIZED AS THREATENED ACCORDING TO THE HELCOM RED LISTS

1.5. Overview of the thematic assessment report

As a basis for the further development of the holistic assessment HELCOM has used a version of the Driver-Activites-Pressures-Impacts-Response (DAPSIR) framework, modified to fit the work under HELCOM and address the needs of the holistic assessment. This approach has been taken to strengthen the holistc aspect of the assessment, enabling a clearer picture both of what we know with respect to the interlinkaged across the framwork, as well as were further development or information is needed. In the modified management framework Respons has been substituted with measures, representing the terminology used in the Baltic Sea Action Plan, and the definition of impact has been expanded to represent the two perspectives presented as part of the assessment: impact to the environment and impact on society. The majority of the assessment work focuses on the environmental perspective (HELCOM 2023a, HELCOM 2023c and HELCOM 2023d, as well as this Thematic Assessment report) and the assessments presented under the Thematic Assessment on Economic and Social Analyses (HELCOM 2023b) represents the societal perspective. This modified framework was adopted in 2020 togheter with the HELCOM Indicator Manual (HELCOM, 2020a). It is foreseen that it will undergo further development towards future assessment to ensure still further improved and actionable assessments.

For the purposes of the holistic assessment in HOLAS 3, the assessment of biodiversity status of the Baltic Sea presents results separately for the main species groups: pelagic communities (including phyto- and zooplankton), benthic communities (including macrophytes and benthic invertebrates), fish, waterbirds, and marine mammals. In addition, evaluation results for foodwebs and bycatch of the Baltic Sea are presented. The report primarily focuses on addressing the state of biodiversity, impacts on biodiversity, and how these are related to changes in pressures from human activities (Figure 1.6).

The report also contains dedicated chapters on threatened species and threatened habitats or biotopes in the Baltic Sea. In addition, the report addresses the status of spatial conservation and restoration efforts to improve the status of biodiversity in the region.

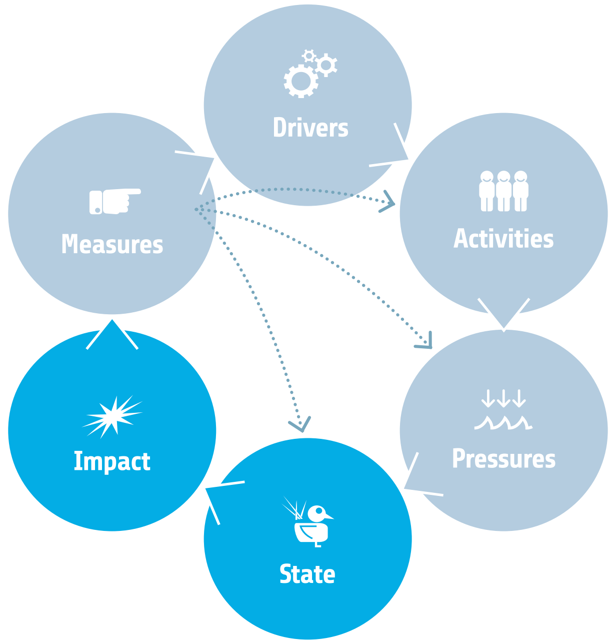

Figure 1.6. Schematic showing what sections of the DAPSIM cycle this assessment focuses on.

All chapters are structured in the same way, as far as feasible. They present key messages, provide background on the topic at hand with a brief explanation on its importance for biodiversity and for management. Assessment results are shown for the assessment period 2016-2021, inlcuding information on confidence in the assessment, evaluations of changes over time, both between assessments and long term, The chapter also presents contextual information on linkages between the topic of the chapter and other parts of the management framework, such as human activities, pressures, and measures. Where possible the latest spatial information has been included. Lastly, each chapter highlights gaps, barriers, or assumptions to suggest development points and points of improvement for future assessments.

2. Overview of the biodiversity assessment approach

2.1. Introduction to biodiversity assessment

With the new core indicators and an updated integrated assessment approach, this assessment represents a milestone in HELCOM development of monitoring and assessment.

2.1.1 Indicator development

The development of HELCOM core indicators (Box 2.1) has progressed further since the previous holistic assessment, (HELCOM 2018a). New indicators are included for the first time in HOLAS 3 and many existing indicators have an expanded geographical coverage or include more species. For assessment of pelagic habitats, the 'Seasonal succession of key phytoplankton groups' indicator (HELCOM 2023e) has been operationalized and is now included in the integrated assessment and the 'Zooplankton mean size and total stock' indicator (HELCOM 2023f) includes more spatial assessment units compared to previous assessments. For the assessment of coastal fish more species are evaluated in the 'Abundance of coastal key fish species' indicator (HELCOM 2023g) and the new indicator 'Size structure of coastal fish' (HELCOM 2023h) is included in the integrated assessment. For the assessment of waterbirds, both the wintering waterbird indicator (HELCOM 2023i) and the breeding waterbird indicator (HELCOM 2023j) cover more species and the integrated assessment is done at a finer spatial scale, compared to the whole Baltic level applied in HOLAS II. For mammals, indicators on abundance and distribution of harbour porpoise (HELCOM 2023k, HELCOM 2023l) have been developed allowing the qualitative assessment of harbour porpoise status. The indicator 'Reproductive status of seals' (HELCOM 2023m) now also includes data for ringed seal in the Bothnian Bay management unit. Further, the indicator 'Number of drowned mammals and waterbirds in fishing gear' (HELCOM 2023n) has been developed allowing evaluation of the bycatch pressure on mammal and

Box 2.1. Core indicators

HELCOM uses core indicators as a way of measuring how the marine environment is doing, i.e. the status of the environment. Researchers involved in HELCOM expert groups have come together to identify threshold values for each indicator. The threshold values define the boundary between good and not good status and have been agreed jointly by all HELCOM Contracting Parties.

The HELCOM indicators build on work over many years and cover several themes. The biodiversity core indicators applied in this assessment signal the status for key species and species groups, addressing for example their abundance, distribution, productivity, physiological or demographic characteristics. In several case, more detailed assessment results can also show how far we are from reaching the threshold values or indicate changes over time.

The thematic assessment of biodiversity gives quantitative results for 29 regionally agreed operational indicators (Table 2.1). For some species, such as harbour porpoise, qualitative information has been used in the integrated assessments, as quantitative information is not available, in order to ensure as comprehensive results as possible. Where qualitative information is included, this was given a lower confidence scoring. Some other assessment elements are only addressed qualitatively at this stage, such as spatial conservation and restoration aspects.

By their nature these HELCOM indicators improve the understanding of the marine environment and have the potential to be of direct relevance within a causal management framework, as the one illustrated in Figure 0.1, their status showing the effect of, and balance between, impacts from human activities and remediating measures, and the natural biogeographical conditions of the Baltic Sea. The evaluations can help guide both policy and management on both a national and regional level. Moreover, the HELCOM indicators provide the Contracting Parties of the Helsinki Convention that are also EU Member States with the possibility to directly address relevant Marine Strategy Framework Directive (MSFD) descriptors and criteria. Similarly, HELCOM indicators can also contribute to other policy initiatives for example supporting the evaluation of relevant United Nations Sustainable Development Goals (UN SDGs).

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.

For more information on HELCOM indicators please see the HELCOM indicator manual (HELCOM 2020a).

Table 2.1. Overview of indicators and other assessment approaches included in the various biodiversity thematic assessment chapters, as well as the indicator type, the type of evaluation and the assessment scale at which the evaluation is done (for more information on assessment scales please see section 2.3.2).

Topic chapter	Indicator (or other approach)	Indicator type/other assessment approach	Evaluation type	Assessment scale	Indicator report
Pelagic habitats (Chapter 3)	Seasonal succession of dominating phytoplankton groups	HELCOM pre-Core Indicator	Quantitative	3	Link
	Diatom/Dinoflagellate index	HELCOM pre-Core indicator (pilot evaluation)	Quantitative	2	Link
	Zooplankton mean size and total stock	HELCOM Core Indicator	Quantitative	2	Link
	Water transparency	HELCOM Core Indicator	Quantitative	4	Link
	Chlorophyll a	HELCOM Core Indicator	Quantitative	4	Link
	Cyanobacterial bloom index	HELCOM pre-Core indicator	Quantitative	2	Link
Benthic habitats (Chapter 4)	State of the soft-bottom macrofauna community	HELCOM Core Indicator	Quantitative	2	Link
	Oxygen debt	HELCOM Core Indicator	Quantitative	2	Link
	Shallow water bottom oxygen	HELCOM Core Indicator	Quantitative	2	Link
	Cumulative impact from physical pressures on benthic biotopes	HELCOM Core Indicator	Quantitative	1x1 km2 grid across assessment scale 1.	Link
	Spatial pressure and impact index	Other assessment approach	Quantitative	1x1 km2 grid across assessment scale 1.	Link
Fish (Chapter 5)	Abundance of coastal fish key functional groups	HELCOM Core Indicator	Quantitative	3	Link
	Abundance of key coastal fish species	HELCOM Core Indicator	Quantitative	3	Link
	Size structure of coastal fish	HELCOM pre-Core indicator	Quantitative	3	Link
	Abundance of salmon spawners and smolt	HELCOM Core Indicator	Quantitative	2	Link
	Abundance of sea trout spawners and parr	HELCOM Core Indicator	Quantitative	3	Link
	Fishing mortality (F/FMSY)	Other assessment approach	Quantitative	ICES assessment units (Subdivisions)	Link
	Stock size (spawning stock biomass)	Other assessment approach	Quantitative	ICES assessment units (Subdivisions)	Link
	Size and age related or demographic aspects of commercial fish	Other assessment approach	Quantitative	ICES assessment units (Subdivisions)	Link
Waterbirds (Chapter 6)	Abundance of waterbirds in the breeding season	HELCOM Core Indicator	Quantitative	2	Link
	Abundance of waterbirds in the wintering season	HELCOM Core Indicator	Quantitative	2	Link
	Breeding success of waterbirds	HELCOM Candidate Indicator	Quantitative	2	Link
	Habitat quality for waterbirds	Other assessment approach	Qualitative	NA	
Marine mammals (Chapter 7)	Distribution of Baltic Grey seals	HELCOM Core Indicator	Quantitative	2	Link
	Distribution of Baltic Ringed seals	HELCOM Core Indicator	Quantitative	2	Link
	Distribution of Baltic Harbour seals	HELCOM Core Indicator	Quantitative	2	Link
	Population trends and abundance of grey seals	HELCOM Core Indicator	Quantitative	2	Link
	Population trends and abundance of ringed seals	HELCOM Core Indicator	Quantitative	2	Link
	Population trends and abundance of harbour seals	HELCOM Core Indicator	Quantitative	2	Link
	Nutritional status of seals	HELCOM Core Indicator	Quantitative	2	Link
	Reproductive status of seals	HELCOM Core Indicator	Quantitative	2	Link
	Harbour porpoise distribution	HELCOM pre-Core indicator	Quantitative/Qualitative	2	Link
	Harbour porpoise abundance	HELCOM pre-Core indicator	Quantitative	2	Link
	Expert-based assessment of the Belt Sea population of harbour porpoises	Other assessment approach	Quantitative/Qualitative	2	Link
Foodwebs (Chapter 8)	(Examples of potential indicator approaches shown)	Other assessment approach	Qualitative	1	Link
By-catch (Chapter 9)	Number of drowned mammals and waterbirds in fishing gear	HELCOM Core Indicator	Quantitative	2	Link
	By-catch risk-area assessment	Other assessment approach	Qualitative	NA	
Threatened species (Chapter 10)	(HELCOM Red List assessment result are shown)	Other assessment approach	Quantitative/qualitative	1	Link
Threatened habitats and biotopes (Chapter 11)	(HELCOM Red List assessment result as shown)	Other assessment approach	Quantitative/qualitative	1	Link
Spatial protection (Chapter 12)	(Baltic Sea MPA network coherence assessment)	Other assessment approach	Qualitative	1	Link
	(MPA management effectiveness assessment)	Other assessment approach	Qualitative	1	Link
Restoration (Chapter 13)	No assessment available	No assessment available	Qualitative	NA	Link

waterbird populations. Table 2.1 gives an overview of indicators included under different topics in the thematic assessment of biodiversity. The dedicated core indicator reports (HELCOM 2023a-ab) give more detailed descriptions of the respective indicators.

2.1.2 Application of the BEAT integrated assessment tool

Box 2.2. What is an integrated assessment?

The HELCOM holistic assessment is a multi-layered product. While the indicator evaluations outlined in Box 2.2 are highly informative on their own, they represent snapshots of individual components of the Baltic Sea ecosystem, or of pressures impacting the environment as a consequence of human activities. However, because a shared reqirement for all the HELCOM indicators is that their underlying monitoring data and evaluation approaches have to be comparable across the Baltic Sea, the individual indicators have the capacity to contribute to broader thematic, integrated and cumulative assessments for the region.

In order to get a more holistic picture of the status of the environment the results of closely related individual indicator evaluations are therefore integrated across topics and themes (Figure B2.2.1).

This is done using agreed methodologies and, where possible, tools have been developed to support the assessment processes. These processes provide ecologically relevant integrated assessments which are presented in thematic assessment reports such as this one. When integrated and agglomerated in a holistic manner these independent components can provide support for an ecosystem-based evaluation of status over a given time period. When these assessments are regularly updated over longer time periods it enable trends to be documented, and allows us to identify improvements towards achieving good status. In doing so these assessments evaluate progress towards the goals and objectives of the Baltic Sea Action Plan (BSAP) and provide the Contracting Parties of the Helsinki Convention with an approach towards their vision to improve the environmental status of the Baltic Sea.

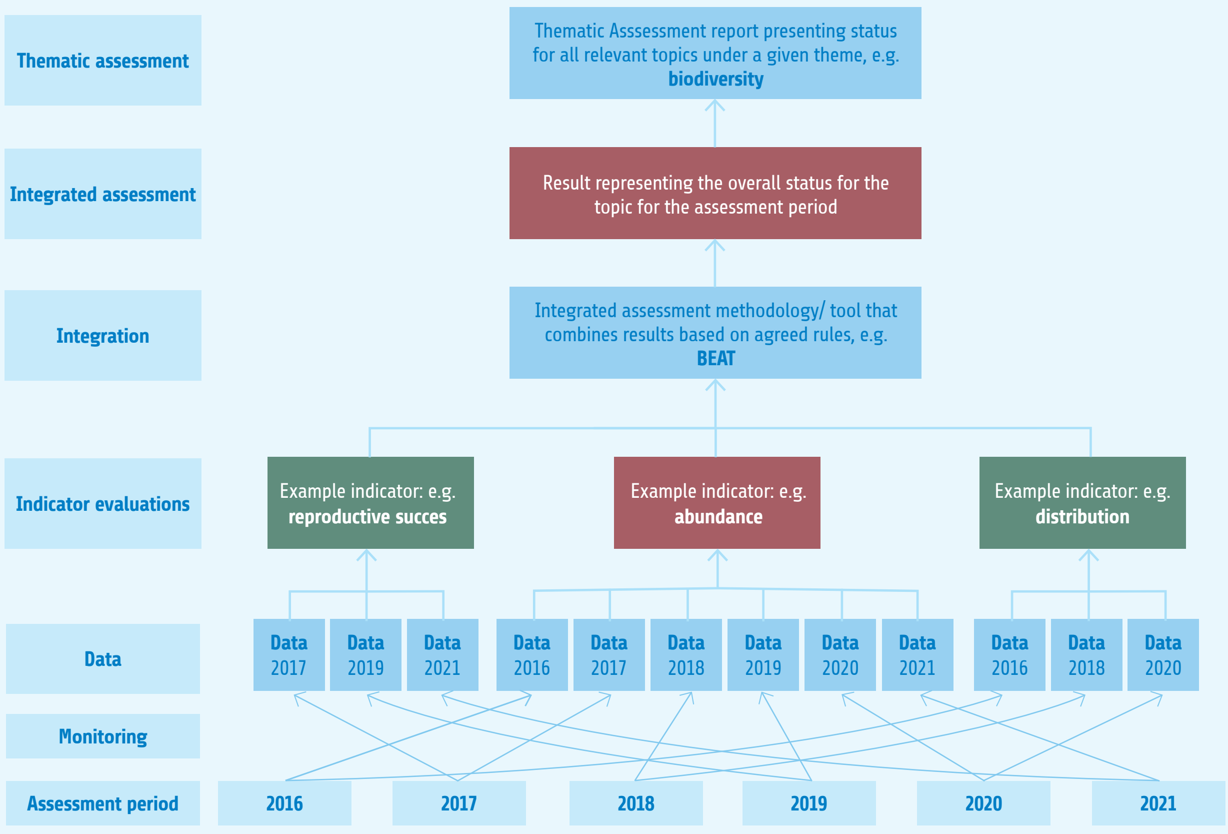

Figure B2.2.1 Conceptual overview of the logic of integrated assessments. conceptual example used red and green to show theoretical failure or achievement of threshold values.

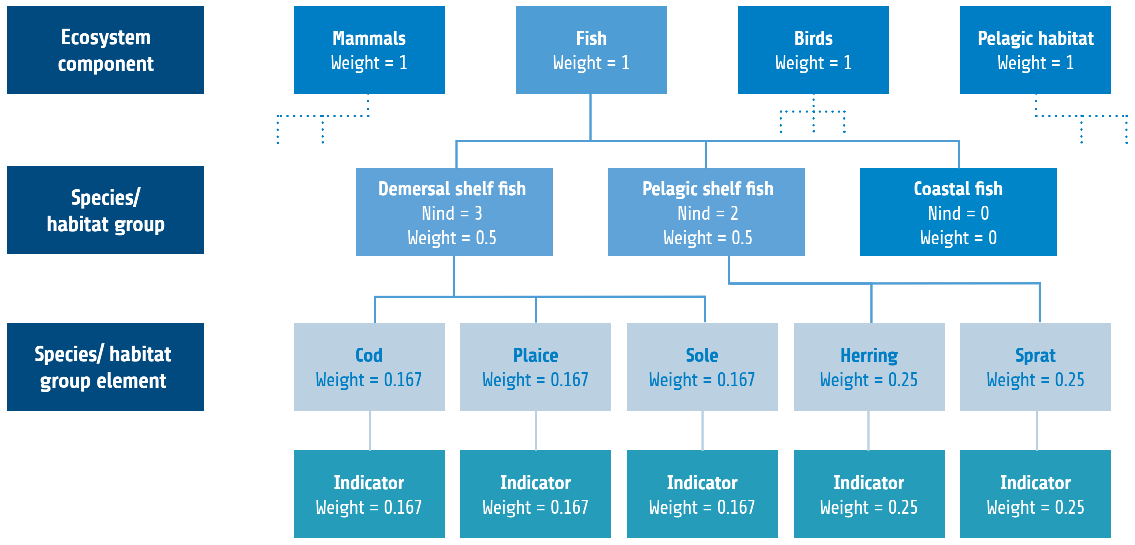

Figure 2.1. An example of the BEAT ecosystem component structure, illustrating how indicators are assigned to the ecosystem elements and how the weight is distributed to indicators and ecosystem elements in the integrated assessment.

Box 2.3. The HELCOM Biodiversity Assessment Tool (BEAT)

The integrated assessment of biodiversity was carried out using the HELCOM BEAT 4.0 tool. The tool integrates individual biodiversty indicator results into estimates of the overall status of each ecosystem component. To accommodate for the different types of indidcators in HELCOM, the tool can handle various types of indicators: monotonic, unimodal, conditional and trend indicators. This is made possible by normalizing the indicators and calculating the distance to the threshold value, so that results for different indicators are comparable.

The first version of BEAT was developed for the first HELCOM holistic assessment (HELCOM 2009, 2010). At that time, one restriction to the assessment was the lack of commonly agreed Baltic-wide indicators. The first version of BEAT relied on indicators for which an acceptable deviation from a reference condition was defined to assess the status. The assessment was based on a set of national case studies, with the aim to present the concept and to initiate a further development of regional indicators and integrated assessments. Due to the development that has followed with respect to both indicators and the assessment approach, it is not possible to directly compare the integrated assessment results from HELCOM (2009) with result for the 2011-2016 assessment period (HELCOM 2018c) or the results presented in this report. The original BEAT tool was later developed into a wider range of purposes, including to better comply with the requirements of the EU Marine Strategy Framework Directive (Andersen et al. 2014). After a review of existing methods, the original BEAT and the related NEAT (Nested environmental status assessment tool) (Berg et al. 2016), were used as the basis for this development. The hierarchical nested structure and integration rules of these tools are also an important feature of the biodiversity assessment tool used in this iteration of the HELCOM holistic assessment.

The integrated assessments of biodiversity status that are presented in the chapters 3,5,6,7 and 9 of this report were carried out using the BEAT tool. The basic methodology was the same as under HOLAS II (HELCOM 2018c, Nygård et al. 2018), however some modifications were made in the nesting structure (explained further below). The BEAT tool integrates individual indicator results into estimates of the overall status of defined ecosystem components. The integrated assessment of biodiversity status was carried out separately for the ecosystem component groups of pelagic habitats, fish, mammals, and water birds. The integrated assessment of benthic habitats is done using the HELCOM Spatial Pressures and Impacts tool (SPIA). The methodology is presented in Chapter 4 and the tool itself is presented in the HOLAS 3 Thematic Assessment Report on Spatial distribution of pressures and impacts in the Baltic Sea (HELCOM 2023a).

In the BEAT tool, each indicator is assigned to its relevant species group or species. The integrations in BEAT follow a hierarchical, nested structure (Figure 2.1). The integration structure is balanced, so that all species groups or species at the same level are weighted equally, regardless of the number of indicators. Only species groups and species for which indicators are available are included in the assessment.

While the default integration rule in BEAT is weighted averaging, the integrations of indicators for HOLAS 3 were adjusted as suitable for the different ecosystem components to more closely follow EU guidance in relation to the MSFD (European Commission 2022) and the Habitats' Directive. Integration steps for each of the ecosystem component are presented in more detail in the respective chapters (3, 5-7).

For spatial representation, BEAT uses the hierarchical structure of HELCOM spatial assessment units (See Section 2.3). Indicator results are presented at their ecologically relevant spatial scales. This generally also reflects the ecologically relevant scale for presenting the integrated results. Spatial aggregations were not needed for fish, water birds or marine mammals (Chapters 5-7), while indicator results for pelagic habitats were integrated using area-based weighting (Chapter 3).

Normalization of indicators under BEAT

The BEAT tool uses so called biological quality ratios (BQR) in the integration process. The biological quality ratios scale the indicators so that they can be comparable with each other in the same assessment, as the indicators are originally assessed by a variety of assessment approaches and measured by different units. For calculation of the biological quality ratios, normalization of the indicators is needed. BEAT normalizes all indicator results to a common scale from 0 to 1, setting the threshold value at 0.6. Biological quality ratios are presented in five equal-distance categories between 0 and 1, where values above 0.6 are interpreted as reflecting good status.

For the normalization, the minimum and maximum values of the indicators were used, as provided by the indicator expert based on common guidance. Identifying the minimum and maximum values is a key issue for a meaningful normalization. When indicator data cover the whole potential range of indicator values possible, the definition of the minimum and maximum values is straightforward. This is, however, not always the case and instructions for definition of minimum and maximum values were provided for cases where the full range of potential indicator values are not available (Figure 2.2). For some indicators minimum and maximum values cannot be defined. For example, assessment results for trend-based indicators and indicators presented only as achieving or not achieving the threshold value a decision tree was used to define the assessment value for BEAT based on four classes (Figure 2.3). In cases where the distance to the threshold could not be defined, the assessment values were presented as 0.25 (not achieving) or 0.75 (achieving the threshold value), with the threshold value set to 0.5. For the integrated assessment of commercial fish, a four-class scale was also applied as reference values for commercial fish assessment are not defined in order to likely be exceeded by a high probability. For commercial fish the number of years within the assessment period in which the threshold value was achieved was used to inform the classification (Table 2.2). Where indicators use a conditional approach, meaning that several parameters were evaluated in the indicator results, the parameter with the lowest BQR value was used in the integration process.

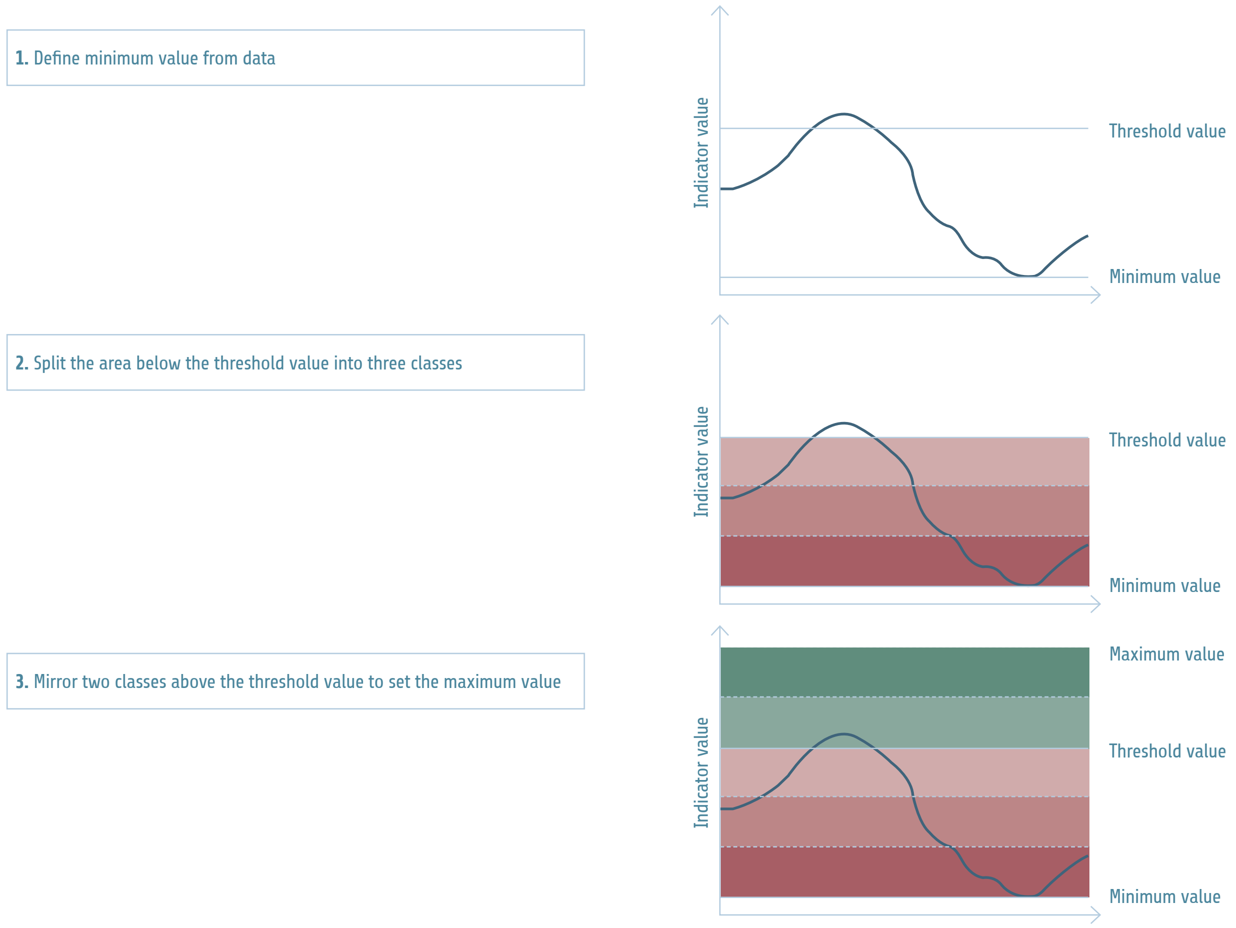

Table 2.2. Classification of indicator results for commercial fish.

How to define status and input value to BEAT 3.0 for trend indicators

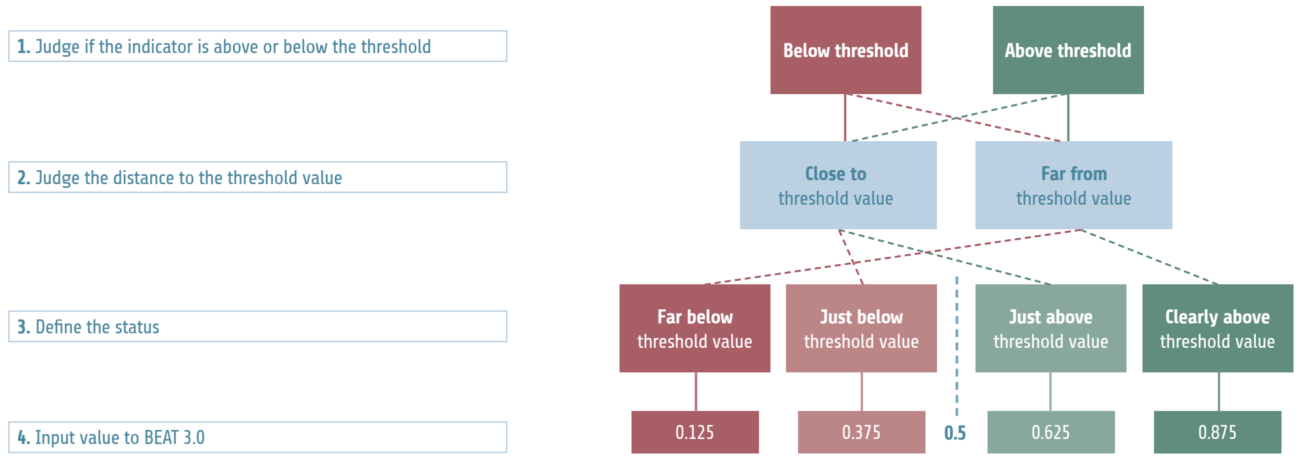

Figure 2.3. Classification of indicator results for trend indicators and qualitative indicators when the distance to the threshold value can be estimated.

Table 2.2. Classification of indicator results for commercial fish.

Value used	Definition
0.125	Threshold value not achieved in any of the years
0.375	Threshold value not achieved for the average of all years, but achieved in at least one of the years
0.625	Threshold value achieved for the average of all years, but not achieved in at least one of the years
0.825	Threshold value achieved in all years

Confidence assessment in BEAT

The BEAT tool produces an integrated confidence assessment in parallel to the status assessment. The confidence rating is based on estimates of confidence in the underlying indicators, as provided by the indicator experts. The integrated confidence is calculated following the same assessment structure as for the corresponding status assessment, however applying weighted averaging in the integration. Thus, the confidence assessment is a result of all included indicators and not only the indicator or component driving the one-out-all-out approach, where relevant.

For estimating confidence in the underlying indicators, the experts on each indicator were asked to consider four confidence aspects and classify these into 'high', 'intermediate' or 'low', for each assessment unit (Table 2.3). The experts were asked to as far as possible base their answers on quantitative information. To enable the integration, the confidence estimates originally provided in categorical form (as low, intermediate and high) were translated into numerical values (0, 0.5 and 1), where higher values mean higher confidence. BEAT first averages the categories per indicator and then integrates the confidence result to a single confidence score according to the relevant integration structure. When presenting the results, confidence scores below 0.5 were classified as low, from 0.5 up to and including 0.75 as intermediate and above 0.75 as high.

Subsequently, the overall integrated confidence is given by additionally considering how well the total set of indicators represents important species and species groups for the assessed ecosystem component. A penalty was applied if a critical species group was not represented by an indicator in the assessment unit, for example due to lack of agreed indicator or data. Definitions of penalties applied are presented in Table 3.

For the assessments of benthic habitats and foods webs dedicated integrated assessment methodology has been used. Results for commercial fish were obtained from the International Council for Exploration of the Sea (ICES).

Output of the BEAT tool

The BEAT tool generates output tables for the integrated assessment of biological status and the confidence assessment. The results for each assessment unit and ecosystem component level are given as one row. The output gives the integrated biological quality ratio (BQR score) per ecosystem component level. The integrated confidence output follows the same structure. When presenting the results in maps, the resulting integrated scores are classified into status categories as outlined in Table 2.3, and confidence categories as shown in Table 2.3 above. For assessment results at the border between two categories, the higher score is used, as based on BQR scores or confidence scores given with two decimals.

Table 2.3. Aspects considered in the assessment of confidence in the integrated assessment of biodiversity using BEAT, and definitions for 'high', 'intermediate' or 'low' confidence.

Confidence aspect	High	Intermediate	Low
Confidence of classification (Estimated **accuracy** of the indicator result, for example the precision of the estimate in relation to the threshold value. The tool also allows for entering standard error values)	The indicator assessment result is considered correct with at least 90 % probability	The indicator assessment result is considered correct with between 70 and 90 % probability	The indicator assessment result is considered correct with less than 70 % probability
Temporal coverage (How well does the data cover inter-annual variability during the assessment period)	Monitoring data is available for all years of the assessment period. For indicators that do not show variability between years, the temporal monitoring requirements are met.	Monitoring data is available for more than three years of the assessment period.	Monitoring data is available for one or two years of the assessment period.
Spatial representation (How well does the indicator data cover spatial variation within the assessment unit)	Data represents the whole assessment unit in a reliable way (at least 80 % of the relevant habitat types occurring in the area are covered, or in cases with a clear spatial gradient or patchiness, the monitoring covers at least 80 % of this variation).	The data represents between 60 and 80 % of the relevant habitat type, or between 60 and 80 % of the spatial variation or patchiness in the assessment unit.	The data represents less than 60 % of the relevant habitat type, or less than 60 % of the spatial variation or patchiness in the assessment unit.
Methodological confidence (Quality of the monitoring methodology)	The monitoring has been conducted according to HELCOM guidelines for parameters where these are available, and the data is quality-assured according to HELCOM or other internationally accepted guidelines.	The monitoring data has been collected only partly according to HELCOM guidelines or originates from mixed sources. The monitoring is partly quality-assured according to HELCOM or other international standards or by national/local standards.	The monitoring has not been conducted according to HELCOM guidelines, has not been quality-assured, or the methodological confidence is considered bad for some other reason.

2.2. Overview of data collection and monitoring

To be able to assess the actual effects the measures taken to limit the negative impact of human activities have on the marine environment there is a need to access extensive temporal and spatial monitoring data, collected in a comparative fashion for the entire region, in order to get as accurate an overview of progress as possible. HELCOM strives to account for this through regionally agreed monitoring programmes. Environmental monitoring is a well-established function in HELCOM, with countries following commonly agreed procedures and collating data in centralized databases.

Monitoring of physical, chemical and biological variables of the Baltic Sea open sea area started already in 1979 and monitoring of inputs of nutrients and hazardous substances was initiated in 1998. Today there are 40 agreed HELCOM monitoring programmes covering sources and inputs of human pressures and various variables reflecting the state of the environment. HELCOM monitoring programmes are compiled in the HELCOM Monitoring Manual and supported by over 40 monitoring guidelines, outlining how monitoring should be implemented and carried out. Both the monitoring programmes and the guidelines are periodically reviewed to ensure they remain current. The following monitoring programmes are of direct relevance for the assessments presented in this report:

- HELCOM monitoring programme Coastal fish
- HELCOM monitoring programme Fisheries by-catch
- HELCOM monitoring programme Marine Bird Health:
- HELCOM monitoring programme marine mammals health status;
- HELCOM monitoring programme Harbour porpoise abundance
- HELCOM monitoring programme Hardbottom species
- HELCOM monitoring programme Marine breeding birds abundance and distribution
- HELCOM monitoring programme Marine wintering birds abundance and distribution
- HELCOM monitoring programme Phytoplankton species composition, abundance and biomass
- HELCOM monitoring programme Seabed habitat physical characteristics
- HELCOM monitoring programme seal abundance
- HELCOM monitoring programme Softbottom fauna
- HELCOM monitoring programme Softbottom flora
- HELCOM monitoring programme Zooplankton species composition, abundance and biomass
- HELCOM monitoring programme Offshore fish
- HELCOM monitoring programme Habitat forming species and substrates

The monitoring is implemented by each of the HELCOM Contracting Parties, i.e. the countries bordering the Baltic Sea. The HELCOM monitoring programmes are the source of data for indicator-based assessments of the state of the marine environment, pressures on the marine environment, as well as the analysis of long-term trends.

Current monitoring and assessment activities are guided by the HELCOM Monitoring and Assessment Strategy which was adopted in 2013, last amended in 2022. The HELCOM Monitoring Manual in turn was developed to support the implementation of the HELCOM Monitoring and Assessment Strategy (HELCOM 2013a). Principles of the HELCOM Monitoring and Assessment Strategy are as follows:

- National monitoring programmes use the principles of the Joint Monitoring System to achieve a high degree of coordination, cooperation, sharing and harmonization.
- The Joint Monitoring System feeds a Data Pool that is the basis for the Assessment System.
- This system produces assessments of the health of the Baltic Sea that can be used by HELCOM countries as well as EU, observers, stakeholders, etc.

HELCOM cooperates with several international organizations to deliver and store monitoring data and information, including the Co-operative Programme for the Monitoring and Evaluation of Long-range Transmission of Air Pollutants in Europe (CLRTAP/EMEP), the International Council for the Exploration of the Sea (ICES), the European Environmental Agency (EEA), and the International Atomic Energy Agency (IAEA).

2.3. Assessment scales

2.3.1 Temporal scale

Each HELCOM holistic assessment covers a timespan of six years, referred to as the assessment period. The current HOLAS 3 assessment focuses on the time period 2016–2021. Hence, the HOLAS 3 assessment period partially overlaps with that of HOLAS II, which covered 2011–2016 (HELCOM 2018a). The first HOLAS (HELCOM 2010) covered years 2003-2007.

In addition, data showing more long-term temporal development have been provided in order to understand long-term trends and evaluate the direction of ongoing changes.

2.3.2 Spatial scales

The HELCOM spatial assessment units are a key tool to perform regional assessments in a coherent way across such a wide variety of topics and features as in HOLAS, while still ensuring that each topic can be assessed at a scale that is ecologically relevant. For the purposes of assessment, HELCOM applied a spatial division of the Baltic Sea into assessment units on five different levels of scale.

- Level 1. HELCOM Marine area 2022. No division: the whole Baltic Sea encompassing the entire HELCOM area,
- Level 2. HELCOM Subbasins 2022. Division of the Baltic Sea into 17 sub-basins,
- Level 3. HELCOM Subbasins with coastal and offshore division 2022. Division of the Baltic Sea into 17 sub-basins and further division into coastal and off-shore areas,
- Level 4a. HELCOM Subbasins with coastal WFD water types of water bodies 2022. Division of the Baltic Sea into 17 sub-basins and further division into coastal and off-shore areas and division of the coastal areas by WFD water types or water bodies.
- Level 4b. HELCOM Subbasins with coastal WFD water types of water bodies 2022 for eutrophication. Division of the Baltic Sea into 19 sub-basins and further division into coastal and off-shore areas and division of the coastal areas similarly as in Level 4a by WFD water types or water bodies with specific subdivisions for eutrophication

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To the extent possible the assessment units are nested, i.e. units with higher spatial resolution can be nested into units with lower spatial resolution in order to allow for comparison across evaluation and assessments which is done at different scale. The assessment units can also be further aggregated within one assessment scale. For example, several sub-basins at scale taken together may comprise the assessment unit with respect to a certain topic. This approach is applied for example in the case of core indicators representing the abundance and distribution of seal populations. Maps showing the delineation of assessment units at each of these scales are presented in attachment four of the HELCOM Monitoring and Assessment Strategy (HELCOM 2013a), as part of HELCOM Joint Coordinated Monitoring System and in detail in attachment 4 “HELCOM Subdivisions of the Baltic Sea”.

The scale at which each assessment is done is dependent on the environmental issue that is being assessed, e.g. for eutrophication or contaminants higher resolution is possible whereas highly mobile marine mammals or birds, which move across large areas, require more coarse scale of the assessment to capture their true distribution.

3. Results for the pelagic habitats assessment

Assessment results in short

- None of the fourteen assessed open sea sub-basins have good status, when combining results for phytoplankton and zooplankton. The status is most deteriorated from the northern Baltic proper up to the Bothnian Bay, and for the Bothnian Bay the integrated assessment results show a clearly deteriorated result compared to previous assessments of the same area. The mean size of zooplankton has increased in some of these areas, which is positive, but the status of phytoplankton is not good.
- Four out of thirteen assessed coastal areas had good status with regards to phytoplankton. The status had changed since the previous assessment for some biological components. Coastal areas are only assessed by phytoplankton indicators.
- The status of zooplankton has improved in the Åland Sea, where their mean size and total biomass have increased. In the Bothnian Bay, zooplankton mean size is in good status, but the total biomass has decreased below the threshold value.
- Phytoplankton seem to follow the desirable seasonal succession in the Arkona Basin, and at some coastal stations.
- None of the open sea or assessed coastal areas had good status from the eutrophication perspective, when also taking the eutrophication indicators into account.

3.1. Introduction to pelagic habitats in the Baltic Sea

The open water column is the key setting for productivity in the Baltic Sea (Figure 3.1). The function of the pelagic habitat is not only dependent on productivity but also the species composition and size structure of the system. The primary producers, the phytoplankton, form the base of the pelagic foodweb. They directly support the growth of species at higher trophic levels being food for zooplankton and benthic animals, or indirectly via the microbial loop. A rough estimation of total phytoplankton biomass commonly used is chlorophyll a content that all phytoplankton contain. The total chlorophyll content does not distinguish between differences in functionality among different phytoplankton, which is important for their role in the foodweb. The major groups of phytoplankton in the Baltic Sea are diatoms, dinoflagellates and cyanobacteria, together with the common ciliate species *Mesodinium rubrum* all with different functions in the system. Phytoplankton blooms are a natural phenomenon in the Baltic Sea ecosystem, with yearly spring blooms dominated by dinoflagellates and diatoms and blooms in late summer dominated by nitrogen-fixing cyanobacteria. However, due to eutrophication the phytoplankton blooms in summer are becoming more frequent and extensive (Vahtera *et al.* 2007).

In open sea areas of the Baltic Sea, herbivorous zooplankton are represented by small crustaceans and several other animal groups, with cladocerans and copepods dominating the total zooplankton biomass. As zooplankton are the main prey for many fish; zooplankton production is of key importance for higher trophic levels in all pelagic habitats. Moreover, the size structure of zooplankton is important for the energy flow in the foodweb because large grazers, such as adult copepods and cladocerans have a higher capacity to consume phytoplankton, being also a preferred food for zooplanktivorous fish.

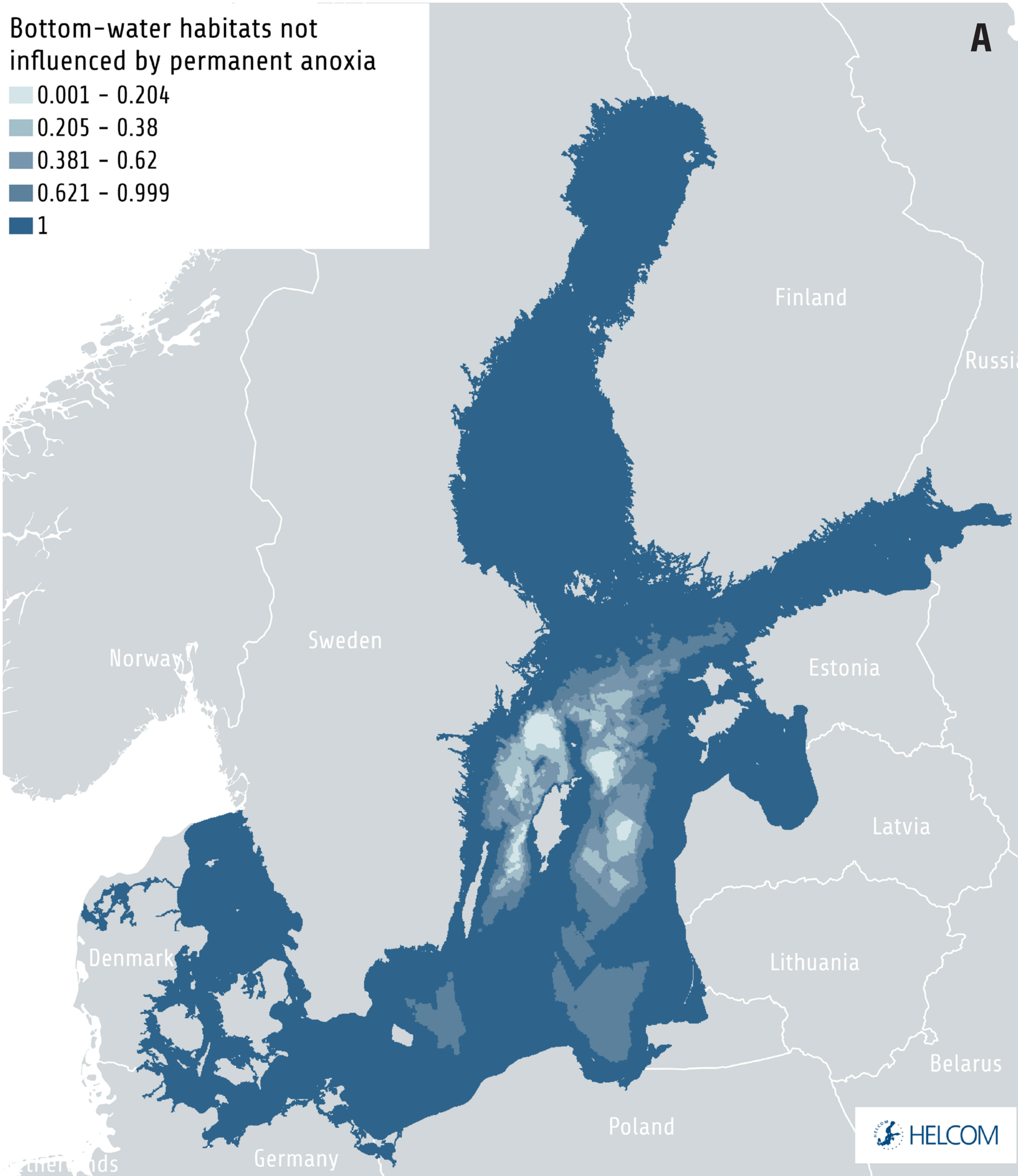


Figure 3.1. Pelagic habitats embody productive surface waters (Chl-A) and deep-water habitats not influenced by permanent anoxia (H2S). On figure A, deep water habitats not influenced by permanent anoxia. On figure B, productive surface waters. Deep-water habitats not influenced by permanent anoxia highlights the suitability of bottom areas for Baltic Sea biota, with regards to the near bottom areas, based on occurrence of hydrogen sulphide (H2S). The lower the value the more the habitat is influenced by permanent anoxia, and thus value 1 indicates areas where the bottom habitats are not influenced. The data were provided by the Leibniz Institute for Baltic Sea Research Warnemünde (IOW), and is based on point measurements and modelling. Data was based on five periods per year, for the 2 years 2016-2021. Productive surface waters uses Springtime Chl-a concentration as a proxy for productive surface waters. Areas with higher production are given higher importance, as they are considered important areas for the Baltic Sea food web. The dataset was prepared by Finnish Environment Institute. Both datasets have been normalised. Pelagic habitats layers as produced by the spatial pressures and impacts (SPIA) tool for HOLAS 3 (For further details about the processing of both datasets see Annex 2 in HELCOM 2023a). (Source: HELCOM 2023a).

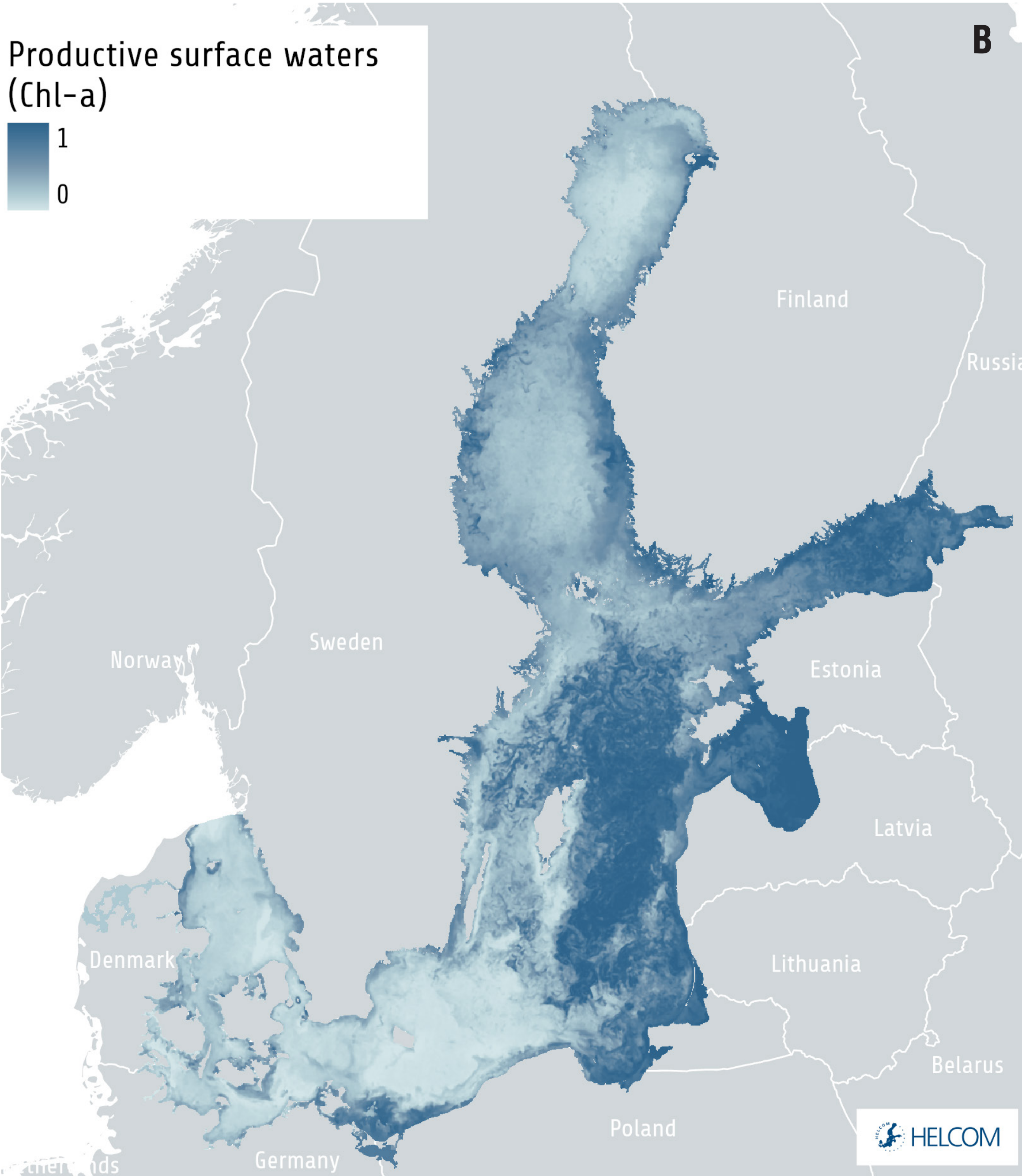


Figure 3.1. (continued). Pelagic habitats embody productive surface waters (Chl-A) and deep-water habitats not influenced by permanent anoxia (H_2S). On figure A, deep water habitats not influenced by permanent anoxia. On figure B, productive surface waters. Deep-water habitats not influenced by permanent anoxia highlights the suitability of bottom areas for Baltic Sea biota, with regards to the near bottom areas, based on occurrence of hydrogen sulphide (H_2S). The lower the value the more the habitat is influenced by permanent anoxia, and thus value 1 indicates areas where the bottom habitats are not influenced. The data were provided by the Leibniz Institute for Baltic Sea Research Warnemünde (IOW), and is based on point measurements and modelling. Data was based on five periods per year, for the 2 years 2016-2021. Productive surface waters uses Springtime Chl-a concentration as a proxy for productive surface waters. Areas with higher production are given higher importance, as they are considered important areas for the Baltic Sea food web. The dataset was prepared by Finnish Environment Institute. Both datasets have been normalised. Pelagic habitats layers as produced by the spatial pressures and impacts (SPIA) tool for HOLAS 3 (For further details about the processing of both datasets see Annex 2 in HELCOM 2023a). (Source: HELCOM 2023a).

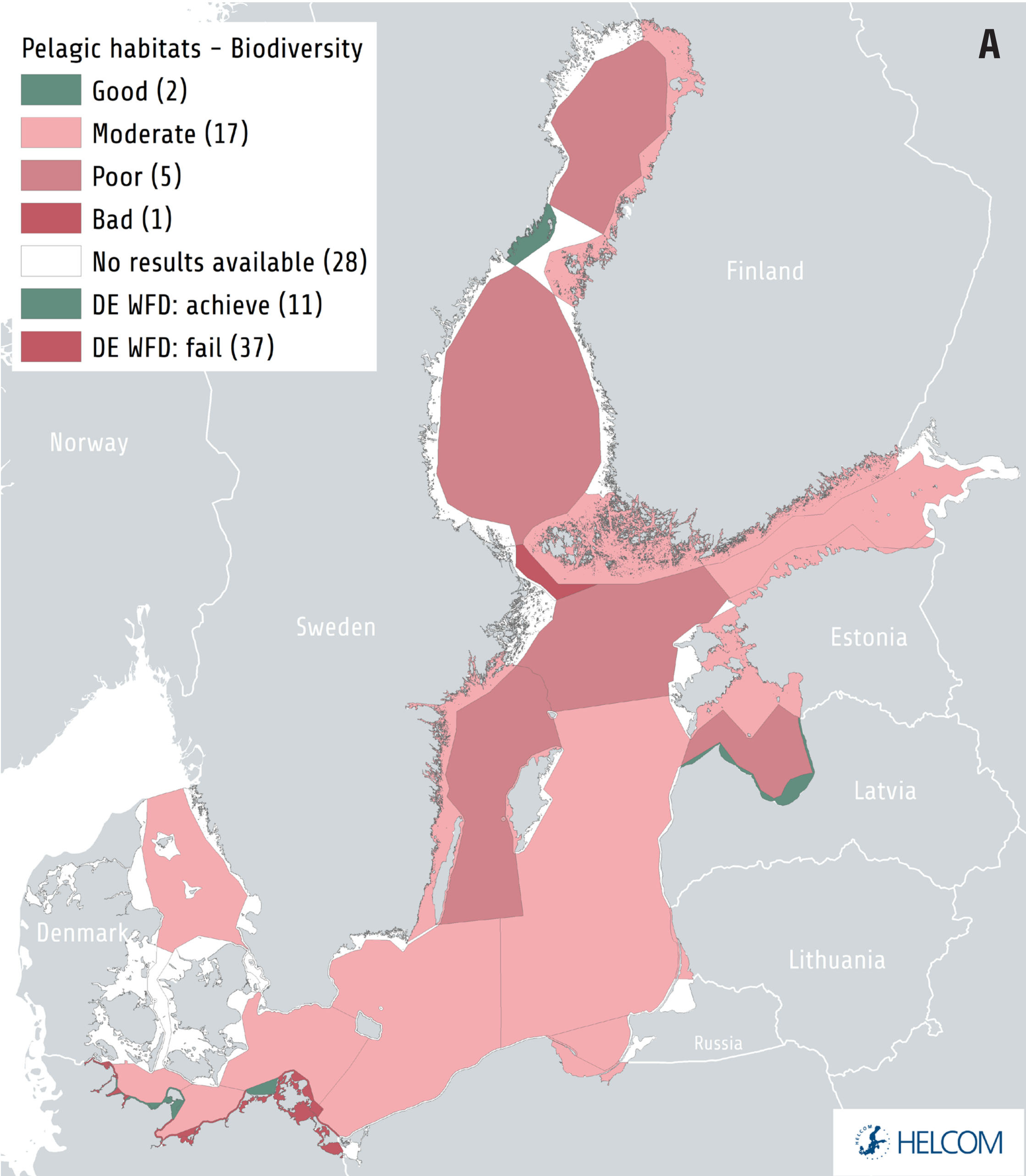
3.2. Assessment results for pelagic habitats

3.2.1 Integrated assessment results for pelagic habitats

The integrated status of pelagic habitats is shown in Figure 3.2 and Table 3.1. The integrated assessment is based on the indicators and indicator evaluation results presented in Section 3.2.2 below. More information on the assessment methodology and approach can be found in Chapter 2 (BEAT methodology) and in Annex 1 (Methodology manuals).

Table 3.1. Results of the integrated assessment of the biological components of the pelagic habitats integrated assessment. The column "Sub-basin" referes to the agreed name of each individual assessment area. "Spatial assessment unit level" indicates at what spatial resolution the assessment was conducted (see Section 2.3.2 or the HELCOM Monitoring and Assessment Strategy for more information on the assessment units used for HELCOM assessments). "Biological Quality Ration" represents the quantitative results of the integrated assessment for the topic, with results >0.6 constituting Good Status (see Section 2.1.1 for more information on the BEAT tool). The column "Status" indicates whether the quantitative assessment results achieve of fail the threshold for good status. The columns"Confidence" and "Confidence Class", respectivey, provides a quantified value for confidence in the assessment and translates this value into a discreet confidence class, in line with the methodology outlined in Section 2.1.1.

Sub-basin	Spatial assessment unit level	Biological Quality Ratio	Status	Confidence	Confidence Class
Kattegat – Open sea	3	0.6	not good	0.75	Intermediate
Kiel Bay – Open sea	3	0.5	not good	0.75	Intermediate
Kiel Bight German Coastal waters	3	0.6	good	0.75	Intermediate
Bay of Mecklenburg – Open sea	3	0.5	not good	0.75	Intermediate
Mecklenburg Bight German Coastal waters	3	0.6	good	0.88	High
Arkona Basin – Open sea	3	0.5	not good	0.94	High
Bornholm Basin – Open sea	3	0.4	not good	0.74	Intermediate
Gdansk Basin – Open sea	3	0.5	not good	0.63	Intermediate
Gdansk Basin Polish Coastal waters	3	0.6	not good	0.88	High
Eastern Gotland Basin – Open sea	3	0.4	not good	0.84	High
Eastern Gotland Basin Lithuanian Coastal waters	3	0.6	not good	0.88	High
Western Gotland Basin – Open sea	3	0.4	not good	0.81	High
Western Gotland Basin Swedish Coastal waters	3	0.5	not good	0.75	Intermediate
Gulf of Riga – Open sea	3	0.4	not good	0.84	High
Gulf of Riga Estonian Coastal waters	3	0.5	not good	0.88	High
Gulf of Riga Latvian Coastal waters	3	0.6	good	0.75	Intermediate
Northern Baltic Proper – Open sea	3	0.2	not good	0.81	High
Gulf of Finland – Open sea	3	0.3	not good	0.81	High
Gulf of Finland Finnish coastal waters	3	0.6	not good	0.88	High
Gulf of Finland Estonian Coastal waters	3	0.5	not good	0.88	High
Åland Sea - Opensea	3	0.2	not good	0.69	Intermediate
Åland Sea - Archipelago Sea Finnish coastal water	3	0.6	not good	0.88	High
Bothnian Sea – Open sea	3	0.3	not good	0.78	High
The Quark Finnish Coastal waters	3	0.4	not good	0.88	High
The Quark Swedish Coastal waters	3	0.7	good	0.75	Intermediate
Bothnian Bay – Open sea	3	0.1	not good	0.78	High
Bothnian Bay Finnish Coastal waters	3	0.5	not good	0.88	High



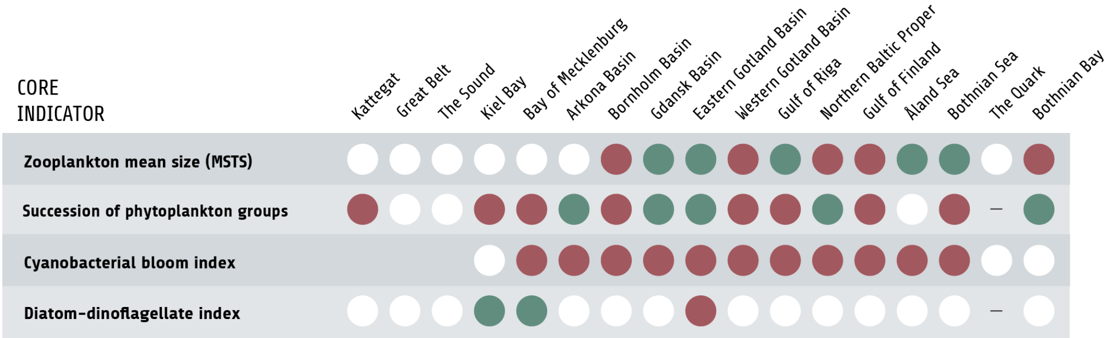
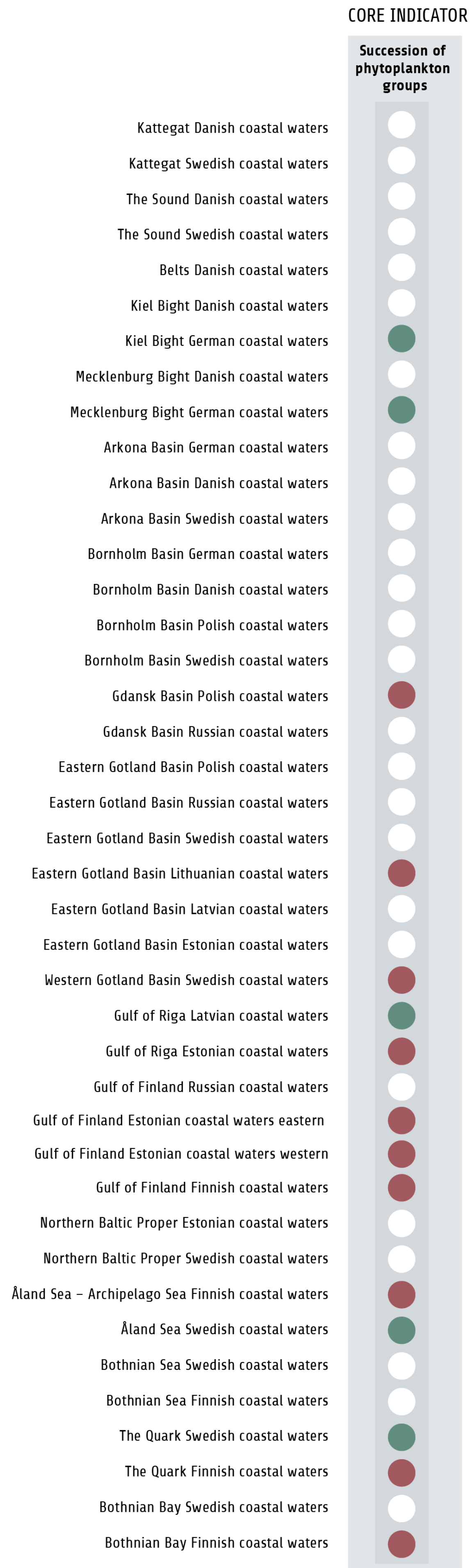
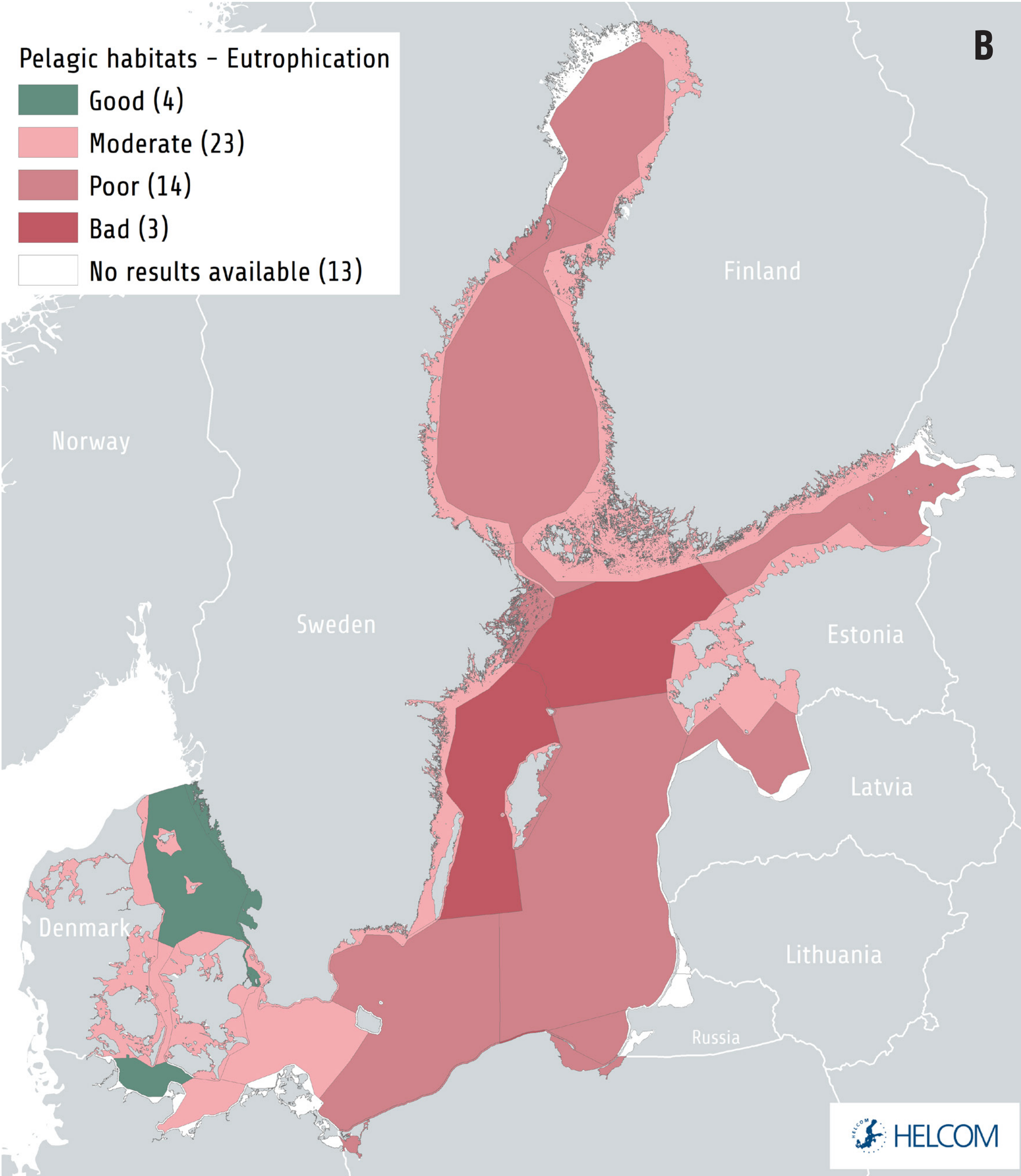


Figure 3.2 Integrated assessment of biological components (A) and eutrophication components (B). Values >0.6 correspond to good status. Corresponding indicator evaluation results for indicators included in the integrated assessment are presented in the bottom and right-hand side of the figure. In the A figure the assessment results for German coastal waters shows the results of the Seasonal succession indicator. In the B figure German coastal waters were excluded from the integrated assessment.





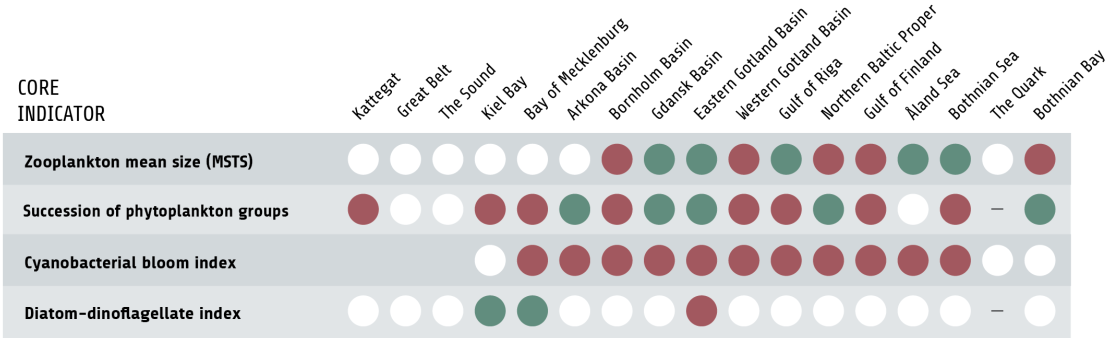
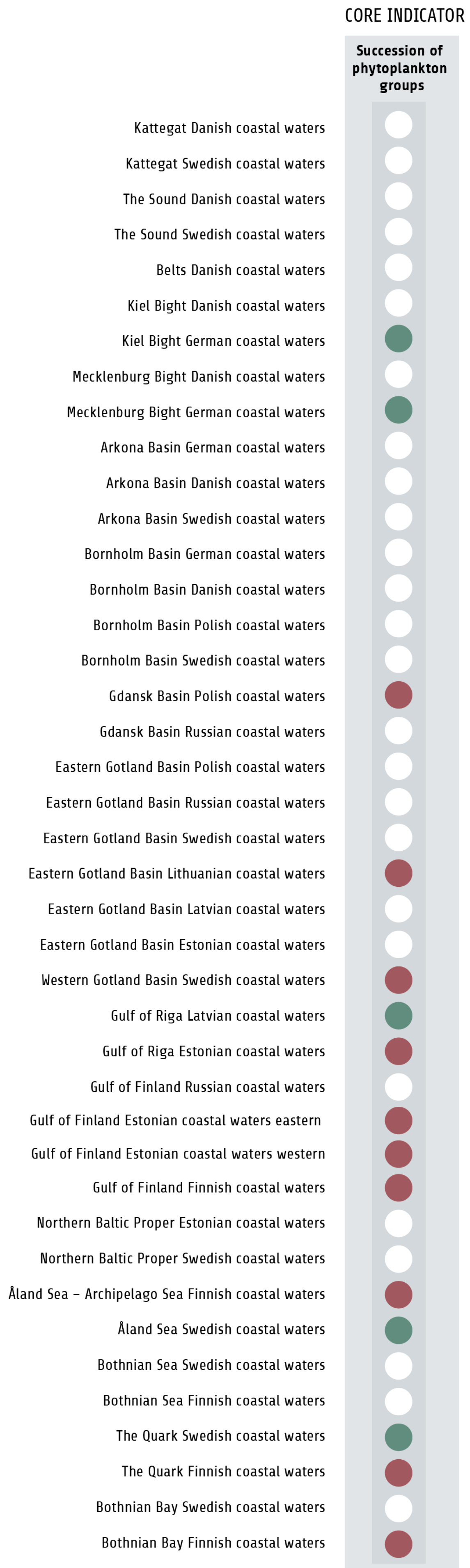


Figure 3.2 (Continued). Integrated assessment of biological components (A) and eutrophication components (B). Values >0.6 correspond to good status. Corresponding indicator evaluation results for indicators included in the integrated assessment are presented in the bottom and right-hand side of the figure. In the A figure the assessment results for German coastal waters shows the results of the Seasonal succession indicator. In the B figure German coastal waters were excluded from the integrated assessment.



3.2.2 Indicator evaluation results for pelagic habitats

The indicators represent components of pelagic habitats and provide more detailed information on the status. Results are presented for the HELCOM indicators Zooplankton mean size and total stock, Seasonal succession of dominating phytoplankton groups, Cyanobacterial bloom index, and the Diatom-dinoflagellate index. In addition, test results for the application of the OSPAR plankton indicator in the Baltic Sea are shown (Box 3.1). It is worth noting that the Diatom-Dinoflagelate index is a HELCOM pre-Core indicator and the results represent a pilot evaluation done for the purpouses of HOLAS 3. Future work on this indicator aims at strengthening the rationale for the indicator, including demonstrating the link to anthropogenic pressures. Future work could also continue to develop the methodology of threshold setting.

An overview of the specific indicator evaluation results for each indicator and area, as well as the respective threshold values, included in the thematic assessment of pelagic habitats for 2016-2021 is presented in Annex 2 in the section Pelagic habitats, as well as in the respective indicator report (HELCOM 2023e, HELCOM 2023f, HELCOM 2023o, HELCOM 2023ac).

Box 3.1 Test of OSPAR plankton indicators for the Baltic Sea

HELCOM conducted a pilot study to evaluate the applicability of OSPAR common indicator PH1/FW5 Plankton lifeforms as a part of the HELCOM BLUES project using data for the Western Gotland Basin, the Bothnian Sea and the Gulf of Riga. This approach does not directly use the existing HELCOM pelagic habitats indicators (e.g., those described for Zooplankton Mean Size and Total Stock or Seasonal Succession of Dominating Phytoplankton Groups) but utilises the same raw data types, the same key species or taxonomic groups, and may also, once further developed, utilise key concepts from these indicators in establishing appropriate life form pairs. This test case was done to evaluate the suitability of the data available in the HELCOM region as well as the methodology, to evaluate the possibility to use a common indicator in a larger area in European waters and thus to enhance comparison between regions.

The PH1/FW5 Plankton lifeforms indicator analyses temporal dynamics of plankton functional groups (lifeforms) using state-space theory (Tett *et al.* 2007, 2008); see https://www.ospar.org/documents?v=39001 for details. Following this approach, we compared the abundance (biovolume or biomass) of selected lifeform pairs between the assessment period (2016-2021) and the available long-term data (Figure Box 3.1-A). In addition, trend analyses were conducted. The following lifeform pairs were provisionally identified for the Baltic plankton and used to calculate the Plankton Index: (i) diatoms vs dinoflagellates, (ii) cyanobacteria vs mixotrophic ciliate *Mesodinium rubrum*, and (iii) microphagous zooplankters versus copepods (without *Copepoda nauplii*) for zooplankton).

Box 3.1 (continued) Test of OSPAR plankton indicators for the Baltic Sea

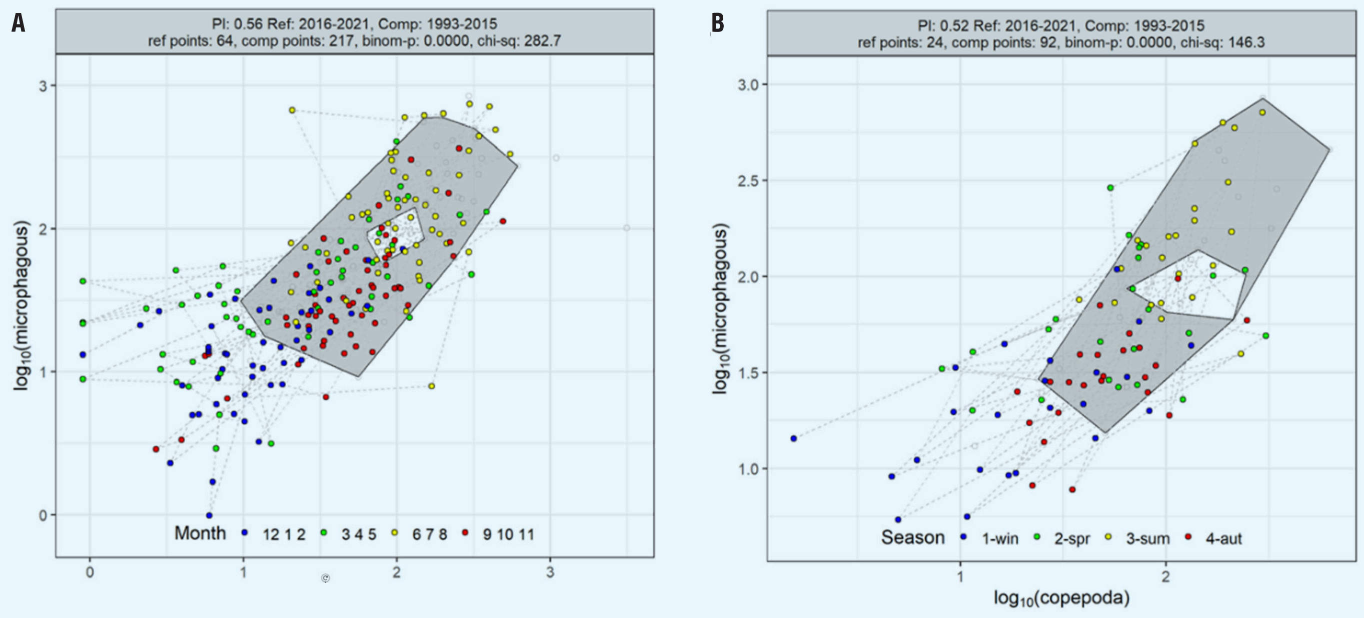


Fig Box3.1-A. Plankton Index calculated using the lifeform pair method for macrophagous and microphagous zooplankton grazers in the Gulf of Riga. Here, two data aggregation approaches were compared: by (A) month and (B) season to evaluate whether the Plankton Index is applicable when the spring-winter data are sparse. The grey envelope encompasses the expected variability during the assessment period, and points falling outside this envelope indicate significant deviations for the observations preceding 2016-2021.

The test outcome: The macrophagous and microphagous zooplankton dynamics indicate that both lifeform pairs significantly increased since the beginning of the time series in the Gulf of Riga. Moreover, the increase was more pronounced for the spring-winter than summer-fall populations. One can speculate that this increase can be related to the higher food availability for both lifeforms in spring-winter due to eutrophication and/or enhanced phytoplankton growth due to warm winters; none of these explanations is exclusive. These findings suggest that more attention should be given to monitoring and evaluating non-summer zooplankton communities. Also, the results were similar between the data aggregated by month and season (Figure Box3.1-A); therefore, our preliminary conclusion is that the Plankton Index can be calculated using the Baltic Sea zooplankton data with less than monthly temporal coverage (e.g., where data for a month may be absent seasonal aggregation can still be appropriately applied).

Challenges identified: The specific pairs of plankton lifeforms for Baltic plankton are not currently available; they need to be selected and validated to ensure they possess relevant functional traits and respond predictably to specific pressures and drivers. The Plankton Index was developed for the North Atlantic plankton communities that are more diverse than in the Baltic Sea (especially its northern and central subbasins). Therefore, the traits used to define the lifeform pairs for the planktonic communities in the OSPAR region are not always relevant for the Baltic plankton. Moreover, the samples used to derive the Plankton Index are collected by the Continuous Plankton Recorder and, thus, have higher spatial and temporal coverage than what is achievable in the HELCOM-guided COMBINE monitoring where stationary sampling is used. Hence, adjusting data aggregation to the spatial and temporal resolution of the observations is needed if Plankton Index is to be employed in the HELCOM assessment.

Future work: The Plankton Index indicator can facilitate the long-term analysis of plankton communities and support the interpretation of the Zooplankton MSTS indicator in the Baltic Sea provided that: (1) a database for plankton functional traits is established, (2) relevant lifeform pairs are identified and validated; and (3) appropriate data aggregation is implemented to account for low sampling frequency outside of the growing season.

Indicator evaluation results for Zooplankton mean size and total stock

The biodiversity core indicator 'Zooplankton mean size and total stock' (HELCOM 2023f) evaluates the zooplankton community structure and total biomass (Figure 3.3). A high zooplankton community biomass dominated by taxa with a relatively large body size represents both favourable fish-feeding conditions and a high potential for efficient utilization of primary production. The long-term data on EQR based on chlorophyll-a, body condition indices for European sprat (Sprattus sprattus) and young Atlantic herring (Clupea harengus), and stock dynamics for herbivorous fish are used to define a reference period and to estimate the subbasin-specific target values for zooplankton mean size and total biomass. Both indicator components, that is to say mean size and total stock, must be significantly above their corresponding threshold values to achieve good status. The statistical significance of crossing a threshold is established using a Cumulative Sum (CuSum) analysis.

The spatial coverage increased from six sub-basins in the HOLAS II assessment to ten in HOLAS 3 assessment. Good environmental status was achieved in five subbasins (Bothnian Sea, Åland Sea, Gulf of Riga, Eastern Gotland Basin and Gdansk Basin; Figure 3.3), whereas good status was not achieved in the Northern Baltic Proper, Western Gotland Basin, Gulf of Finland and Bornholm due to the low mean body size, and the Bothnian Bay due to the low total biomass.

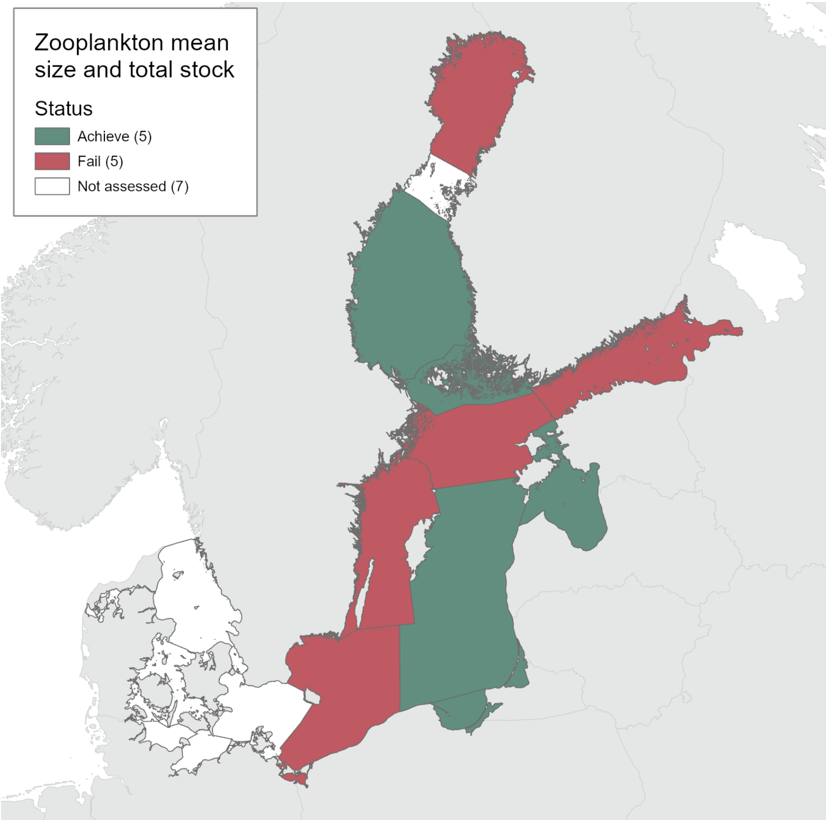


Figure 3.3. Evaluation results of the status of the zooplankton indicator 'Mean size and total stock' at assessment scale 2 for the assessment period 2016–2021. Assessment scale indicates at what spatial resolution the assessment was conducted, scale 2 refering to a division of the Baltic Sea into sub-basins (see Section 2.3.2 or the HELCOM Monitoring and Assessment Strategy for more information on the assessment units used for HELCOM assessments). (Source: HELCOM 2023f).

Results for seasonal succession of dominating phytoplankton groups

One of the phytoplankton indicators used is the pre-core indicator Seasonal succession of dominating phytoplankton groups (HELCOM 2023e) where the groups combined encompass the majority of the biomass produced. The reasoning is that the temporal succession over the year should not be altered too much to indicate good status. If good status is not achieved the separate results of the groups included can be evaluated to understand the underlying problem. The spatial coverage has increased from last assessment from seven sub-basins to 13 and six coastal sites to 13. Seven out of 26 areas achieve good status, mainly coastal sites (Figure 3.4).

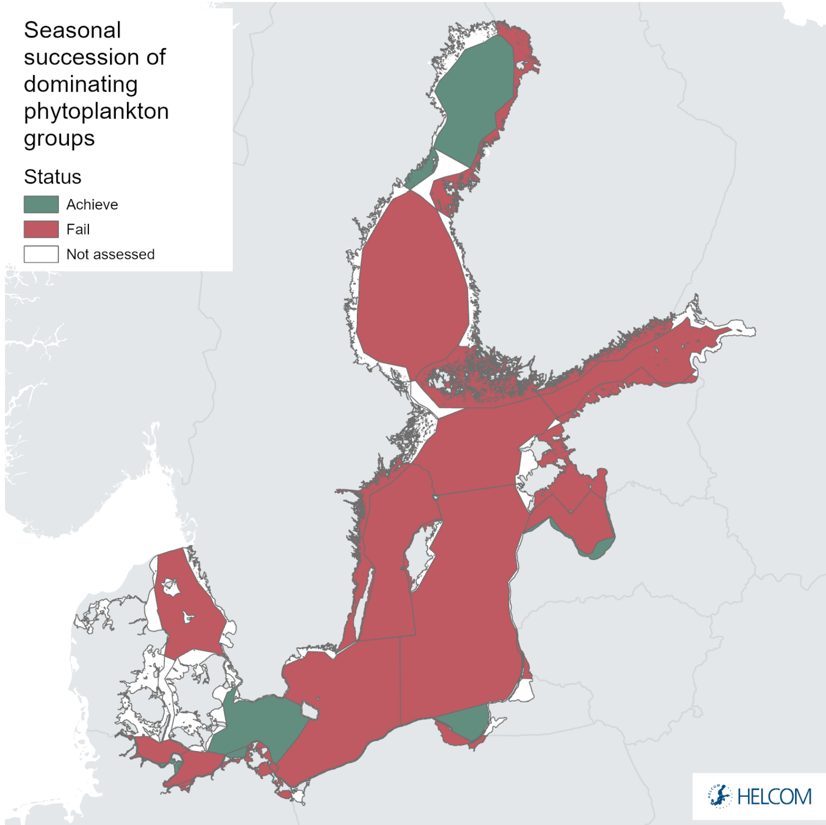


Figure 3.4. Results of the status evaluation of the phytoplankton indicator 'Seasonal succession of dominating phytoplankton groups' at scale 3 for the assessment period 2016–2021. Assessment scale indicates at what spatial resolution the assessment was conducted, scale 3 refering to a division of the Baltic Sea into sub-basins and further divided into coastal and open sea areas (see Section 2.3.2 or the HELCOM Monitoring and Assessment Strategy for more information on the assessment units used for HELCOM assessments). (Source: HELCOM 2023e).

Indicator evaluation results for cyanobacterial Bloom Index

Another phytoplankton indicator used is the pre-core eutrophication indicator, cyanobacteria bloom index (HELCOM 2023ac). The indicator combines satellite data of surface accumulations with fixed station data of cyanobacteria biomass in the period June-August. Good status is achieved if the temporal and spatial occurrence of cyanobacteria blooms do not appear above its defined limits. Since last assessment four more areas are included so the spatial coverage has increased. None of the 13 assessed open sea areas had good environmental in this assessment (Figure 3.5).

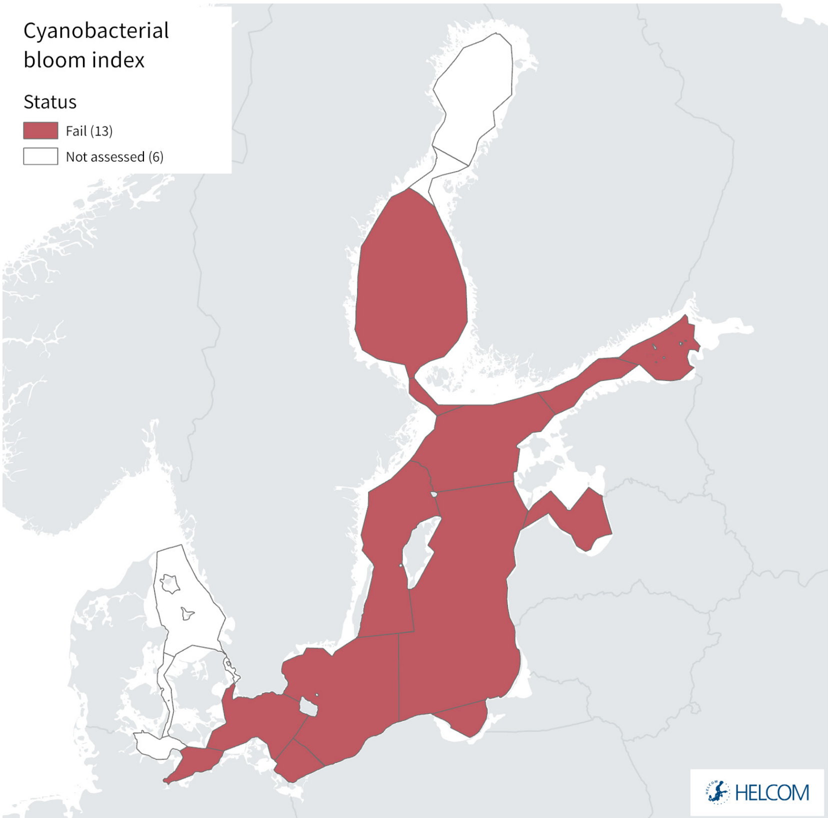


Figure 3.5. Evaluation of the status of the phytoplankton indicator 'Cyanobacterial bloom index' at scale 2 for the assessment period 2016-2021. Assessment scale indicates at what spatial resolution the assessment was conducted, scale 2 refering to a division of the Baltic Sea into sub-basins (see Section 2.3.2 or the [HELCOM Monitoring and Assessment Strategy]() for more information on the assessment units used for HELCOM assessments). (Source: HELCOM 2023ac).

Indicator evaluation results for diatom-dinoflagellate ratio

Besides the indicators used in the BEAT analyses, the indicator diatom-dinoflagellate index (HELCOM 2023o) is also used to assess (parts of) the Baltic Sea. At the moment, it has the status of a test indicator and assesses the spring bloom dynamics of diatoms and dinoflagellates, comparing recent ratios of dia:dino with historical ones to evaluate status. The status varies between the basins with diatom dominance (Kiel Bay and Bay of Mecklenburg) to equal ratios (Eastern Gotland Basin). The spatial scale has increased since last assessment from one area to three areas. Two out of three areas were assessed to good status (Figure 3.6).

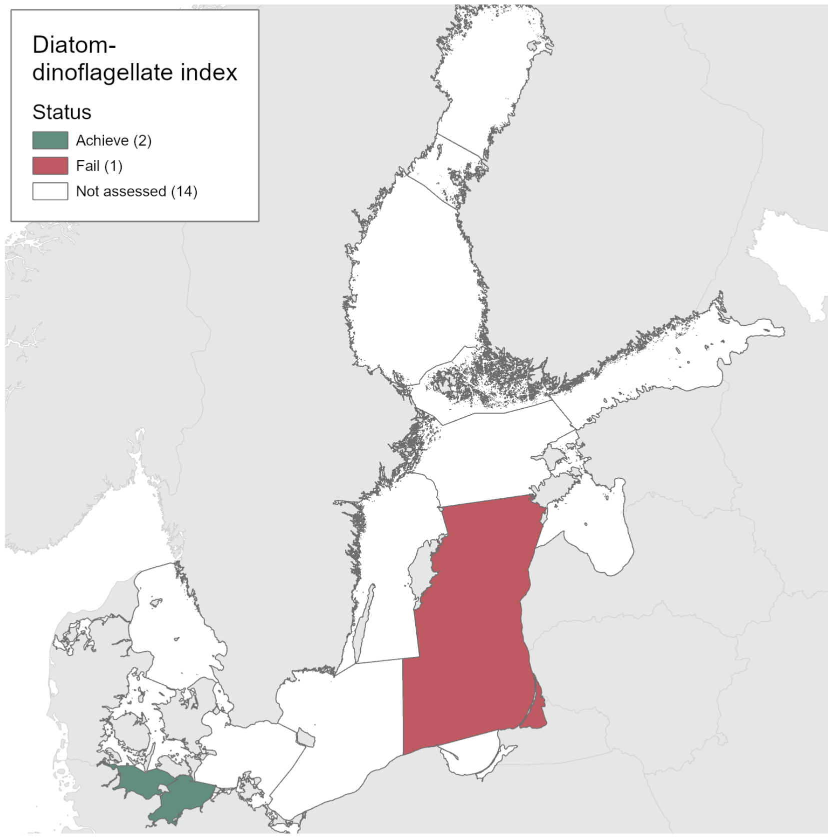


Figure 3.6. Evaluation of the status of the phytoplankton indicator 'Diatom-dinoflagellate ratio' at scale 2 for the assessment period 2016-2021. Assessment scale indicates at what spatial resolution the assessment was conducted, scale 2 refering to a division of the Baltic Sea into sub-basins (see Section 2.3.2 or the [HELCOM Monitoring and Assessment Strategy]() for more information on the assessment units used for HELCOM assessments). (Source: HELCOM 2023o).

3.3. Changes over time for pelagic habitats

3.3.1 Trends between assessments

The components of the thematic assessment have partly been changed since the last assessment 2011-2016 resulting in a more biologically focused assessment. The indicator seasonal succession of dominating phytoplankton groups is included instead of the more general eutrophication indicator chlorophyll a. The seasonal succession of dominating phytoplankton groups was assessed by itself in the last assessment but has now been implemented in the integrated biological assessment. When looking at table 3.3, comparing the outcome in 2011-2016 and 2016-2021 it needs to be emphazssed that the components have changes between the assessment periods and comparison should be made with a cautious eye. The spatial coverage of all indicators applied in the assessment has greatly increased since the last assessment for HOLAS II. Although the assessment is done at the assessment scale 3, i.e. including both open sea and coastal waters, integrated BQR results are only available at scale 2, i.e for open sea. As a consequence, the trend comparison (Table 3.3) includes only open sea assessment units. The overall assessment from a eutrophication perspective of the pelagic habitat has not changed since the last assessment made for HOLAS II when including the eutrophication indicators. Even if the overall assessment is not altered since last assessment each individual indicator assessment result has changed. The changes in assessment per indicator is presented in Annex 3 under 3.1 Indicator evaluations for pelagic habitats.

Table 3.3. Overview of trends in the results and status of the assessment for pelagic habitats across the 2011–2016 and 2016–2021 assessments. An increasing Biological Quality Ratio value indicates an improving trend, decreasing Biological Quality Ratio value indicates a deteriorating trend.

Assessment scale	Assessment Unit Code	Biological Quality Ratio 2016-2021	Status 2016-2021	Confidence	Biological Quality Ratio 2011-2016	Status 2011-2016	Confidence	Trend
3	Kattegat	0.6	not good	Intermediate	1.0	good	Intermediate	down
3	Great Belt				0.5	not good	Intermediate	
3	The Sound				0.6	not good	Intermediate	
3	Kiel Bay	0.5	not good	Intermediate	0.4	not good	Intermediate	up
3	Bay of Mecklenburg	0.5	not good	Intermediate	0.5	not good	Intermediate	same
3	Arkona Basin	0.5	not good	High	0.3	not good	Intermediate	up
3	Bornholm Basin	0.4	not good	Intermediate	0.5	not good	Intermediate	down
3	Gdansk Basin	0.5	not good	Intermediate	0.6	not good	Intermediate	down
3	Eastern Gotland Basin	0.4	not good	High	0.4	not good	Intermediate	same
3	Western Gotland Basin	0.4	not good	High	0.4	not good	High	same
3	Gulf of Riga	0.4	not good	High	0.4	not good	Intermediate	same
3	Northern Baltic Proper	0.2	not good	High	0.3	not good	Intermediate	down
3	Gulf of Finland	0.3	not good	High	0.4	not good	High	down
3	Åland Sea	0.2	not good	Intermediate	0.3	not good	High	down
3	Bothnian Sea	0.3	not good	High	0.5	not good	High	down
3	The Quark				0.4	not good	Intermediate	
3	Bothnian Bay	0.1	not good	High	0.5	not good	High	down

3.3.2 Long term trends

Table 3.4 show the long-term trends for zooplankton in each Baltic Sea subbasin looking at biomass, abundance and mean size, based on the longest timeseries available for each area. Each component of the indicator is presented with the whole timeseries to better understand the dynamics of each component.

Table 3.4 Long-term trends for zooplankton biomass, abundance and mean size in each subbasin evaluated in HOLAS 3. Mann-Kendall test was first applied on the entire dataset, and then on the data for the last 12 years. Significant trend ($p < 0,05$) is indicated by ↑ and ↓ and → indicates no change. Arrows up indicate an increase of the component which also contributes to achieving good ecological status and an arrow down indicate a decrease in the component and not contributing to good ecological status.

Sub-basin	Entire time series				Last 12 years		
	Biomass	Abundance	Mean size	Period (years)	Biomass	Abundance	Mean size
Bothnian Bay	↓	↓	↑	1979-2021	↓	→	↑
Bothnian Sea	↑	→	↑	1979-2021	→	→	→
Åland Sea	→	→	↓	1982-2021	→	→	→
Northern Baltic Proper	→	↑	↓	1979-2021	→	→	→
Gulf of Finland	→	↑	↓	1980-2021	→	→	→
Gulf of Riga	↑	→	→	1993-2021	→	→	→
Eastern Gotland Basin	→	↑	↓	1979-2021	→	→	→
Western Gotland Basin	↓	→	↓	1976-2021	→	→	↑
Gdansk Bay	→	→	↑	1986-2021	↑	↑	↑
Bornholm	→	→	↓	1979-2021	→	→	→
All subbasins assessed	→	↑	↓	1976-2021	→	↑	→

3.4. Relationship of pelagic habitats to drivers and pressures

The status of pelagic habitats is affected by human induced pressures. One of the most important pressures affecting the status of pelagic habitats is eutrophication, and therefore a separate assessment of the eutrophication impacts on these habitats was carried out, based on selected eutrophication indicators with relevance to pelagic habitats. The assessment confirmed the relevance of this pressure, with almost the whole Baltic Sea expect some Western Baltic Sea basins being eutrophied (Fig. 3.2B). Hazardous substances (Figure 3.7), as well as natural and human-induced changes in climate also excert pressures on pelagic habitats.

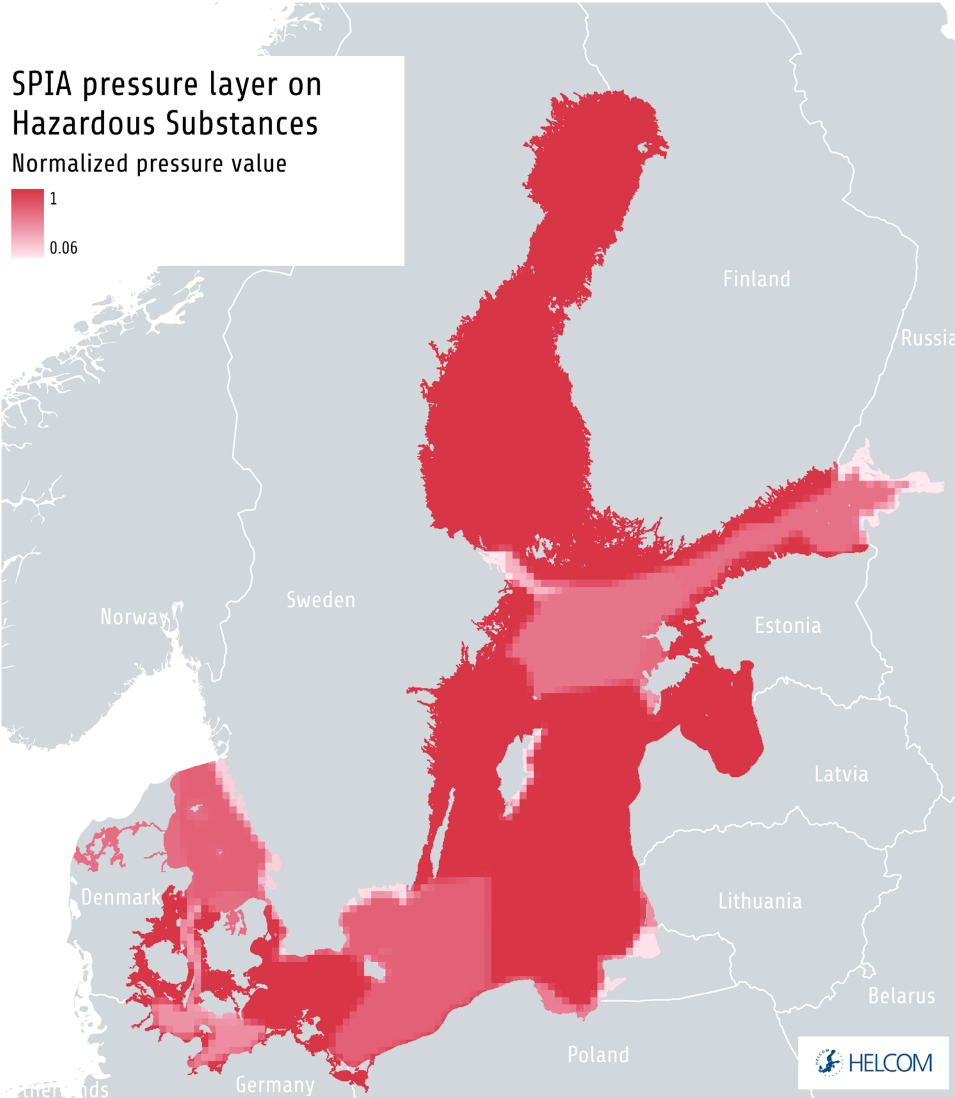


Figure 3.7. Hazardous substances pressure layer based on data from 2016–2021 from the spatial pressures and impacts assessment tool (SPIA) (HELCOM 2023a). The layer depicts the pressure of hazardous substances in the Baltic Sea, based on the data from the HOLAS3 integrated hazardous substances assessment. The methodology utilizes the integrated status values available for each HELCOM assessment unit on level 3. The results are based on multiple hazardous substances groups integration, done through the CHASE tool. The integrated assessment assess the hazardous substances status in biota, water and sediment, and final result in based on the worst status. As the SPIA is carried out using a 1x1km grid and the Integrated hazardous substances is assessed on vector-based HELCOM assessment units, the vector data is rasterized. First, the vector data is rasterized to 100x100m resolution, and thereafter it is aggregated to 10x10km grid using a mean value. A 10 km grid is used in order to make the gradients between assessment units slightly smoother and finally values are converted to 1x1 km resolution. (Source: HELCOM 2023a)

3.4.1 Relationship of zooplankton to drivers and pressures

Herbivorous zooplankton are indirectly affected by eutrophication via changes in primary production and phytoplankton composition and directly by predation. Moreover, climate change has been demonstrated to be a significant driver of zooplankton worldwide. To a lesser extent, zooplankton can also be affected by hazardous substances and invasive species. Moderate eutrophication is expected to increase herbivorous zooplankton reproduction and abundance due to increased food availability. In contrast, fish predation is expected to decrease large zooplankton prey, with a consecutive decline in mean size, due to the size-selective predation, and deplete the total biomass.

3.4.2 Relationship of phytoplankton to drivers and pressures

Phytoplankton are directly affected by eutrophication and grazing from herbivorous zooplankton. They are also indirectly affected by predation at other trophic levels in the foodweb. To a lesser extent they are affected by hazardous substances. Climatic changes will affect the phytoplankton community structure. While it is assumed that dinoflagellates blooms will increase and diatom blooms decrease and thus result in a changed community and altering of the pelagic habitat, the direct relations are not yet fully understood.

3.5. Assessment methodological details

The methodology used for the integrated assessment of pelagic habitats is presented in Annex 1, section Pelagic habitat assessment methodology.

3.6. Follow up and needs for the future with regards to pelagic habitats

In general the pelagic habitat assessment still needs significant developments in the future. Work should focus on strengthening the indicator links to pressures and on setting thresholds that represent a mostly undisturbed Baltic Sea, i.e. is in accordance with GES.

The assessment of pelagic habitat addresses the Baltic Sea Action Plan (BSAP) biodiversity segments 'Natural distribution, occurrence and quality of habitats and associated communities' as well as *functional, healthy and resilient foodwebs. It also addresses the segment eutrophication with 'Natural levels of algal blooms' and 'natural distribution and occurrence of plants and animals'. The assessment also addresses the EU Marine strategy framework directive: Descriptor 1: 'Biological diversity is maintained. The quality and occurrence of habitats and the distribution and abundance of species are in line with prevailing physiographic, geographic and climatic conditions'; Descriptor 4 Ecosystems, including foodwebs: Criterion D4C1: The diversity (species composition and their relative abundance) of the trophic guild is not adversely affected due to anthropogenic pressures. Criterion D4C2: The balance of total abundance between the trophic guilds is not adversely affected due to anthropogenic pressures.
Eutrophication is one pressure for the pelagic habitat. HELCOM is actively working on reducing eutrophication problems (see for example Baltic Sea Action Plan; HELCOM 2021a). The results in the pelagic assessment do not present any clear sign of recovery in relation to eutrophication. This is especially true when looking at the eutrophication indicators. Besides eutrophication phytoplankton and zooplankton are also important in identifying changes in the foodweb. The drivers and pressures to these changes in the pelagic system are more difficult to elucidate as the system is complex. The function and role of the species of the pelagic system is still in need of further knowledge. A better understanding of the pelagic system and all its components would enhance further development of existing indicators as well as new indicators. The OSPAR indicator, PH1/FW5 Life form pairs, was tested in the HELCOM BLUES project and did present some additional results that could support the understanding of the system. Substantial work is however needed for a broader implementation of the indicator in the Baltic Sea. Substantial work is needed on species functionality in the pelagic system to be further developed in the Baltic Sea. Even if the spatial coverage has substantially been improved for this assessment period covering most of the areas with monitoring gaps in spatial coverage could still be filled in the future.

Towards future assessment the possibility to develop biodiversity indicators that estimate the taxonomic and functional biodiversity in the communities, e.g. how many phytoplankton taxa occur in various subbasins as well as what the functional diversty of those communities are, could be explored.

4. Results for the benthic habitats assessment

Assessment results in short

- The overall results give that large parts of the Baltic Proper and the Sounds do not have good status with regard to benthic habitats, while that status is good in most of the Gulf of Bothnia. Benthic habitats were evaluated regarding the aspects of soft-bottom macrofauna, shallow-water oxygen, oxygen debt and cumulative impact from physical pressures.
- Soft-bottom macrofauna shows good status in all evaluated subbasins, except the Bay of Mecklenburg, Gulf of Riga and Gulf of Finland.
- For shallow-water oxygen, five out of eleven assessment units reach the set threshold values.
- Evaluation of oxygen debt below the halocline is applicable in the Bornholm Basin and Baltic Proper. Good status for oxygen debt was not achieved in any of these areas. Oxygen debt has increased in all basins since the early 1900s, with the strongest increase in recent years since the early 1990s.
- The cumulative impact-risk from physical pressures is generally highest in the southern Baltic Sea and in the Kattegat, which have pressures with wide spatial extent, such as bottom trawling.
- As there are no spatial threshold values for benthic broad habitat-types, a full status assessment per broad habitat type and assessment unit could not be carried out.

4.1. Introduction to benthic habitats in the Baltic Sea

The seabed of the Baltic Sea covers several types of habitats and biotopes, from species-rich seagrass meadows and macroalgae in shallow areas (Figure 4.1), to soft bottom fauna which can also thrive at greater depths. Benthic habitats are however affected by several pressures, including habitat loss and disturbance as well as 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 with implications for overall foodweb productivity.

The strong salinity gradient from north to south, is reflected in the species composition of Baltic Sea benthic communities, which is reflected in the distribution maps in Figures 4.1 and 4.2, where species which require higher salinity such a *Fucus*, *Furcellaria* and *Zostera* exhibiting the end of their distributional range in the Quark and the Bothnian Sea, respectively. Primarily freshwater species such as *Fontinals* and *Callitiriche,* in turn, do not show a significant southward distribution beyond the Bothnian Sea. In general the Baltic Sea exhibits decreasing species diversity along with decreasing salinity towards the inner sub-basins (Gogina *et al.* 2016). Due to its small size and narrow inlet most of the Baltic Sea has no significant diurnal tides and as a result species are continuously submerged. In addition to the salinity, the type, variability and availability of substrate also play a role in the distributional patterns of benthic species in the Baltic Sea and can vary significantly in different parts of the region.

The southern Baltic Sea is dominated by marine species, such as polychaete worms and molluscs, including the bivalves ocean quahog (*Arctica islandica)* and boreal Astarte (*Astarte borealis)*. Eelgrass *(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 macroalga.

The relative dominance of marine species decreases with decreasing salinity gradient, and freshwater macrophytes become gradually more abundant. Typical invertebrate species further in

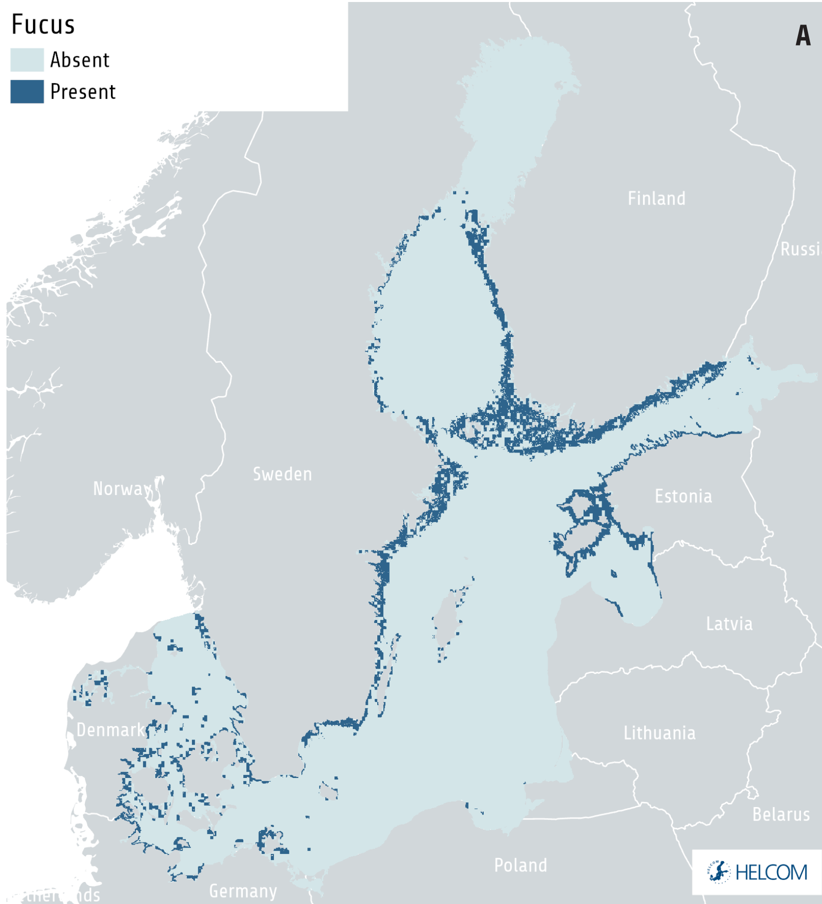


Figure 4.1. Distribution of example macrophyte species in the Baltic Sea. Figures A)–C) represent algae species, the first two of which requires hard substrate whereas the third, Charophytes inhabit sediment habitats. D)–I) represent aquatic vascular plants which require sediment habitats and figure J)water mosses, which require hard substrates. (source: HELCOM 2023a and HELCOM SPIA tool).

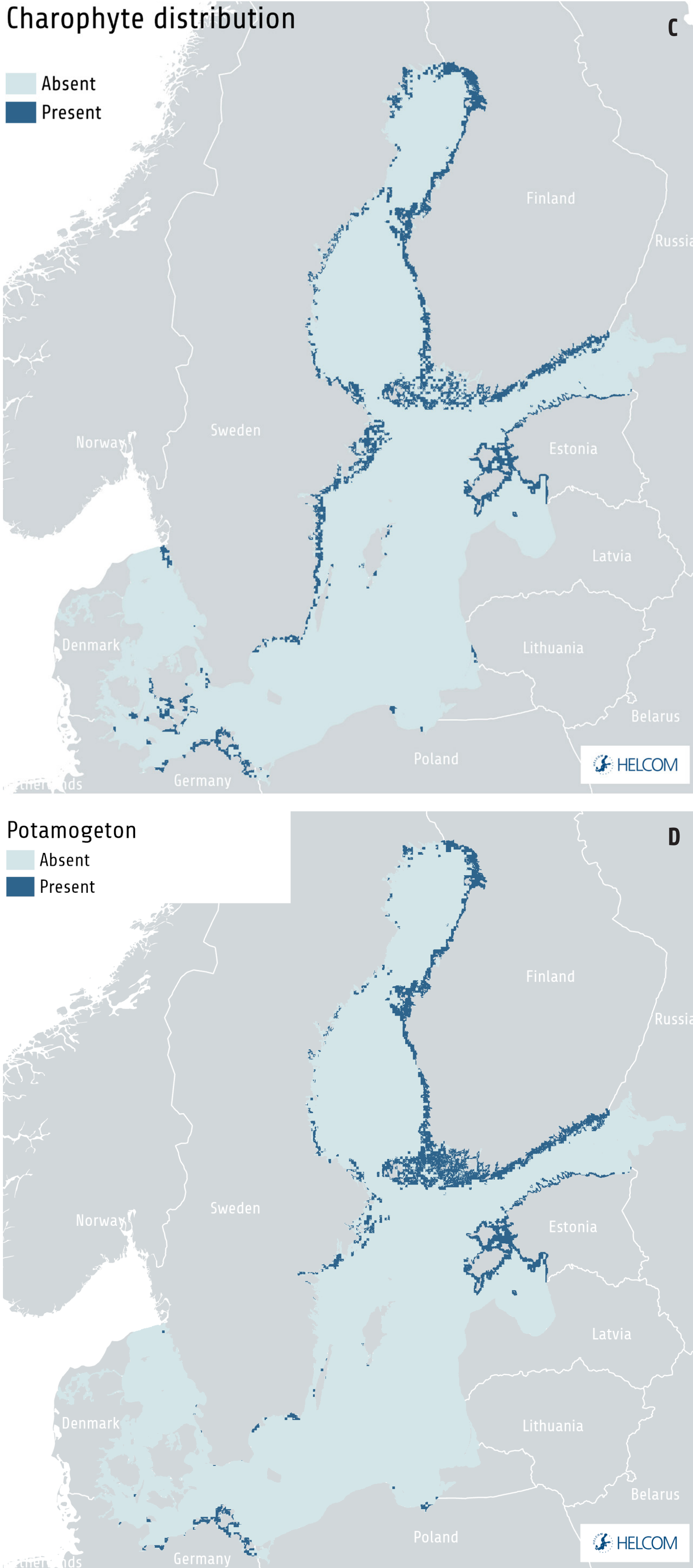


Figure 4.1. (Continued). Distribution of example macrophyte species in the Baltic Sea. Figures A)-C) represent algae species, the first two of which requires hard substrate whereas the third, Charophytes inhabit sediment habitats. D)-I) represent aquatic vascular plants which require sediment habitats and figure J) water mosses, which require hard substrates. (source: HELCOM 2023a and HELCOM SPIA tool).

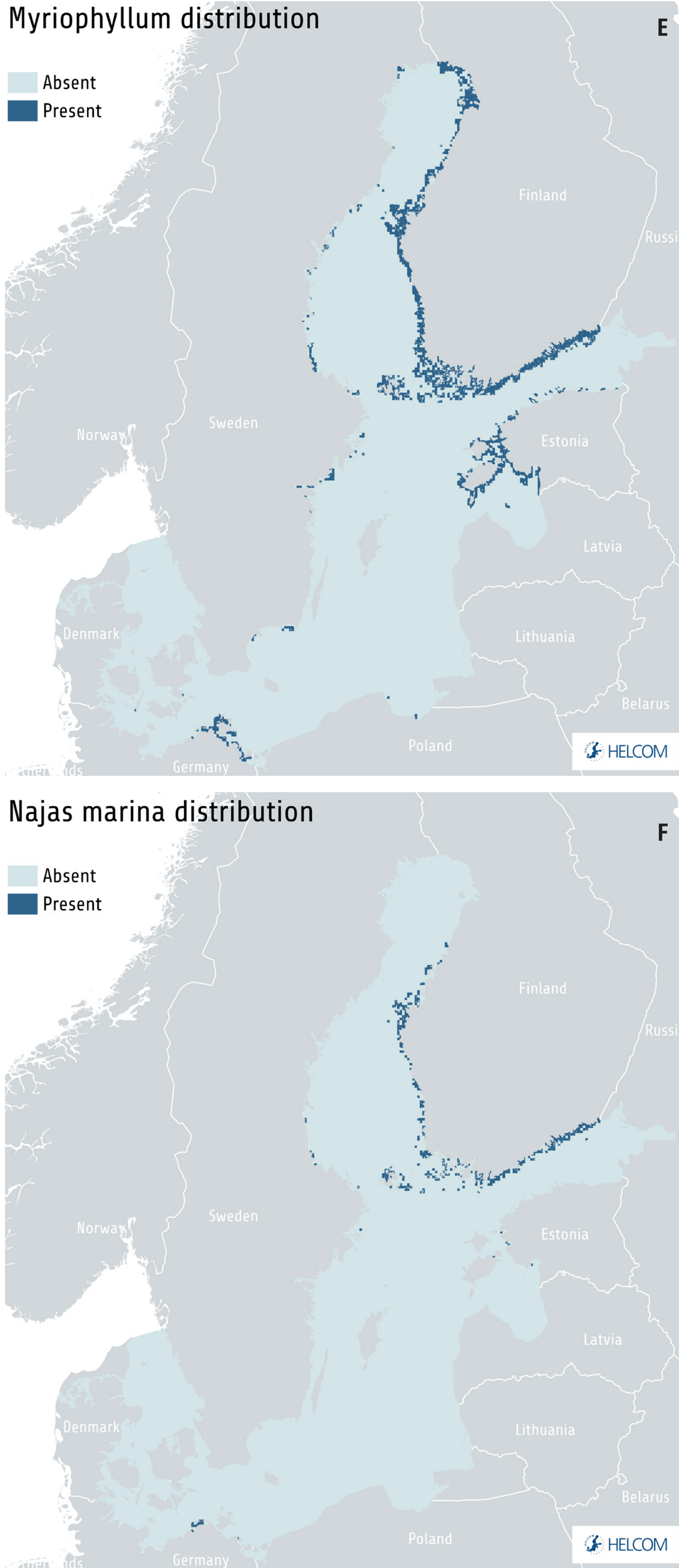


Figure 4.1. (Continued). Distribution of example macrophyte species in the Baltic Sea. Figures A)-C) represent algae species, the first two of which requires hard substrate whereas the third, Charophytes inhabit sediment habitats. D)-I) represent aquatic vascular plants which require sediment habitats and figure J) water mosses, which require hard substrates. (source: HELCOM 2023a and HELCOM SPIA tool).

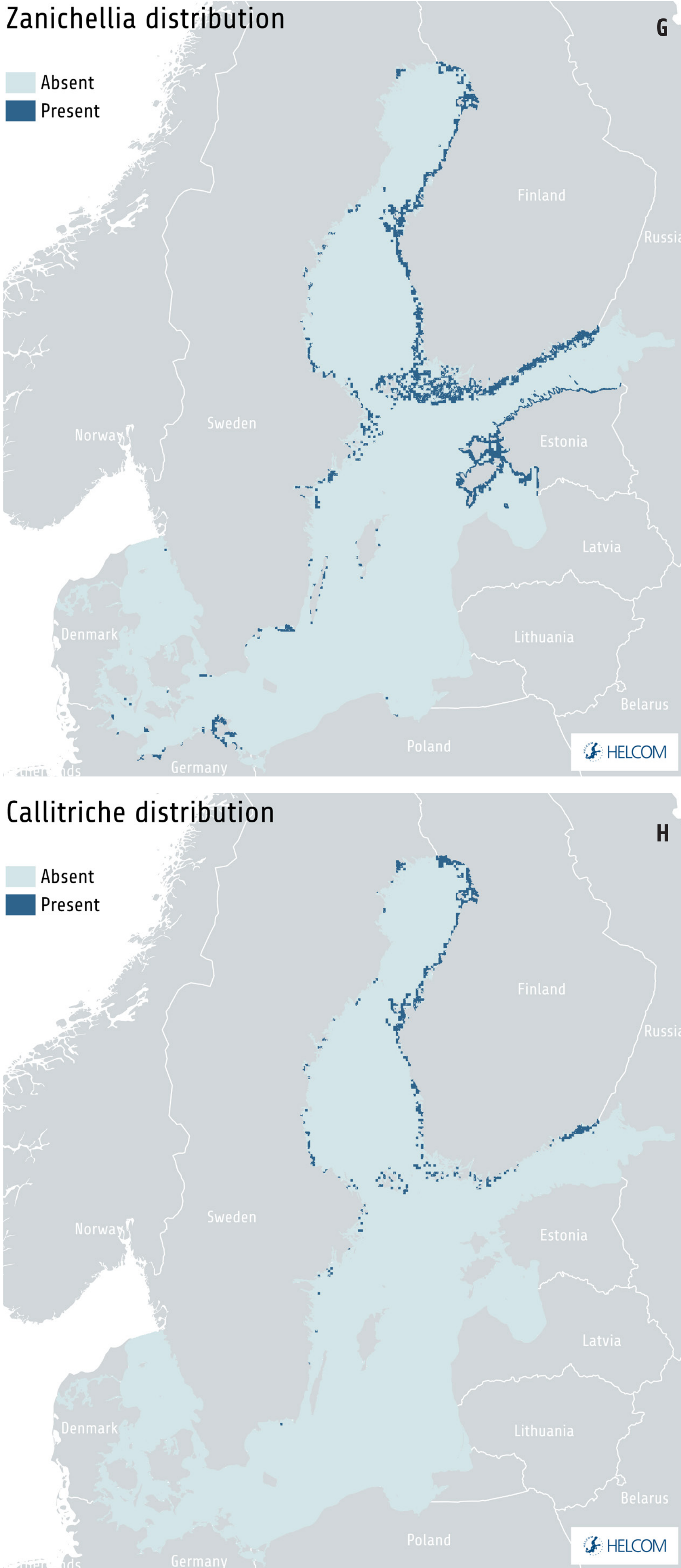


Figure 4.1. (Continued). Distribution of example macrophyte species in the Baltic Sea. Figures A)-C) represent algae species, the first two of which requires hard substrate whereas the third, Charophytes inhabit sediment habitats. D)-I) represent aquatic vascular plants which require sediment habitats and figure J) water mosses, which require hard substrates. (source: HELCOM 2023a and HELCOM SPIA tool).

State of the Baltic Sea
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Biodiversity
4. Benthic habitats

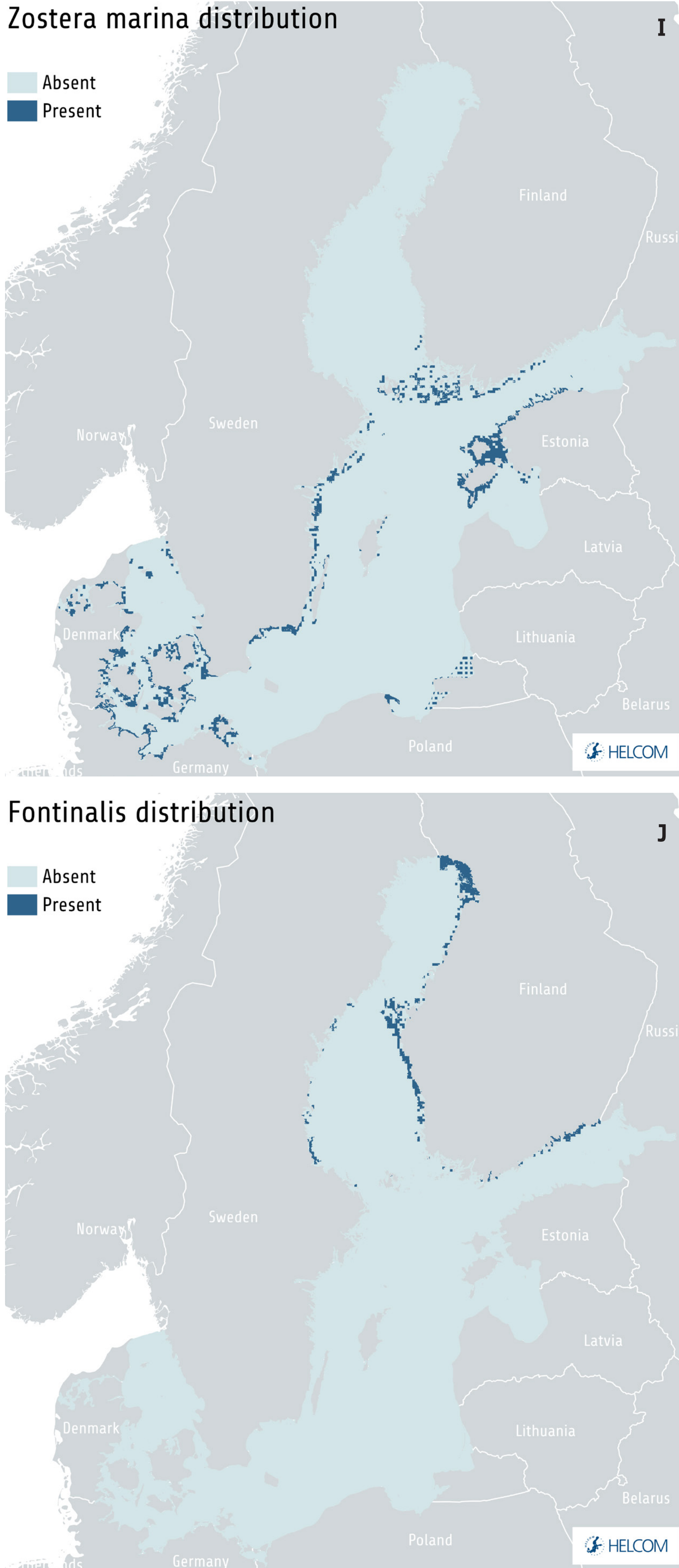


Figure 4.1. (Continued). Distribution of example macrophyte species in the Baltic Sea. Figures A)-C) represent algae species, the first two of which requires hard substrate whereas the third, Charophytes inhabit sediment habitats. D)-I) represent aquatic vascular plants which require sediment habitats and figure J) water mosses, which require hard substrates. (source: HELCOM 2023a and HELCOM SPIA tool).

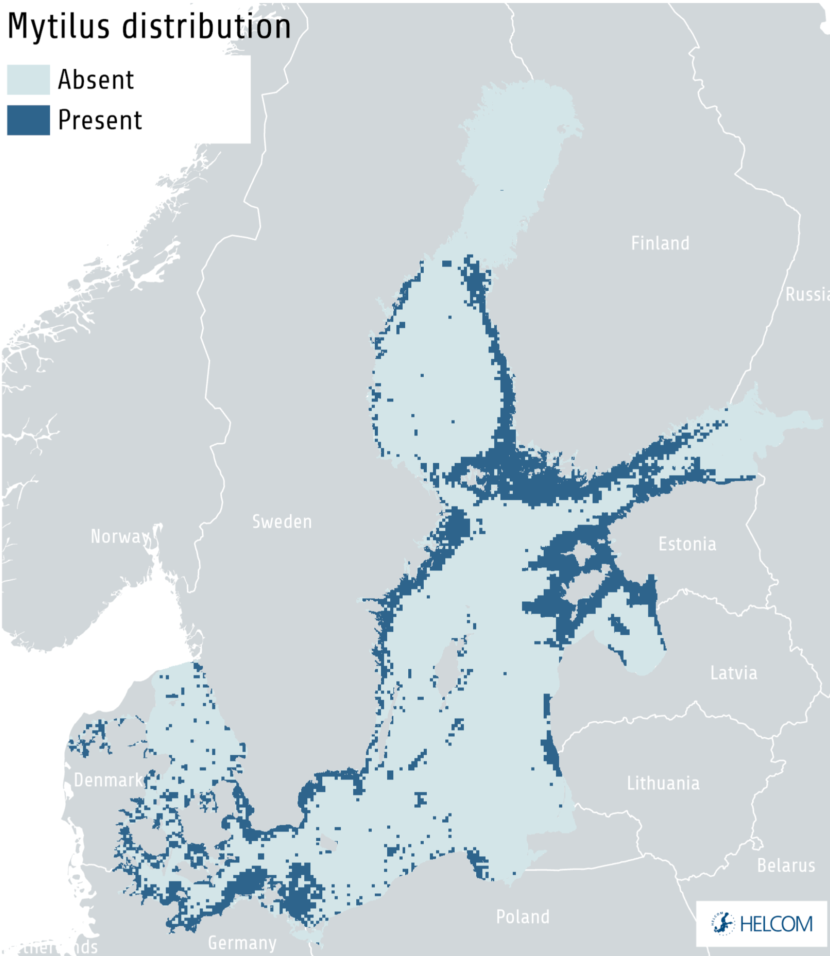


Figure 4.2. Distribution of example zoobenthic species in the Baltic Sea, here species belonging to the genus Mytilus (source: HELCOM 2023a).

along the salinity gradient include amphipods (mainly *Monoporeia affinis*), the isopod *Saduria entomon*, and the Baltic clam (*Macoma balthica*). Many freshwater invertebrate species 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 (Figure 4.1d). Different species of characean algae occur on soft bottoms in shallow coastal areas in most of the Baltic Sea but are dependent on sufficient water quality (Figure 4.1c). Macroalgae *Fucus* spp. (Figure 4.1a) are structurally important on hard bottoms in many parts of the Baltic Sea, transforming bare rock into living environments for many other species.

4.1.1 Importance of benthic habitats for the Baltic Sea ecosystem

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). Macrofaunal species live either on top of the sediment or in the sediment as infauna. The macrozoobenthic community influences the marine nutrient turnover by coupling biological and physicochemical cycles of both compartments, known as the benthic-pelagic coupling. In addition to forming a link between the water mass and the sediments, the macrozoobenthic species also form an important link in the marine foodweb. Many of the macrozoobenthic species are primary consumers that filter particles from the water or graze on and in the sediments, while others are predators and scavengers. 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).

4.1.2 Importance of benthic habitats for management

Reducing pressures and ensuring 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). Moreover, as the main part of the seafloor is covered by soft sediments, the macrozoobenthic community is a key component to be considered in any evaluation of the status of the environment.

In addition to providing vital ecosystem functions, benthic habitats and their associated species and communities also provide valuable ecosystem services, including carbon and nutrient assimilation, storage, and sequestration (examples in Figures 4.3 and 4.4) and nursery areas for fish (See chapter on ecosystem services in the HOLAS 3 Economic and Social Analyses (HELCOM 2023b).

For the purpose of the integrated assessment of the status of benthic habitats the Baltic Sea seafloor is divided based on 18 benthic broad habitat types (BHTs), in line with EUNIS classification used under EU MSFD. The spatial division is based on substrate and depth zone (Figure 4.5) and the spatial presentation of the BHTs originate from the EUSeaMap 2021 data, and cover the whole Baltic Sea region. As they cover the whole region, the BHT map ensures that there is at least one habitat to all parts of the assessment area. All 18 Broad habitat types are included in HOLAS 3, as compared to eight that were included in HOLAS II.

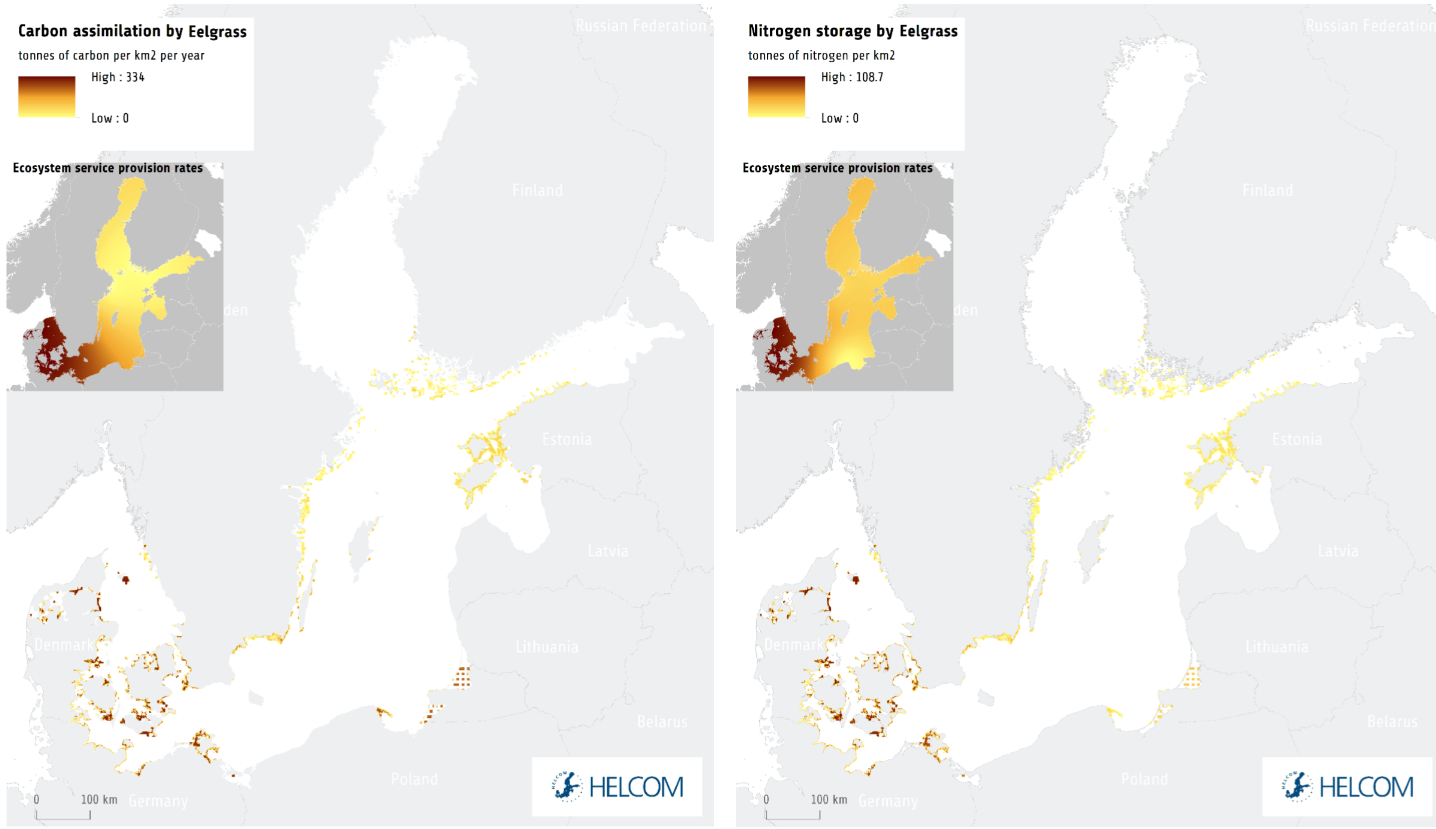
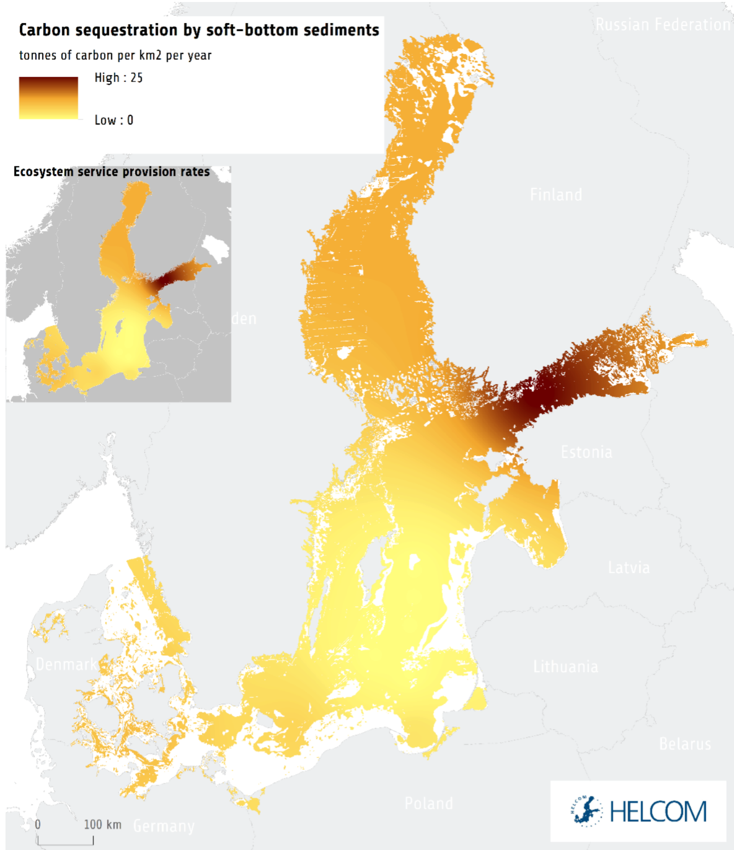


Figure 4.3. Spatial assessment of carbon assimilation and nitrogen storage by eelgrass in the Baltic Sea. The values are presented in tonnes of carbon or nitrogen, per km² per year respectively. The smaller map in the upper left corner illustrates the ecosystem service provision rates, which were generated by interpolating data from various scientific sources (carbon: Röhr *et al.* 2016, Duarte 1990, nitrogen: Röhr *et al.* 2016, Jankowska et al. 2016, Dahl *et al.* 2016). From the HOLAS 3 Thematic Assessment Report on Economic and Social Analyses (HELCOM 2023b).



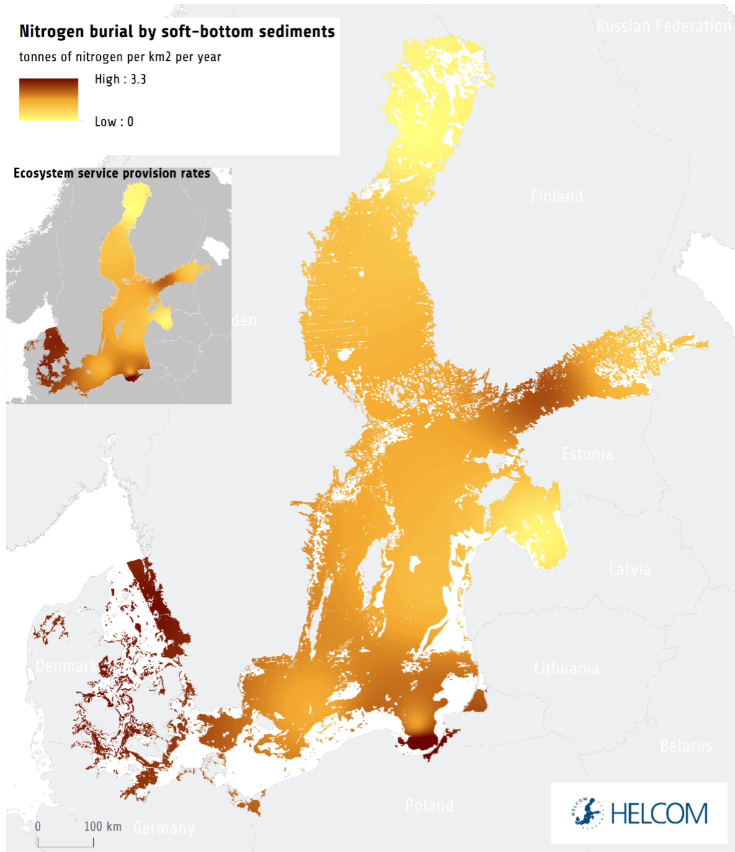


Figure 4.4. Map showing the spatial assessment of carbon sequestration (top) and nitrogen burial (bottom) by soft-bottom sediments in the Baltic Sea. The values are presented in tonnes of carbon per km^2 per year and tonnes of nitrogen per km^2 per year, respectively. The smaller map in the upper left corner illustrates the ecosystem service provision rates, which were generated by interpolating data (for carbon sequestration sub-basin average values, from Winogradow and Pempkowiak (2013, and for nitrogen burial from Lønborg and Markager (2021). From the HOLAS 3 Thematic Assessment Report on Economic and Social Analyses (HELCOM 2023b).

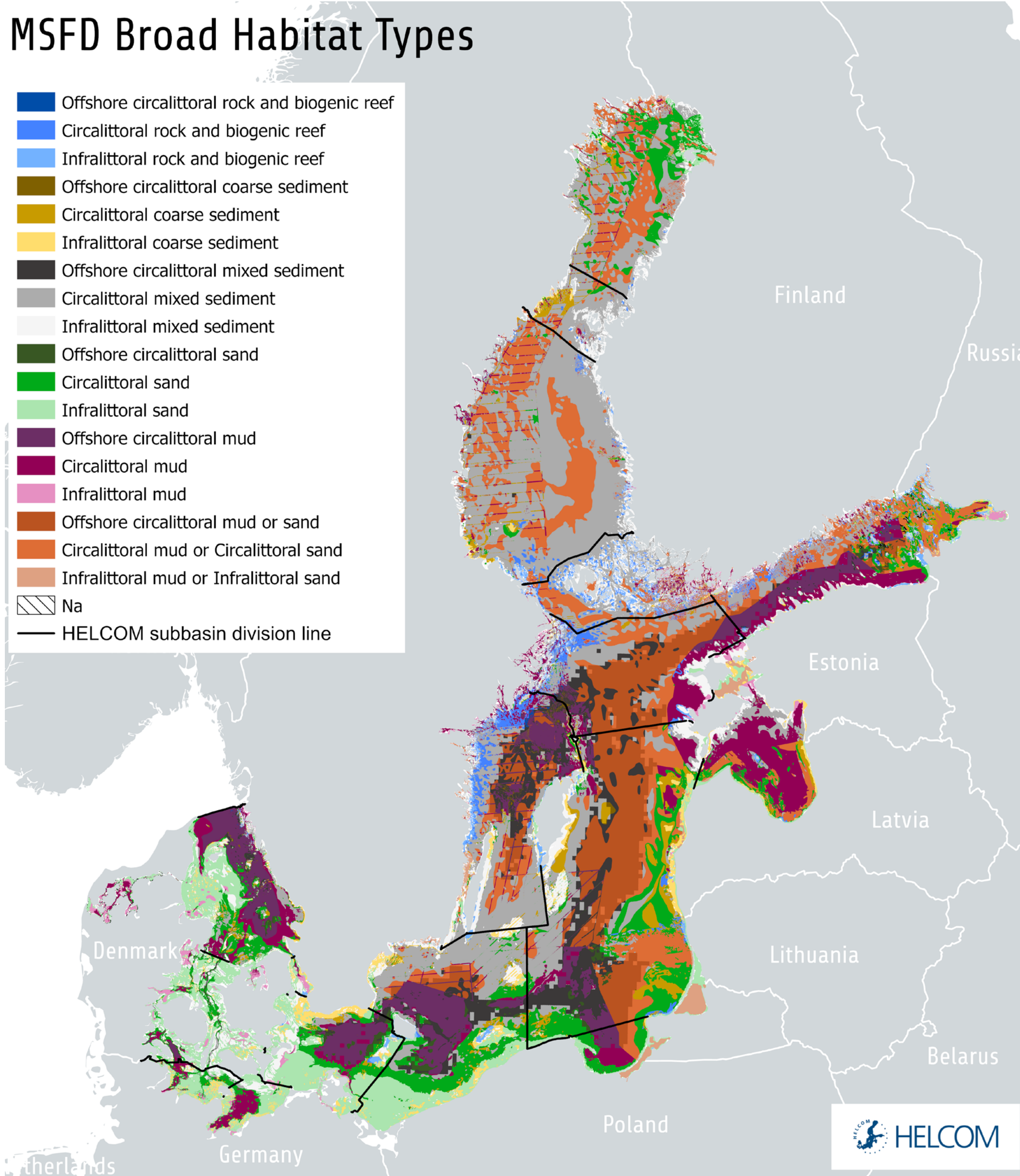


Figure 4.5. Benthic broad habitats types (BHTs) based on EUSeaMap. To explore the broad habitat types in more detail please visit the HELCOM Map and Data Services.

Box 4.1 Habitat modelling and habitat maps

While collection of, and access to, marine habitat data is progressively improving it is unrealistic to expect access to recent habitat data covering the entire seafloor. In order to still achieve an overview with full coverage of seabed habitats across the assessment area the assessment relies on modelling to bridge the gap between the individual datapoints. This also links hydrogeographical and geological survey information to expected habitat type. As presented in section 4.2.2 the HOLAS 3 integrated assessmen of benthic habitats uses modelled habitat maps produced under the EMODNet EUSeaMap-project. While modelling is a highly useful tool it is important to recall that the type, quality and confidence in the outputs of modelling exercises depend on the amount and quality of input data and the assumptions of the model itself. As a consequence, different models can produce different results, potentially even when using the same data. As part of the work to produce the HOLAS 3 'Cumulative impact from physical pressures on benthic biotopes' indicator evaluation (HOLAS 2023p) a test case was produced where the EU SeaMap results were compared to the result of national modelling exercises in German waters. As can be seen in Figure Box 4.1.1 some difference in classification of habitats are present between the two modelled maps, a difference driven by access to more and higher frequency data for the development of the national map.

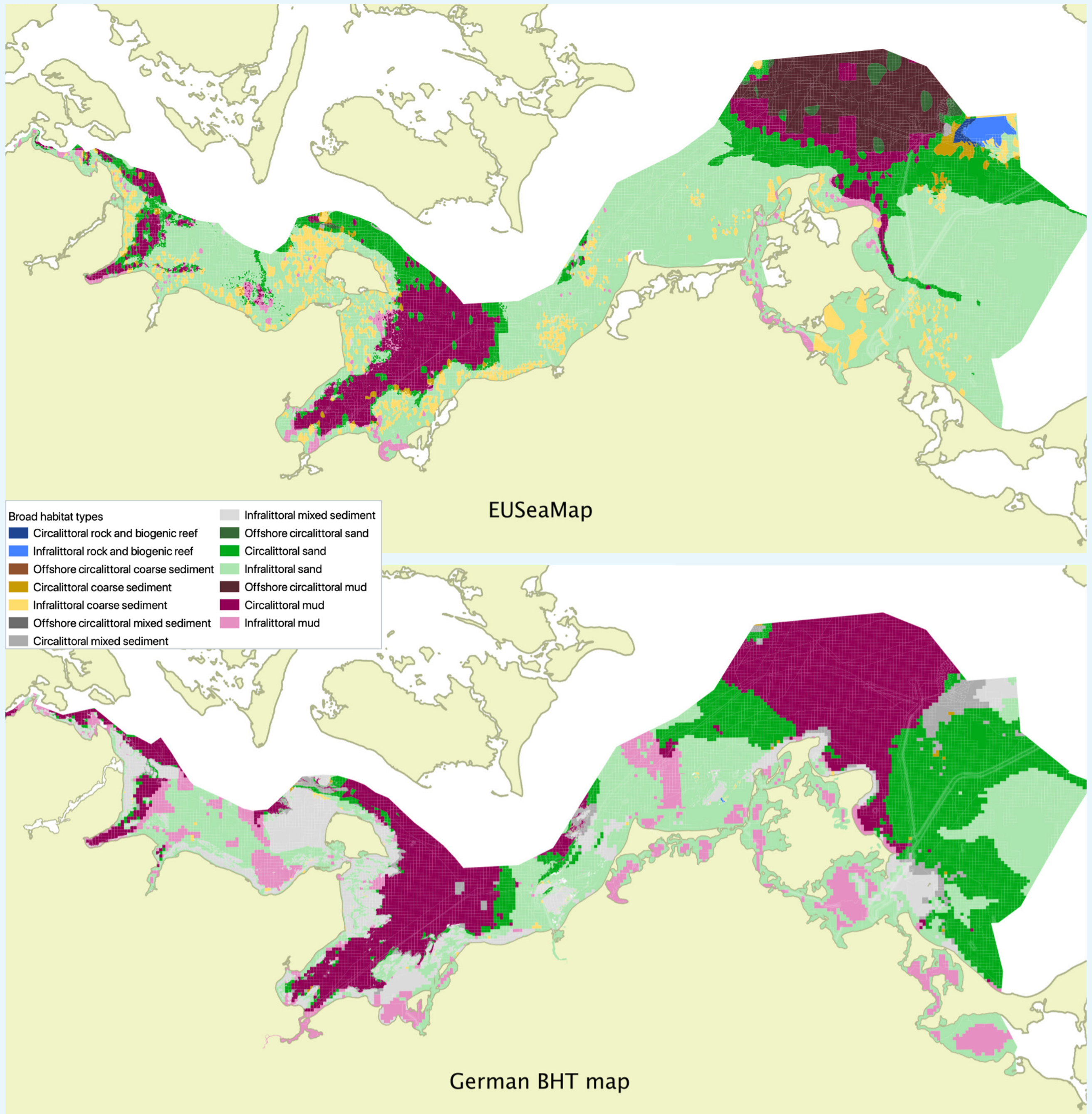


Figure Box 4.1.1. Results of two different models (EUSeaMap and national German model) for the same area of the Baltic Sea. For more information on the methodology used to produce the maps please see EUSeaMap Technical Report (Vasquez *et al.* 2021) and HELCOM 2023p, respectively.

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Box 4.2 Effect on evaluation results when using different habitat modelling products

The results of any data driven evaluation or assessment is highly dependent on the quality of the data on which the assessment is built. In the case of the benthic habitats assessment and evaluations a key component is the information on the distribution of each habitat type (see Box 4.1), as the different habitats have different sensitivity to different pressures. When using modelled habitat maps as the basis for status evaluation and assessments, these evaluations in turn are potentially being used as the basis for decision making and management planning, it is important to consider that the results of the assessment are directly affected by the underlying map. To check the possible effect of using different habitat maps on the results of an evaluation, the two versions of modelled maps presented in Box 4.1 were used for a test case evaluation of the HELCOM indicator Cumulative impact from physical pressures on benthic biotopes. As can be seen in Figure Box 4.2.1 the use of different habitat maps results in differences in the frequency and distribution of the subsequent impact classes across the assessment area used for the test case. This test case highlights the importance of developing high quality and high resolution habitat maps to strengthen the evaluation of benthic habitats and support management needs.

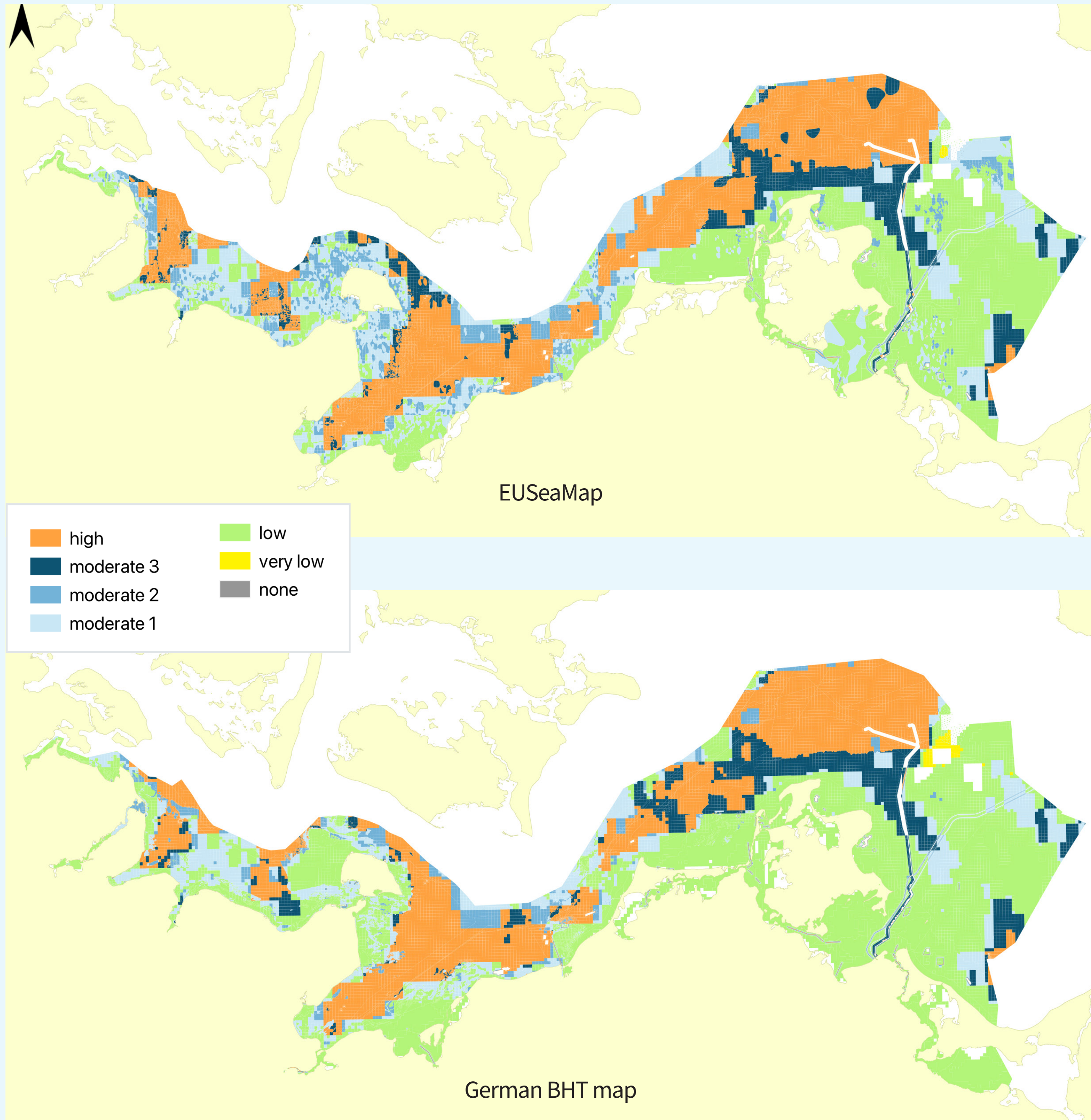

Figure Box 4.2.1. Variations in results when applying the same indicator evaluation methodology on habitat maps produced using two separate models (EUSeaMap and national German model) for the same area of the Baltic Sea. For more information on the methodology used to produce the maps please see EUSeaMap Technical Report (Vasquez et al. 2021) and HELCOM 2023p, respectively.

4.2. Assessment results for benthic habitats

4.2.1 Integrated assessment results for benthic habitats

The output of the assessment shows information on the total area of each BHT impacted or lost across the entire Baltic Sea region, as well as the percentages of each BHT impacted or lost per assessment unit (i.e. 17 sub-basins times the number of relevant BHTs present per sub-basin). This provides a summary of available information, however does not include a quantitative threshold.

The integrated assessment results for benthic habitats are shown in Figure 4.6. There are no spatial threshold values for the benthic broad habitat types agreed within HELCOM. Proposed thresholdvalues are in the process of being developed at EU level. These quantified spatial thresholds delineate:

— the maximum proportion of a benthic broad habitat type in an assessment area that can be lost is 2% of its natural extent (≤ 2%).
— the maximum proportion of a benthic broad habitat type in an assessment area that can be adversely affected is 25% of its natural extent (≤ 25%). This includes the proportion of the benthic broad habitat type that has been lost.

As the threshold values have not yet been finalised by EU at the time of finalising HOLAS 3, these threshold values are not used in the assessment. The assessment results are presented as failing or achieving good status based on the 0.6 Biological Quality Ration value used for all integrated assessments of biodiversity as part of the BEAT tool. More information on the assessment methodology and approach can be found in Chapter 2 (BEAT methodology) and in Annex 1 (Methodology manuals).

The assessment was based on the indicators soft-bottom macrofauna, shallow-water oxygen, oxygen debt and cumulative impact from physical pressures, which spatially overlap (see section 4.6 for details on the methodology). A summary of the results are shown in table 4.1 and 4.2, as well as in Figure 4.6. A confidence scoring is also applied for the overall integrated assessment, reflecting the uncertainty of the assessment applied. A confidence map is included in Figure 4.6. For a full overview of the results and conficence per broad habitat type and sub-basin please see Annex 4.

4.2.2 Indicator evaluation results for benthic habitats

The status assessment of benthic habitats presented in Section 4.3.1 is based on the indicators, and subsequent indicator evaluation results. An overview of the specific indicator evaluation results for each include indicator and area, as well as the respective threshold values, included in the thematic assessment of benthic habitats for 2016-2021 is presented in Annex 2 in the section Benthic habitats. These indicator evaluations represent components of benthic habitats or impacts on these.

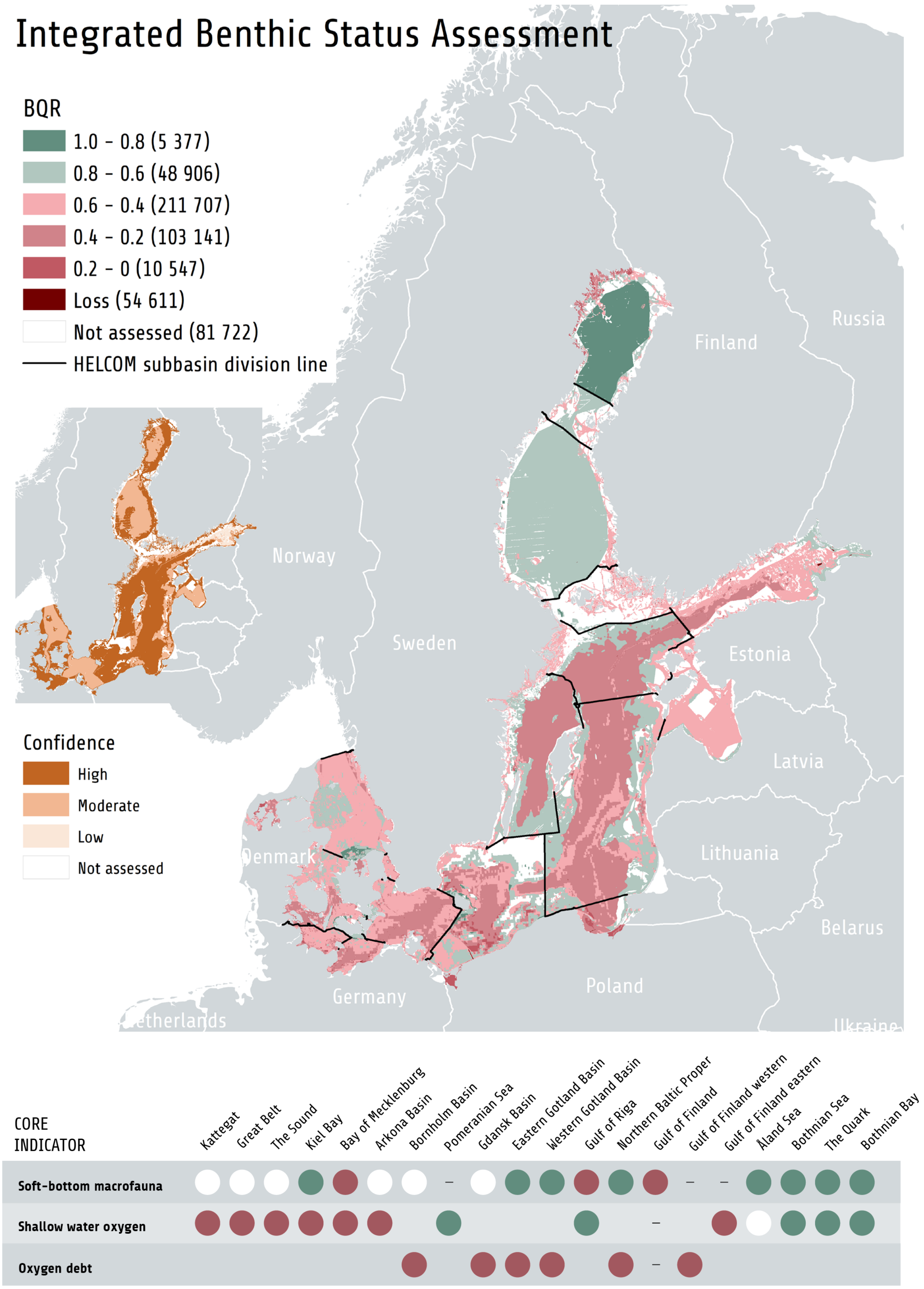

Figure 4.6. Integrated assessment results for status of benthic habitats in the Baltic Sea, for the assessment period 2016-2021. Biological quality ratios (BQR) above 0.6 correspond to good status. Confidence is presented in the map insert on the left hand-side of the figure. Numbers presented in brackets represent the number of assessed grid-cells which fall in each given category. Corresponding indicator evaluation results for indicators included in the integrated assessment are presented in the bottom of the figure.

Table 4.1. Results of the integrated assessment of benthic habitats by sub-basin.

Grand total per sub-basin		Area (km²)	Proportion of Baltic Sea/sub-basin	Nr of BHTs which do not occur in this sub-basin (categories NA and area outside BHT excluded)
Åland Sea	Total size of sub-basin/% of Baltic Sea area	15861	3,8%	3
	Achieve	631	4,0%	
	Fail	4672	29,5%	
	Loss	45	0,3%	
	Adversely affected	4717	29,7%	
	NA	10514	66,3%	
Arkona Basin	Total size of sub-basin/% of Baltic Sea area	17365	4,2%	3
	Achieve	698	4,0%	
	Fail	16467	94,8%	
	Loss	55	0,3%	
	Adversely affected	16523	95,1%	
	NA	144	0,8%	
Bay of Mecklenburg	Total size of sub-basin/% of Baltic Sea area	4520	1,1%	10
	Achieve	375	8,3%	
	Fail	4121	91,2%	
	Loss	18	0,4%	
	Adversely affected	4139	91,6%	
	NA	6	0,1%	
Bornholm Basin	Total	41360	10,0%	0
	Achieve	9440	22,8%	
	Fail	22920	55,4%	
	Loss	51	0,1%	
	Adversely affected	22970	55,5%	
	NA	8950	21,6%	
Bothnian Bay	Total size of sub-basin/% of Baltic Sea area	31915	7,7%	6
	Achieve	23061	72,3%	
	Fail	3483	10,9%	
	Loss	52	0,2%	
	Adversely affected	3535	11,1%	
	NA	5319	16,7%	
Bothnian Sea	Total size of sub-basin/% of Baltic Sea area	58707	14,2%	1
	Achieve	48867	83,2%	
	Fail	2751	4,7%	
	Loss	43	0,1%	
	Adversely affected	2794	4,8%	
	NA	7046	12,0%	

Table 4.1. (Continued) Results of the integrated assessment of benthic habitats by sub-basin.

Grand total per sub-basin		Area (km²)	Proportion of Baltic Sea/sub-basin	Nr of BHTs which do not occur in this sub-basin (categories NA and area outside BHT excluded)
Eastern Gotland Basin	Total size of sub-basin/% of Baltic Sea area	74944	18,2%	0
	Achieve	19905	26,6%	
	Fail	48587	64,8%	
	Loss	39	0,1%	
	Adversely affected	48626	64,9%	
	NA	6413	8,6%	
Gdansk Basin	Total size of sub-basin/% of Baltic Sea area	5845	1,4%	2
	Achieve	685	11,7%	
	Fail	4308	73,7%	
	Loss	30	0,5%	
	Adversely affected	4337	74,2%	
	NA	823	14,1%	
Great Belt	Total	10666	2,6%	4
	Achieve	1805	16,9%	
	Fail	8566	80,3%	
	Loss	100	0,9%	
	Adversely affected	8666	81,2%	
	NA	196	1,8%	
Gulf of Finland	Total size of sub-basin/% of Baltic Sea area	29259	7,1%	0
	Achieve	3103	10,6%	
	Fail	18459	63,1%	
	Loss	235	0,8%	
	Adversely affected	18694	63,9%	
	NA	7462	25,5%	
Gulf of Riga	Total size of sub-basin/% of Baltic Sea area	18696	4,5%	6
	Achieve	804	4,3%	
	Fail	13209	70,6%	
	Loss	24	0,1%	
	Adversely affected	13232	70,8%	
	NA	4659	24,9%	
Kattegat	Total size of sub-basin/% of Baltic Sea area	23924	5,8%	3
	Achieve	6321	26,4%	
	Fail	17417	72,8%	
	Loss	76	0,3%	
	Adversely affected	17494	73,1%	
	NA	109	0,5%	

Table 4.1. (Continued) Results of the integrated assessment of benthic habitats by sub-basin.

Grand total per sub-basin		Area (km^2)	Proportion of Baltic Sea/sub-basin	Nr of BHTs which do not occur in this sub-basin (categories NA and area outside BHT excluded)
Kiel Bay	Total size of sub-basin/% of Baltic Sea area	3436	0,8%	5
	Achieve	146	4,2%	
	Fail	3273	95,3%	
	Loss	3	0,1%	
	Adversely affected	3276	95,3%	
	NA	14	0,4%	
Northern Baltic Proper	Total size of sub-basin/% of Baltic Sea area	32836	8,0%	0
	Achieve	7536	22,9%	
	Fail	21871	66,6%	
	Loss	68	0,2%	
	Adversely affected	21939	66,8%	
	NA	3362	10,2%	
The Quark	Total size of sub-basin/% of Baltic Sea area	7899	1,9%	6
	Achieve	3117	39,5%	
	Fail	1263	16,0%	
	Loss	15	0,2%	
	Adversely affected	1278	16,2%	
	NA	3504	44,4%	
The Sound	Total size of sub-basin/% of Baltic Sea area	919	0,2%	
	Achieve	13	1,5%	3
	Fail	839	91,3%	
	Loss	39	4,2%	
	Adversely affected	878	95,5%	
	NA	28	3,0%	
Western Gotland Basin	Total size of sub-basin/% of Baltic Sea area	33994	8,2%	0
	Achieve	9164	27,0%	
	Fail	20299	59,7%	
	Loss	27	0,1%	
	Adversely affected	20325	59,8%	
	NA	4505	13,3%	

Table 4.2 Summary of results of the integrated assessment of benthic habitat per broad habitat type.

BHT	Spatial extent	Total	Achieve	Fail	Loss	Adversely affected	NA	Nr of sub-basins where this BHT does not occur
Circalittoral coarse sediment	Area in km^2	12877	946	4682	17	4699	7232	
	%	3,1%	7,3%	36,4%	0,1%	36,5%	56,2%	0
Circalittoral mixed sediment	Area in km^2	104628	62579	23592	67	23659	18390	
	%	25,4%	59,8%	22,5%	0,1%	22,6%	17,6%	0
Circalittoral mud	Area in km^2	33342	6333	21706	43	21749	5260	
	%	8,1%	19,0%	65,1%	0,1%	65,2%	15,8%	0
Circalittoral mud or Circalittoral sand	Area in km^2	54454	30206	18208	50	18258	5991	
	%	13,2%	55,5%	33,4%	0,1%	33,5%	11,0%	6
Circalittoral rock and biogenic reef	Area in km^2	7656	298	2010	13	2022	5337	
	%	1,9%	3,9%	26,2%	0,2%	26,4%	69,7%	2
Circalittoral sand	Area in km^2	35765	18041	14695	40	14735	2989	
	%	8,7%	50,4%	41,1%	0,1%	41,2%	8,4%	0
Infralittoral coarse sediment	Area in km^2	8848	312	6673	48	6721	1815	
	%	2,1%	3,5%	75,4%	0,5%	76,0%	20,5%	0
Infralittoral mixed sediment	Area in km^2	22638	3400	11956	133	12090	7148	
	%	5,5%	15,0%	52,8%	0,6%	53,4%	31,6%	0
Infralittoral mud	Area in km^2	4242	599	3149	61	3211	432	
	%	1,0%	14,1%	74,2%	1,4%	75,7%	10,2%	0
Infralittoral mud or Infralittoral sand	Area in km^2	4565	639	1471	58	1529	2397	
	%	1,1%	14,0%	32,2%	1,3%	33,5%	52,5%	6
Infralittoral rock and biogenic reef	Area in km^2	5190	308	2473	40	2513	2369	
	%	1,3%	5,9%	47,6%	0,8%	48,4%	45,6%	1
Infralittoral sand	Area in km^2	31745	10461	18582	214	18796	2488	
	%	7,7%	33,0%	58,5%	0,7%	59,2%	7,8%	0
Offshore circalittoral coarse sediment	Area in km^2	796	0	655	0	656	140	
	%	0,2%	0,0%	82,4%	0,0%	82,4%	17,6%	6
Offshore circalittoral mixed sediment	Area in km^2	19514	859	18488	7	18495	160	
	%	4,7%	4,4%	94,7%	0,0%	94,8%	0,8%	4
Offshore circalittoral mud	Area in km^2	27155	118	26293	10	26303	734	
	%	6,6%	0,4%	96,8%	0,0%	96,9%	2,7%	5
Offshore circalittoral mud or Offshore circalittoral sand	Area in km^2	33823	247	33474	25	33498	78	
	%	8,2%	0,7%	99,0%	0,1%	99,0%	0,2%	9
Offshore circalittoral rock and biogenic reef	Area in km^2	215	1	159	0	159	55	
	%	0,1%	0,3%	74,2%	0,0%	74,3%	25,5%	9
Offshore circalittoral sand	Area in km^2	3094	150	2910	2	2912	33	
	%	0,8%	4,8%	94,0%	0,1%	94,1%	1,1%	5

Soft-bottom macrofauna

The indicator evaluates the status of the soft-bottom macrofauna community occurring in the open sea areas of the Baltic Sea. In Northern Baltic Proper, Gulf of Finland, Eastern Gotland Basin and Western Gotland Basin only areas above the permanent halocline are evaluated. The current evaluation result shows good status in most of the evaluated assessment units (Figure 4.7) (HELCOM 2023q).

Shallow water oxygen

The shallow-water near-bottom oxygen indicator (HELCOM 2023ad), a HELCOM pre-core indicator, is applied for the Western Baltic Sea (including the Pomeranian Bay), the Gulf of Riga, Gulf of Finland Eastern, and the Gulf of Bothnia. During the assessment period 2016-2021, the threshold value was achieved, thus good status was achieved in the following assessment units: Bothnian Sea, the Quark, Bothnian Bay, Gulf of Riga and Pomeranian Bay. The Eastern Gulf of Finland and the western Baltic Sea assessment units including the Kattegat, Great Belt, the Sound, Kiel Bay, Bay of Mecklenburg and Arkona Basin all failed to achieve the set threshold values and are therefore regarded as not in good l status (Figure 4.8).

Oxygen debt

Oxygen debt is applied in the Bornholm Basin and Baltic Proper. Neither of these assessment areas have achieved oxygen debt values below the threshold value (Figure 4.9). Oxygen debt below the halocline has increased in all basins since the early 1900s. The increase has been strongest in recent years since the early 1990s (HELCOM 2023ae).

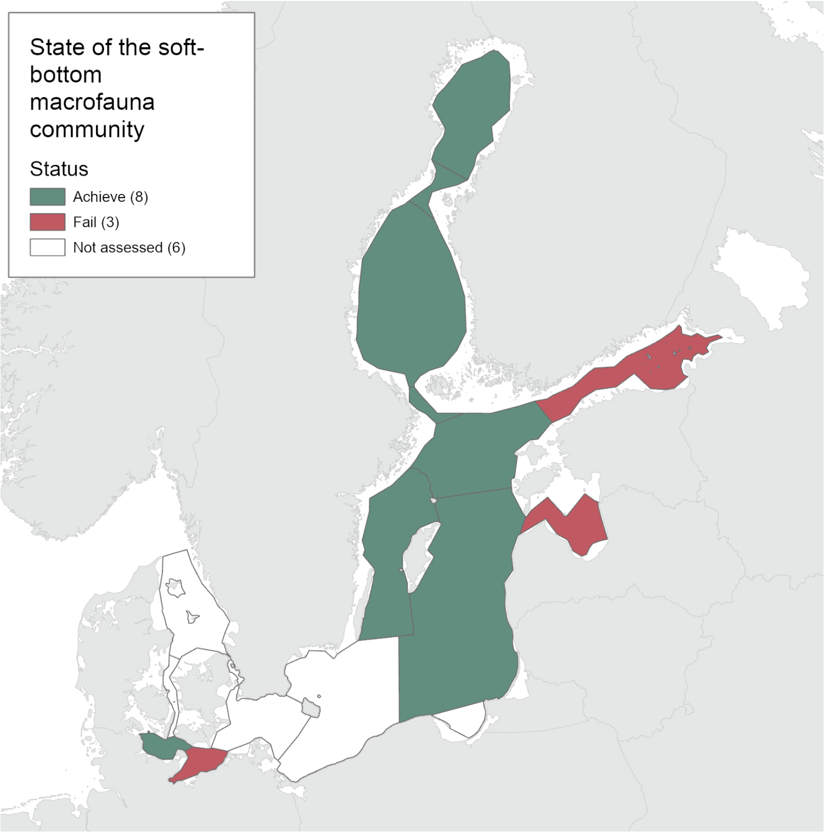

Figure 4.7. Status evaluation based on the indicator 'State of the soft-bottom macrofauna community'. The indicator evaluates the open sea areas of the Baltic Sea. (Source: HELCOM 2023q).

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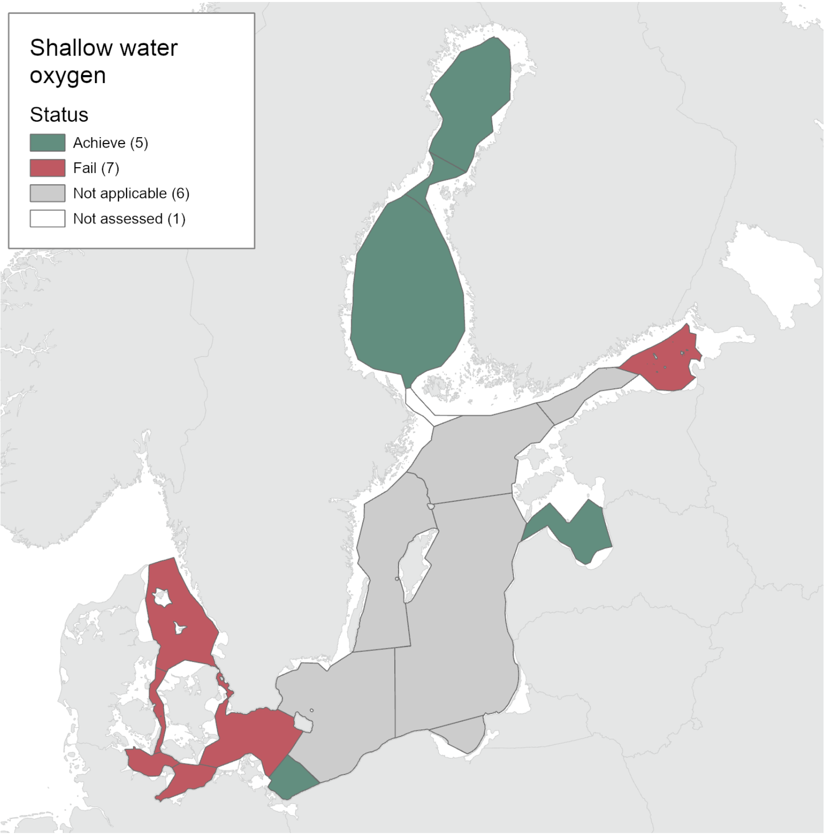

Figure 4.8. Results of the indicator evaluation results for the pre-core indicator 'shallow water oxygen' (source: HELCOM 2023ad).

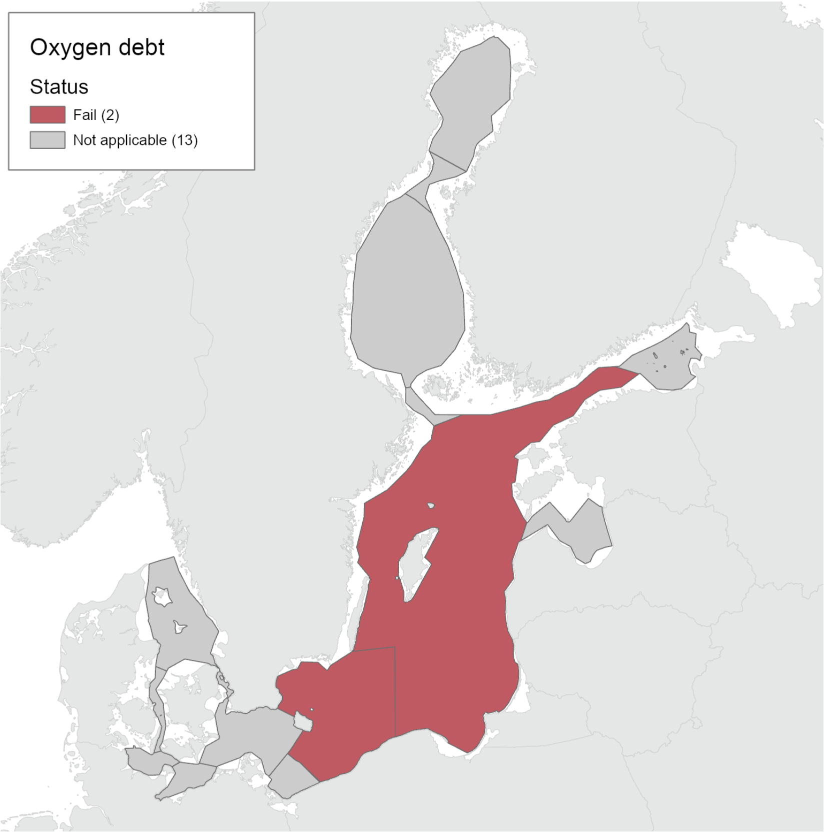

Figure 4.9. Status assessment results based on evaluation of the indicator 'Oxygen debt' (source: HELCOM 2023ae).

Cumulative impact from physical pressures on benthic biotopes (CumI)

The indicator Cumulative impact from physical pressures on benthic biotopes (CumI) (HELCOM 2023p) performs a predictive evaluation of the cumulative (i.e., aggregated) potential impact of several anthropogenic physical pressures on the benthic biotopes of the Baltic Sea. The current evaluation of the CumI includes bottom trawling fishery and mariculture, extraction and disposal of sediments (e. g. dredging and dumping), construction/building and operation of pipelines and cables, platforms and wind farms, coastal protection and shipping. The indicator predicts the cumulative impact of these multiple pressures.

The highest cumulative impact risk from the physical pressures listed above generally occurs in the southern part of the Baltic Sea and in the Kattegat (Figure 4.10), dominated by wide-area pressures such as bottom trawling fishery. Locally, in archipelago areas and especially in coastal fairways, erosion from shipping can have an impact on seafloor sediments. Pressures such as coastal protection are constrained to very narrow stretches or points on the coastline and are occurring in the whole Baltic Sea region.

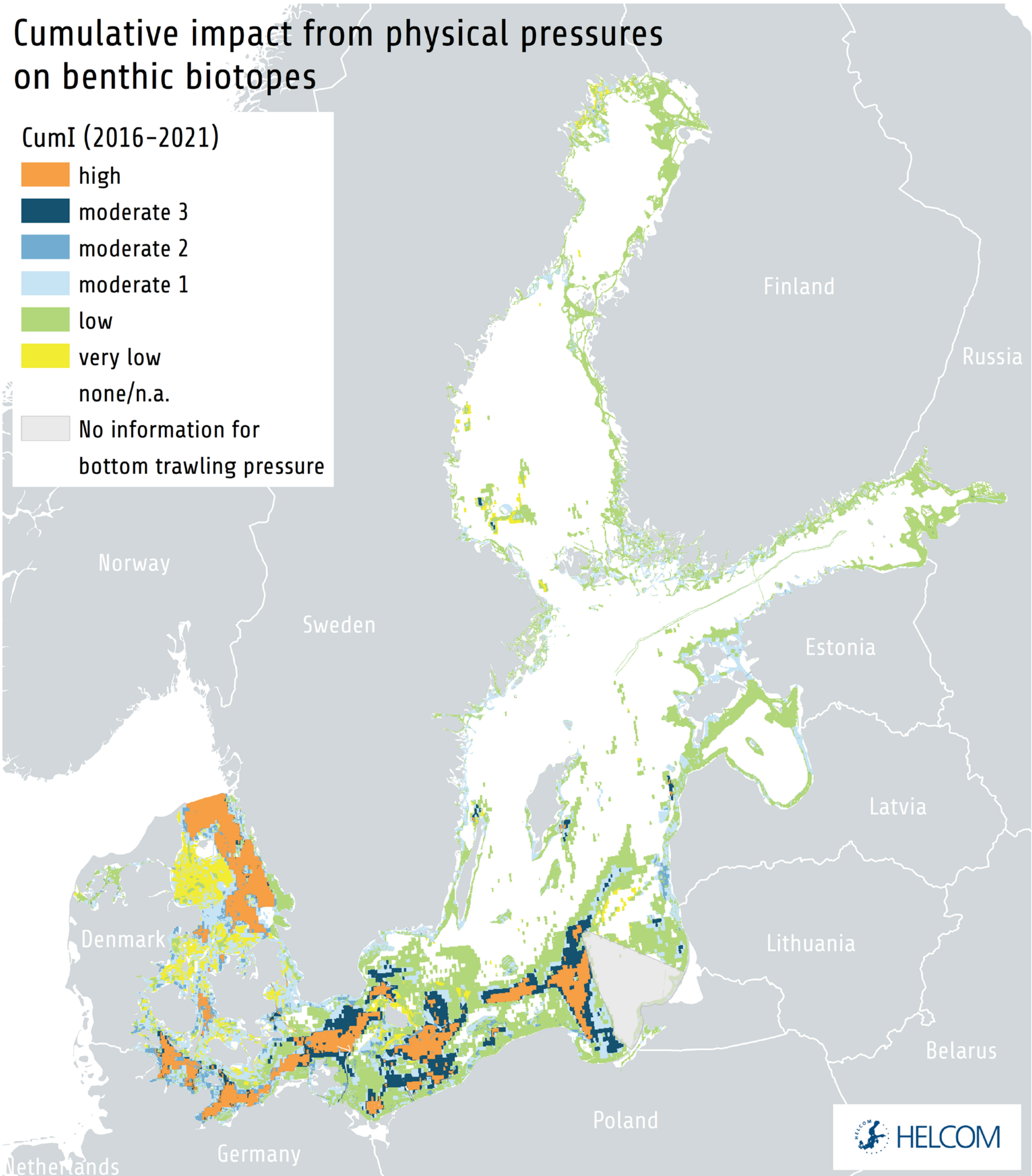

Figure 4.10. Evaluation result of the Cumulative impact from physical pressures on benthic biotopes indicator in the Baltic Sea using HELCOM data from the assessment peripd 2016-2021. The map shows the combined potential impact from physical disturbance, including bottom trawling fishery and mariculture, extraction and disposal of sediments, platforms and wind farms, pipelines and cables, coastal protection and shipping. The area off the coast of Oblast Kaliningrad is a region without information on physical pressures from bottom trawling fishery, a major regional pressure; the general area without data is marked with a half-transparent grey "triangle". White areas within the Baltic Sea area represent regions with no impact. (Source: HELCOM 2023p).

4.3. Changes over time for benthic habitats

4.3.1 Trends between assessments

As the integration methodology, as well as indicators included in the assessment, have significantly changed since the assessment in 2018 it is not possible to provide a comparison across assessments for benthic habitats.

4.3.2 Long term trends

Changes over time for shallow-water oxygen

In the Gulf of Finland, the near-bottom oxygen concentrations at depths of >= 60 m show a declining long-term temporal trend (1906-2021) (Stoicescu *et al.* manuscript). Although near-bottom salinity values do not show a constant long-term trend, periods with decreasing (mid-1970s to the beginning of 1990s) and increasing (beginning of 1990s to the present) salinities can be observed. These periods are associated with distinct changes in oxygen conditions – a decrease in salinity corresponds to an increase in oxygen values and vice versa. Although deep layer temperature also exhibits an oscillating nature, as salinity and oxygen, the amplitude is smaller. Still, a clear increase in temperature is seen, especially in the last three decades (1990- 2021, 0.07 degrees per year).

Changes over time for oxygen debt

Oxygen debt below the halocline has increased in all basins since the early 1900s. The increase has been strongest in the Baltic Proper (Figure 4.11) and the increase has been steep since the early 1990s and very steep between the previous and current assessment periods. The Bornholm Basin experiences larger inter-annual variability because of larger variations in the oxygen concentrations, mainly due to natural water flows or processes.

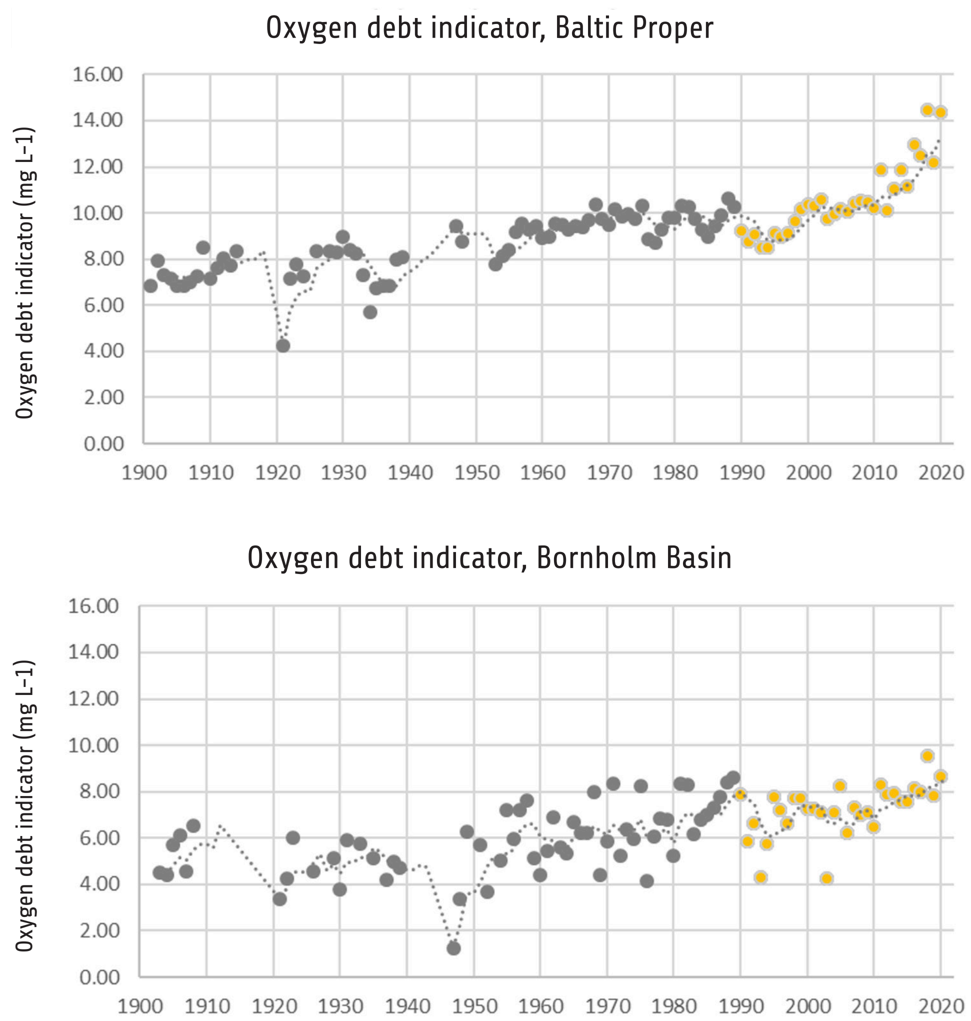

Figure 4.11. Temporal development in the core indicator 'Oxygen debt' in the Baltic Proper (containing Eastern Gotland Basin, Gulf of Gdansk, Western Gotland Basin, Northern Baltic Proper and Gulf of Finland), showing the volume specific oxygen debt below the halocline based on the data and sub-basin division delineation of HELCOM (2018a). Note that the oxygen debt indicator value can exceed the solubility of oxygen since it also includes the oxygen required to oxidize reduced compound like e.g. hydrogensulfide. The dashed line shows the five-year moving average The significance of the trend was tested for the period 1990-2019 by the Mann-Kendall nonparametric test. The data within the examined period are colored orange to visualize the tested significant (p<0.05) deteriorating trend (an increasing trend in oxygen debt signifies deteriorating oxygen conditions). (source: HELCOM 2023x).

4.4. Relationship of benthic habitats to drivers and pressures

4.4.1 Human activities and associated pressures

Eutrophication is one of the main threats to the biodiversity of the Baltic Sea and is caused by excessive inputs of nutrients to the marine environment (See Figure 3.7 in Chapter 3 and HELCOM 2023d). Eutrophication is driven by a surplus of the nutrients nitrogen and phosphorus in the sea. Nutrient over-enrichment causes changes in algal species composition and nuisance blooms of algae, increased turbidity and eventually oxygen depletion which have a severe negative impact on benthic communities.

The benthic biotopes in the Baltic Sea are also negatively affected by several human activities causing physical disturbance to the seafloor. For example bottom trawling fishery and mariculture, extraction and disposal of sediments, constructions, coastal protection and shipping all exert direct and indirect pressures on benthic habitats (Figures 4.12-14).

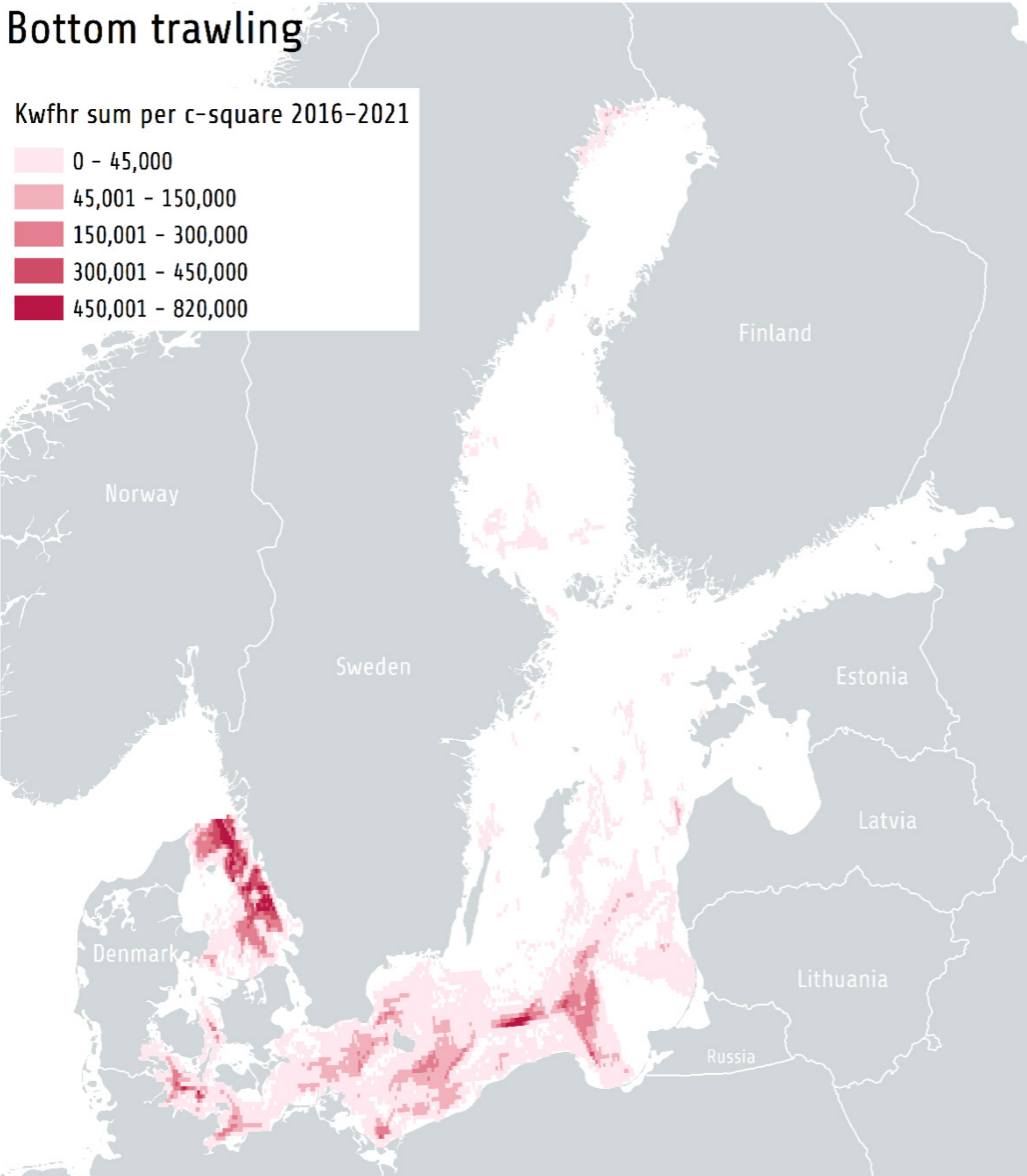

Figure 4.12. Spatial distribution and intensity of bottom trawling in the Baltic Sea 2016-2021

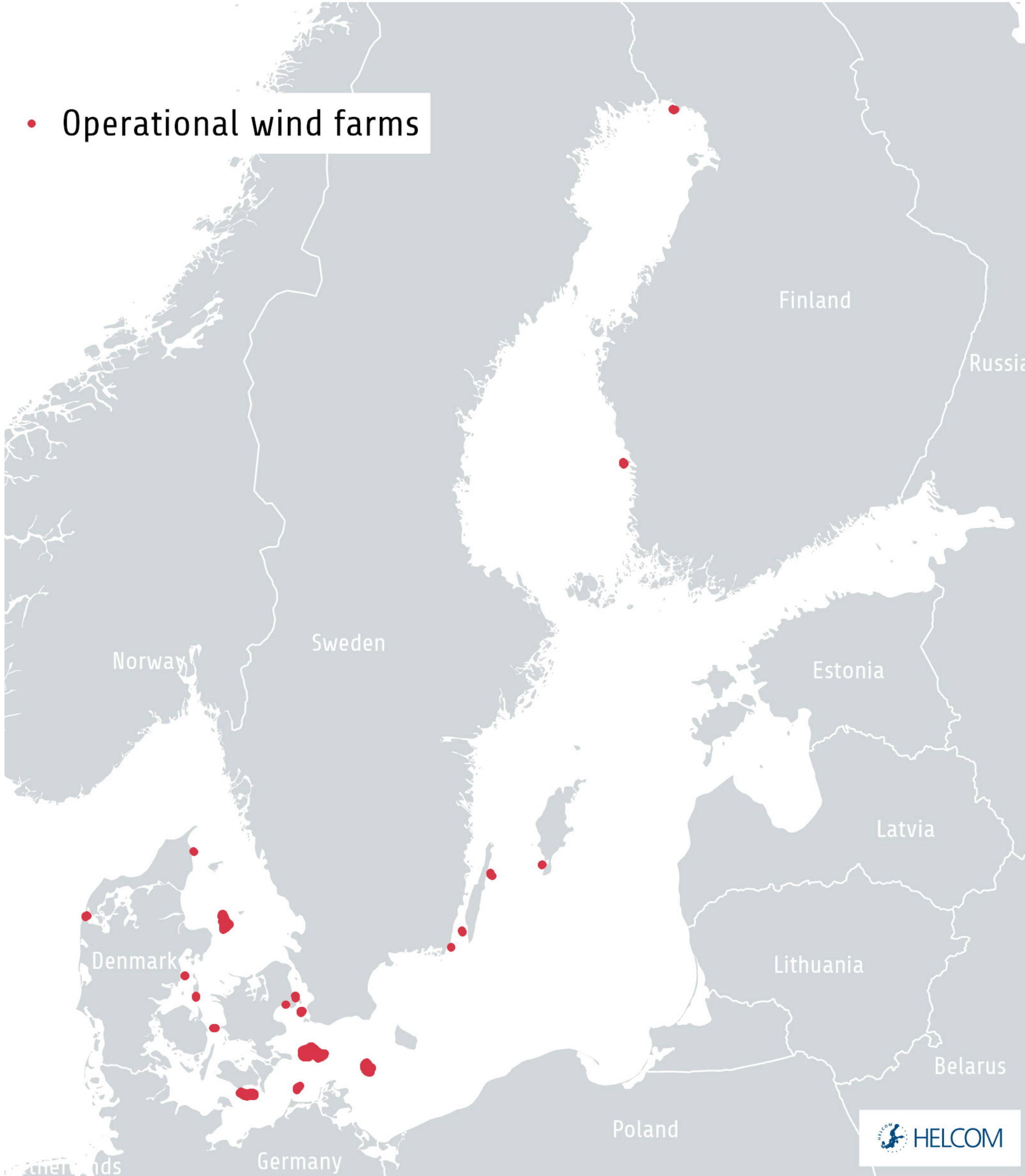

Figure 4.13. Extraction of sand and gravel areas in 2016-2021. During sand and gravel extraction sediment is removed from the seabed, for use in construction, coastal protection, beach nourishment and landfills, for example. Sand and gravel extraction can be performed using either static dredging or 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). Map prepared with the use of the spatial distribution of pressures and impacts tool (SPIA) (source HELCOM 2023a).

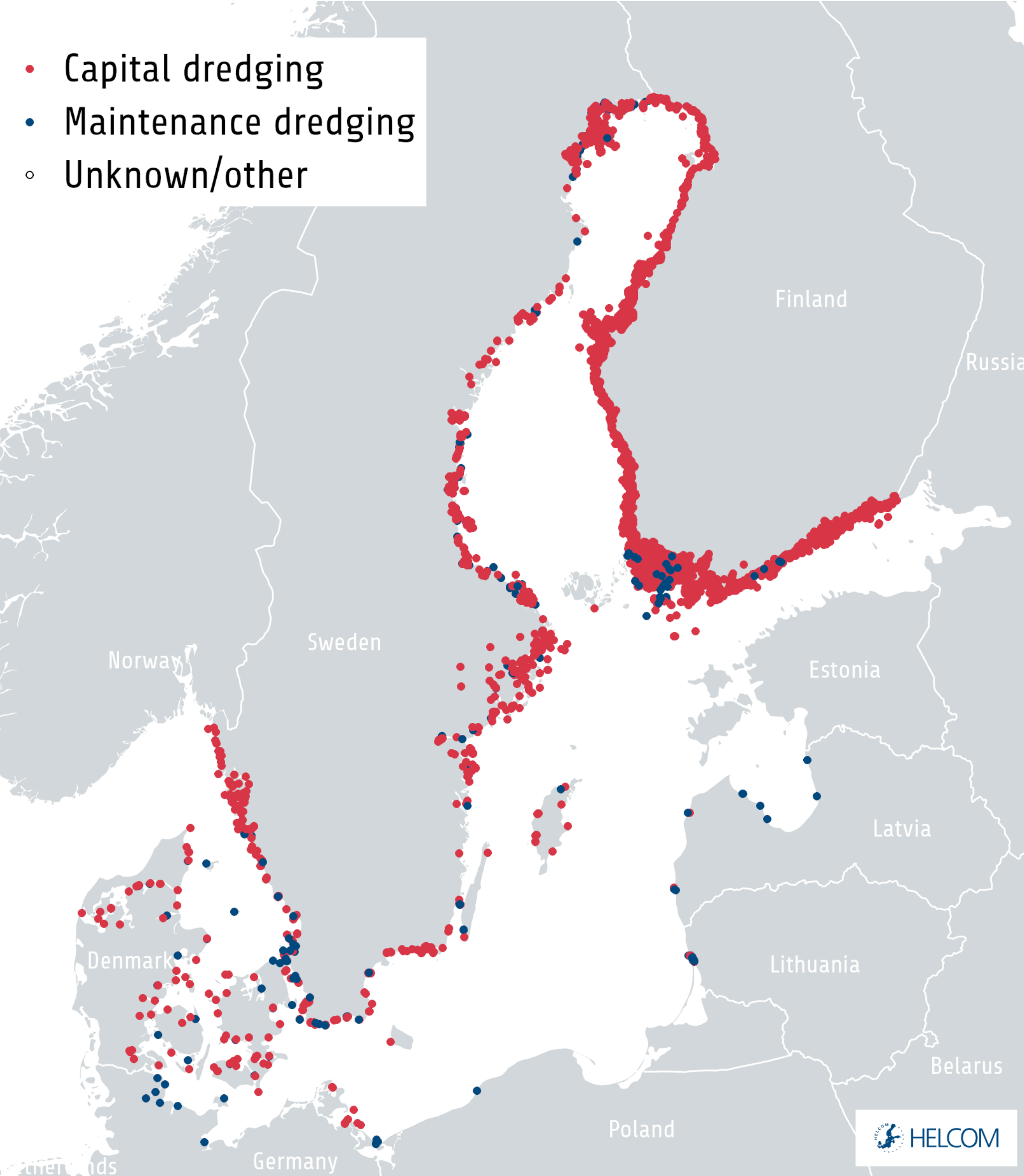

Figure 4.14. Maintenance, capital and unknown dredging operations in the Baltic Sea in 2016-2021. Dredging activities are usually divided into capital dredging and maintenance dredging. Capital dredging is carried out when building new constructions, increasing the depth in existing waterways, or making 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 and 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. Map prepared with the use of the spatial distribution of pressures and impacts tool (SPIA) (source HELCOM 2023a).

In addition to disturbance of benthic habitats, human activities can also result in actual loss of habitat. The Following human activities were considered to cause loss in the assessment: Bridges and other constructions, Cables, Coastal defence and flood protection, Capital dredging, Extraction of sand and gravel, Finfish mariculture, Harbours, Land claim, Marinas and leisure harbours, Oil platforms, Pipelines, Shellfish mariculture, Watercourse modification and Offshore wind turbines. The level of long-term physical loss of seabed in the Baltic Sea was estimated to be less than 1% on the regional scale for the assessment period (HELCOM 2023a). The highest estimates of potential loss at the level of sub-basins ranged between 2% and 7% in Great Belt and The Sound (Figure 4.15). In the majority of the sub-basins, less than 1% of the seabed area was estimated to be potentially lost.

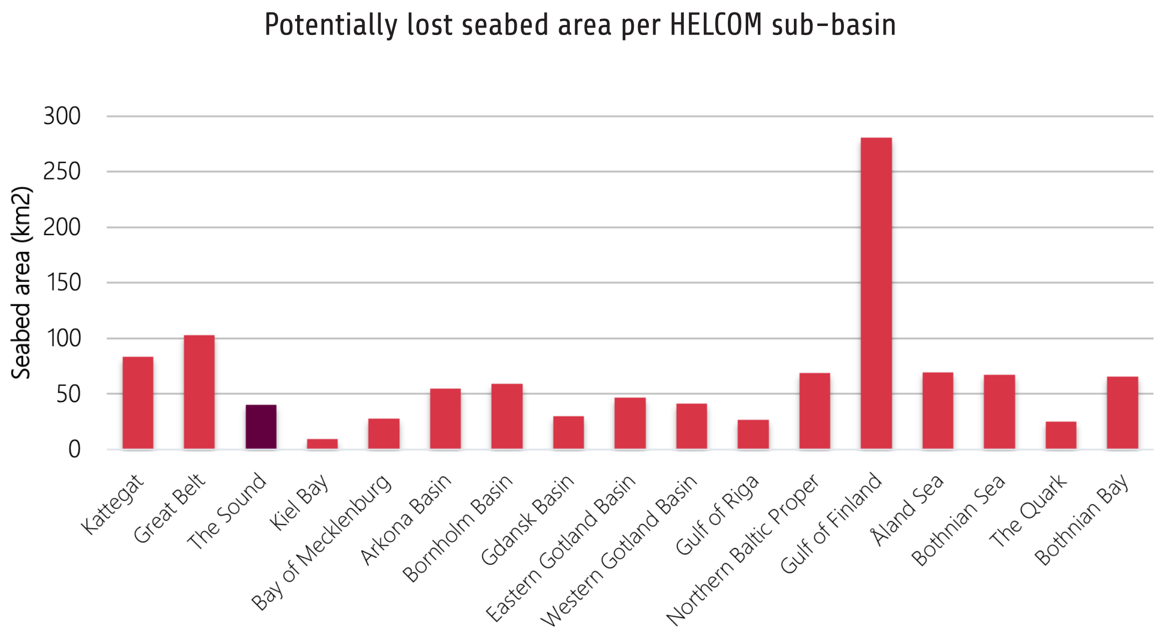

Figure 4.15. Estimated seabed area potentially lost due to human activities per Baltic Sea sub-basin, given as square kilometres. Values were estimated from spatial data on human activities attributed to causing physical loss. Dark red indicates sub-basins where this represents 1-10% of the total area. For the other sub-basins, the lost seabed area was estimated to cover less than 1% of the total area.(Source HELCOM 2023a).

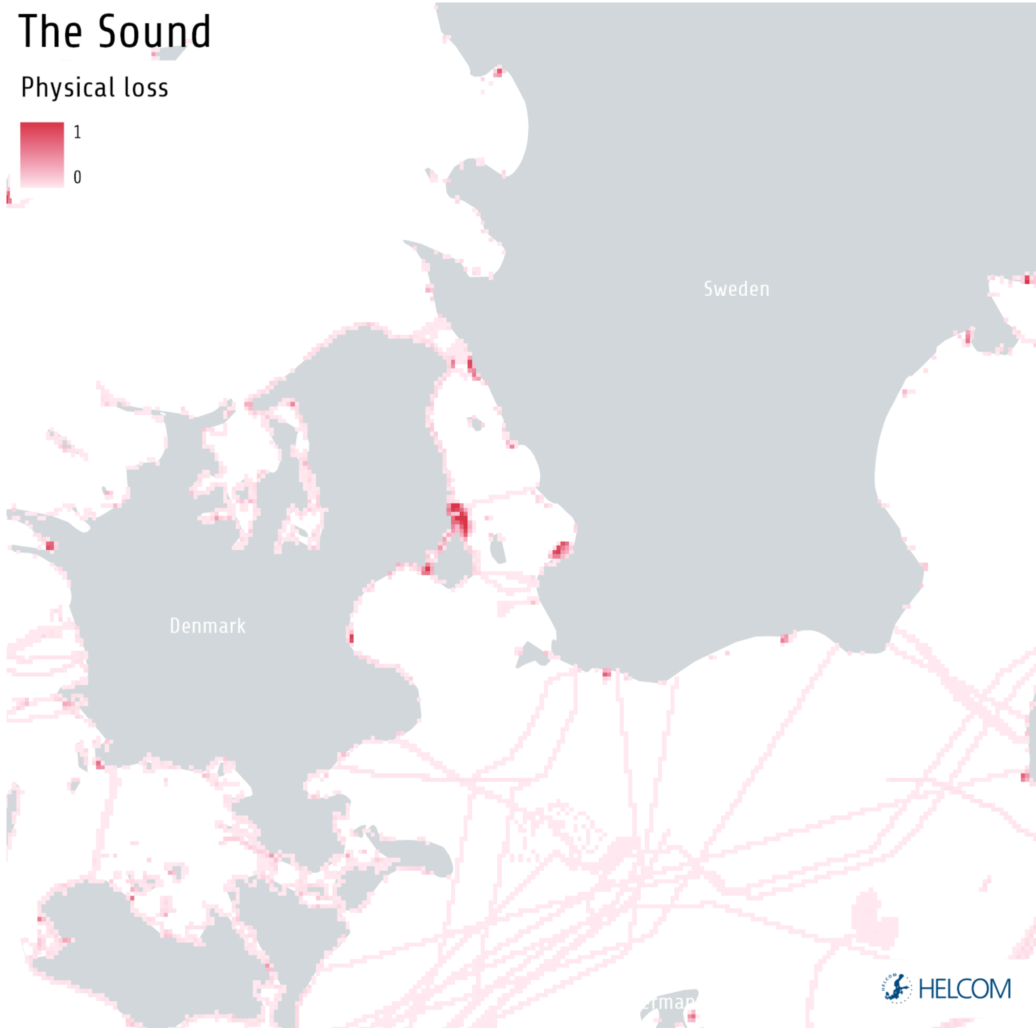

Figure 4.16. Overview of the sub-basin with the highest values for potential physical loss: the Sound. (Source: HELCOM 2023a).

Figure 4.16 shows parts of the sub-basins that presented the highest estimates of potential loss. shows parts of the sub-basins that presented the highest estimates of potential loss. The human activities mainly connected to potential seabed loss for the Baltic Sea were harbours, coastal defence and marinas and leisure harbours. (HELCOM 2023a).

4.4.2 Climate Change

Climate change effects on the Baltic Sea environment are complex and may follow different patterns across the region. Certain trends can however be expected. For example, water temperature and sea level are projected to rise whereas sea ice cover is projected to decrease. Increased freshwater inflows would bring more dissolved organic carbon to the sea, affecting benthic habitats by changes in pelagic primary production and phytoplankton sedimentation. Such a scenario would be expected in the Gulf of Bothnia region. In the Baltic proper the combined effects of warming and planned nutrient reductions will eventually lead to less carbon reaching the seafloor, reducing benthic animal biomass. In the Baltic Sea, many benthic species exist at the edge of their distribution, and even small fluctuations in temperature and salinity can impact their abundance, biomass, and spatial distribution (HELCOM/Baltic Earth, 2021).

4.4.3 Relationship of soft-bottom macrofauna community to drivers and pressures

Soft-bottom macrofauna community composition is a good indicator of environmental status as the results integrate several pressures on the environment over a moderate time period. Changes in the the soft-bottom macrofauna community can, however, only be indirectly linked to anthropogenic pressures. The soft-bottom macrofauna community structure is affected by eutrophication (including oxygen deficiency), changes in water and sediment quality and hydrographic conditions such as salinity or temperature, as well as physical damage to the seafloor (Table 7).

The anthropogenic pressure the indicator clearly reacts to in large areas of the Baltic Sea is eutrophication that causes hypoxia and anoxia in bottom waters (Pearson and Rosenberg 1978, Hyland *et al.* 2005, Norkko 9 *et al.* 2006). Hypoxia has resulted in habitat destruction and the elimination of benthic macrofauna over vast areas, and has severely disrupted benthic foodwebs. Species composition changes as conditions deteriorate, and the advantage gained by smaller-sized and/or tolerant species results in decreasing total biomass and diversity of the soft-bottom macrofauna community as sensitive, large-sized and long-lived species disappear. The most severe damage from the physical pressure of bottom trawling is apparent in the southern areas of the Baltic Sea where trawling intensity is higher and the soft-bottom macrofauna community is dominated by very long-lived species of clams and mussels. In other coastal areas the main physical damage of relevance to the soft-bottom macrofauna community stems from dredging activities and dumping of dredged materials. Dredging and dumping activities can change local hydrographical conditions as well as change siltation rates, especially in the short term.

4.4.4 Relationship of shallow-water oxygen and oxygen debt to drivers and pressures

Oxygen depletion is an indirect effect of eutrophication having an indirect link to anthropogenic pressures, through increased anthropogenic nutrient loads and subsequent increase of organic matter sedimentation.

Diffuse sources constitute the highest proportion of total nitrogen (nearly 50%) and total phosphorus (about 56%) inputs to the Baltic Sea (HELCOM 2022a). For total nitrogen, atmospheric deposition on the sea has the second highest share (24%) followed by natural background loads (20%) and point sources (9%). Natural background loads have the second highest share of total phosphorus inputs to the Baltic Sea (20%), followed by point sources (17%) and atmospheric deposition (7%). Point sources include activities such as municipal wastewater treatment plants, industrial plants and aquacultural plants and diffuse sources consists of natural background sources, and anthropogenic sources as agriculture, managed forestry, scattered dwellings, storm water etc.

Oxygen concentrations in the Baltic Sea deep water are impacted by climate change induced variations in the deep-water transport and mixing/stratification. The effect of climate change to the nutrient pools is not yet separable from the other pressures, and the future nutrient pools will dominantly be affected by the development of nutrient loading. Climate change is, with medium confidence, considered to increase the stratification, further deteriorate near-bottom oxygen conditions and increase the internal nutrient loading. (HELCOM/Baltic Earth, 2021).

4.4.5 Relationship of cumulative impact indicator from physical pressures on benthic biotopes to drivers and pressures

HELCOM completed a Red List assessment for Baltic Sea benthic biotopes, habitats and biotope complexes in 2013. For those benthic biotopes that had experienced, or were expected to experience in the future, a decline high enough to warrant a listing in the threat categories, were further considered to identify the major cause of decline. The threats were categorized and the main threat categories causing physical disturbance to benthic biotopes, based on used data, are benthic biotopes were 'Fishing', 'Construction' and 'Mining and quarrying', additional ones that may cause physical damage included 'Tourism', 'Water traffic' and 'Ditching' (HELCOM 2013b). In the 2018 HOLAS II update of the 'State of the Baltic Sea' report, the top human activities causing cumulative impacts on benthic habitats were bottom trawling, shipping, recreational boating and sediment dispersal caused by various construction and dredging activities and deposit of dredged sediment (HELCOM 2018a).

The Cumulative impact from physical pressures on benthic biotopes (HELCOM 2023p) is structured around these main uses and human activities known to have impact on benthic biotopes through physical disturbance, especially those with large spatial impacts. Activities causing more local pressures include tourism and leisure activities and infrastructure.

4.5. Assessment methodological details

The methodology used for the integrated assessment of benthic habitats is presented in Annex 1, section Benthich habitat assessment methodology. The layers and undelying data can be found in the HELCOM Map and Data Services.

4.6. Follow up and needs for the future with regards to benthic habitats

4.6.1 HELCOM actions

In terms of the HELCOM Baltic Sea Action Plan (HELCOM 2021a), the assessment targets the ecological objectives "Natural distribution, occurrence and quality of habitats and associated communities" and "viable populations of all native species" within the BSAP segment Biodiversity, however actions of both direct and indirect relevance for benthic habitats and seafloor integrity are included in both the Biodiversity and Seabased-activities segments of the BSAP, as listed in Table 4.3.
In addition to the 2021 BSAP actions listed here the HELCOM Recommendations 40-1 Conservation and protection of marine and coastal biotopes, habitats and biotope complexes categorized as threatened according to the HELCOM Red Lists, 35/1 System of coastal and marine Baltic Sea Protected areas (HELCOM MPAs) and 15/1 Protection of the coastal strip all have relevance for benthic habitats and biotopes as they outline measures for the protection of benthic habitats.

4.6.2 Other international commitments

The EU Marine Strategy Framework Directive and the EU Habitats Directive both outline measures for improving the status of benthic habitats and the upcoming EU Restoration Regulation, which requires the restoration of a percentage of the habitats identified in its Annexes, covers a broad range of marine habitats in the Baltic Sea.

Table 4.3. 2021 Baltic Sea Action Plan actions of relevance for benthic habitats.

Code	Action
B25	Map ecosystem services and the present and potential spatial distribution of key ecosystem components, including habitat forming species such as bladder wrack, eelgrass, blue mussel and stoneworts Baltic-wide, by 2025.
B26	Protect key ecosystem components including habitat forming species by 2030, by: — assessing the state of, and threats to these key ecosystem components by 2023 — implement effective and relevant threat mitigation measures based on the threat and state assessments, including restricting human activities associated with causing physical loss or disturbance, by 2030 — identifying suitable measures and types of habitats, biotopes and key ecosystem components for passive or active restoration by 2025 and implementing programmes for restoration as outlined in the HELCOM Restoration Action plan by 2030.
B27	By 2025 develop and by 2026 start implementing a HELCOM Action Plan for habitat and biotope restoration, including qualitative and quantitative regional targets, a prioritized list of actions, and an associated implementation toolbox outlining best practices and methods for restoration in the Baltic Sea region.
B28	Update the HELCOM Red List Assessments by 2024, including identifying the main individual and cumulative pressures and underlying human activities affecting the red listed biotopes and habitats.
B29	By 2025 develop, and by 2027 implement, and ensure compliance with, ecologically relevant conservation plans or other relevant programmes or measures, limiting direct and indirect pressures stemming from human activities for threatened and declining biotopes and habitats
B30	Develop tools for and regularly assess the effectiveness of other conservation measures for habitats and biotopes besides marine protected areas (MPAs), with the first assessment to be done by 2025, as well as assess the effect on biotopes and habitats through risk and status assessments by 2029.
B31	Identify by 2022 data needs for spatial pressure and impact assessment of human activities, including cumulative impacts, and implement by 2024 at the latest methods for mapping and assessment of adverse effects on the ecosystem of human activities in the Baltic Sea region.
B32	Update the HELCOM Underwater biotope and habitat (HUB) classification where gaps have been identified by 2024, and by 2025 develop a fully functioning translation matrix between HUB, Marine Strategy Framework Directive (MSFD) broad habitat types, Habitats Directive habitats and the European Nature Information System (EUNIS), in co-operation with the European Marine Observation and Data network (EMODnet).
S64	Enforce and implement by 2025, in line with the update of the marine protected area (MPA) management guidelines, effective management plans and/or conservation measures to not allow destructive and exploitative activities related to the seabed that may compromise the conservation objectives of MPAs.
S65	By 2026 implement a common approach to address and where possible minimize the loss of and disturbance to seabed habitats caused by human activities.
S66	Regularly update and improve the HELCOM Recommendation and Guideline for handling dredged material at sea using the best available knowledge to minimize environmental impact of these activities further developing Best Environmental Practice (BEP) and Best Available Technique (BAT) for dredging and depositing operations.
S67	Define the characteristics of benthic habitats, develop core indicators and undertake an integrated assessment of the status of benthic habitats, including their structure, function, distribution and extent of loss, no later than 2023, leading to the identification of measures to reduce adverse effects where needed. Work should be done in close cooperation with work undertaken by Contracting Parties in other relevant fora, taking into account activities in EU Technical Group on seabed habitats and sea-floor integrity (TG Seabed), and considering the ICES advice on a sea-floor assessment process.
S68	Develop a map service for lost and disturbed habitats under the HELCOM Map and Data Service by 2024

4.6.3 Needs for the future assessments

Assessment development needs with regards to soft-bottom macrofaunal community

For an optimal evaluation of the status of soft-bottom communities, the benthic macrofauna needs to be monitored in all coastal and open sea assessment units. Monitoring design should optimally take into account the habitat heterogeneity within the assessment unit to cover the spatial variation in communities. Ideally, the same methodology should be applied throughout the Baltic Sea. Improved benthic habitat maps in the future would also support better application of this indicator in downstream assessment processes (e.g. the integrated assessment of benthic habitats) and further improve confidence. Additional developments to explore temporal trends may also be of value.

Assessment development needs with regards to shallow-water oxygen

The indicator is in test use in HOLAS 3, with an aim of developing it toward core indicator status by HOLAS 4. The development work includes potentially combining and harmonizing the approaches used in different assessment units. In addition, it may be relevant to explore development in other sub-basins where the oxygen debt indicator is also applied (should shallow waters in those basins be relevant to assess) with spatial integration of the two indicators as a subsequent step. The current pre-core indicator addresses a significant issue both from a policy and ecological perspective and is also relevant due to its links with benthic habitats so harmonization and further development beyond HOLAS 3 would be valuable.

Assessment development needs with regards to oxygen debt indicator

Future development of the oxygen debt indicator would need to consider (1) a possible differentiation of threshold values for good status in deep basins currently evaluated as one Baltic Proper assessment unit, (2) how saltwater transport in deep basins and/or MBI intensities or changes in hydrographic conditions are best taken into account, and (3) whether there is a need to account for changes in nutrient input in the indicator calculations.

Assessment development needs with regards to cumulative impact from physical pressures on benthic biotopes

There is a clear need to improve the harmonization and regular collection of relevant human activities data in the HELCOM region. Addressing this is considered as important not only for the *CumI* indicator but for a number of other relevant processes in HELCOM or future HOLAS assessments. It is important that such issues will be considered under the post-HOLAS 3 review process and the issue has already been raised to the State and Conservation Working Group. This also includes the reporting of human activities data with proper and uniform metadata making it possible to clearly distinguish between data not reported, not available or a pressure not being present.

Further, the current quality of benthic habitats maps can be a limiting factor in such assessments and improvements in both national and regional maps to support future assessments are vital.

To assess the magnitude of trawling pressure, *CumI* uses/applies surface SAR which summarizes surface abrasion caused by all trawling activities within a defined space and time. The assessment resolution of trawling pressure is thus inherently depending on the resolution of SAR data available in respect to space, time and intensity. More detailed information on trawling gear types or métiers has now become available. Different trawling activities penetrate the seabed substrate to different extents and there is growing evidence that depletion of benthic fauna correlates with penetration depth (Hiddink *et al.et al.* 2017). Consequently, once agreed on trawling gear types/métiers associated penetration depth of the trawling gear types/métiers should be taken into account in addition to the SAR values to assess the future magnitude of pressure caused by physical disturbance through mobile fishing gears (Eigaard *et al.et al.* 2016, ICES 2016, Rijnsdorp *et al.* 2020). Additionally better resolution of fishing data could give a more accurate estimate of bottom trawling data. Currently the scale is quite coarse and likely overestimates the extent of bottom trawling.

When the *CumI* was developed for HOLAS 3, frequency information was not readily available for the individual pressures. Hence, frequency is currently not used in the evaluation. To keep the current evaluation as close as possible to the agreed evaluation protocol for HOLAS 3, frequency information now available in the newly submitted data sets is still left out.

Last, the approach applied in this indicator utilizes sensitivity scores as part of the basis on which predicted impacts are derived. These sensitivity scores are derived from experimental work are based on expert judgement e.g., literature, experience, and literature surveys, and all have been regionally reviewed and adapted where required for sub-regional specificity and are therefore considered to be of low confidence. However, as with all scientific endeavors knowledge increases and better information becomes available over time. New sensitivity scores need to be included as they become available and designated scientific work on this issue is likely highly valuable to support the assessment evaluation of benthic habitats. Likewise, studies to evaluate or ground truth the in-situ relationship between status of benthic habitats (and their biotopes) in relation to the expected impacts generated via CumI would be valuable.

Other future assessment development needs

In addition to the development needs for the existing HELCOM indicators, there are aspects of benthic habitats currently not addressed by any indicator, including but not limited to an indicator specifically evaluating the status of hard substrate habitats based on monitoring data – to complement the soft substrate indicator. Such gaps will need to be identified, and the development towards filling them commenced, towards future assessments.

5. Results for the fish assessments

Assessment results in short

- The integrated status of coastal fish using HELCOM indicators was evaluated as good in two out of twenty-two assessed coastal areas.
- The status of the migrating species salmon and sea trout varies geographically. Salmon stocks in the northern Baltic rivers have improved, while salmon in many rivers further south are far from good status, based on HELCOM indicators.
- The European eel remains critically endangered.
- Only four commercial fish stocks showed good status, out of the fifteen stocks that could be evaluated with respect to both fishing pressure and stock size. Eighteen commercially important stocks could not be evaluated.
- Evaluation of fish age and size structure are imperative for achieving sufficient confidence in the assessment results for commercial fish. Changes over time in fish age/size structure were evaluated for the first time in HOLAS, for fourteen stocks, but work should continue to develop assessment approaches in relation to definitions of good status.

5.1. Introduction to fish in the Baltic Sea

5.1.1 Importance of fish for the Baltic Sea ecosystem

Fish are present in all types of habitats of the Baltic Sea. Coastal and open sea areas are characterized by different species assemblages. There are also clear differences in species composition and in the composition of functional groups among sub-basins, due to the salinity differences (Koehler *et al.* 2022). About 230 fish species are recorded in the Baltic Sea, distributed over species of both freshwater and marine origin (HELCOM 2020b).

The spatial variability is enhanced by the fact that many fish are highly mobile and alter their key habitat over the year. Several species of marine origin, such as herring (*Clupea harengus*) and cod (*Gadus morhua*), migrate between coastal and offshore areas for spawning or feeding, and some populations move between the Baltic Sea and the North Sea. The migrating species, salmon (*Salmo salar*) and sea trout (*Salmo trutta*), are born and spawn in rivers or streams, but spend most of their life in the Baltic Sea. Coastal areas and freshwater tributaries are key spawning habitats for freshwater species, such as perch (*Perca fluviatilis*), pike (*Esox lucius*) and cyprinids (Cyprinidae). The European eel (*Anguilla anguilla*) is highly migrant, with eel from the Baltic Sea being part of the same population as all other European eels.

5.1.2 Fish and Baltic Sea environmental management

Fish are important providers of several ecosystem services in the Baltic Sea. The role of piscivores for regulating foodwebs and maintaining trophic structure is increasingly recognised (Olsson 2019), in parallel with worrying declines in several key piscivores in the Baltic Sea, such as cod and pike. Several fish species are also important prey items, constituting a key food source for other fish, as well as for sea birds and marine mammals (Hansson *et al.* 2017, Scotti *et al.* 2022).

Fish are also an important source of livelihood for humans. Twenty-three species are listed as commercially important at the regional scale, based on their contribution to the 98% cumulative landings in terms of weight or value in years 2015-2019 (HELCOM 2021b, see also ICES 2022a). The extent of fishing varies, however, between countries (Box 5.1) and over time (see box 9.1), related to for example differences in the availability of fish and the viability of fisheries.

Box 5.1. Overview of the fisheries in the Baltic Sea

More than 50 species are landed in commercial fisheries in the Baltic Sea (ICES 2022a). Of these, 23 species are identified as being of commercial importance, based on their contribution to the cumulative 98% of landings in terms of either weight or economic value, including both open sea and coastal fisheries (HELCOM 2021b). Several of the commercial species are managed as more than one stock. The weight and value of the recreational and subsistence fishery is higher than that of the commercial fisheries for some species and regions (Hyder et al. 2018, HELCOM 2020c). All fish species and stocks identified as having regional commercial importance (HELCOM 2021b) are listed in Table 5.2.

The pelagic species sprat (*Sprattus sprattus*) and herring (*Clupea harengus*) have the highest share of the landings, contributing to over 80% of the landings by weight (ICES 2021a, HELCOM 2021b). The main part of the pelagic landings is used for fish meal production, animal fodder, or oil, although pelagic fish in the small-scale fishing are for consumption. Landings of other fish are used for human consumption.

The pelagic commercial fishery is widespread in the Baltic Sea. Demersal open sea fish are mainly caught in the southern parts of the region (ICES 2022b), while fisheries on other species mainly occur along the coast. Sweden, Denmark, and Poland have the biggest fleets (ICES 2022b). The total landings are highest for Poland, Finland, Sweden, and the Russian Federation, with low interannual variation. Total fishing effort, at the Baltic Sea scale, has decreased in recent years (ICES 2021a). For an overview of the intensity of extraction of herring, cod and sprat during the assessment period 2016-2021 please Figure Box 5.1.

The main target species for recreational and subsistence fisheries varies between sub-basins, depending on which species occur naturally. Cod (*Gadus morhua*) is important in the southern Baltic Sea, flounder (*Platichthys flesus*) and turbot (*Scophthalmus maximus*) are mainly caught in the central and southern Baltic Sea, while salmon (*Salmo salar*) and sea trout (*Salmo trutta*) are caught throughout the region. Pikeperch (Sander lucioperca), pike (*Esox lucius*), perch (*Perca fluviatilis*), and whitefish (*Coregonus maraena*) are important species for recreational fishing in the central and northern Baltic Sea (HELCOM 2020c). In some areas, the volume of landings in recreational and subsistence fisheries is higher than that of the commercial fisheries, especially for freshwater species, such as pikeperch, pike, perch, and whitefish.

Unintentional bycatches of birds and mammals occur mainly in gillnet fisheries, where a growing issue relates to risks for harbour porpoise (ICES 2020a), which is critically endangered in the Baltic Proper (ICES 2020a; Chapter 9).

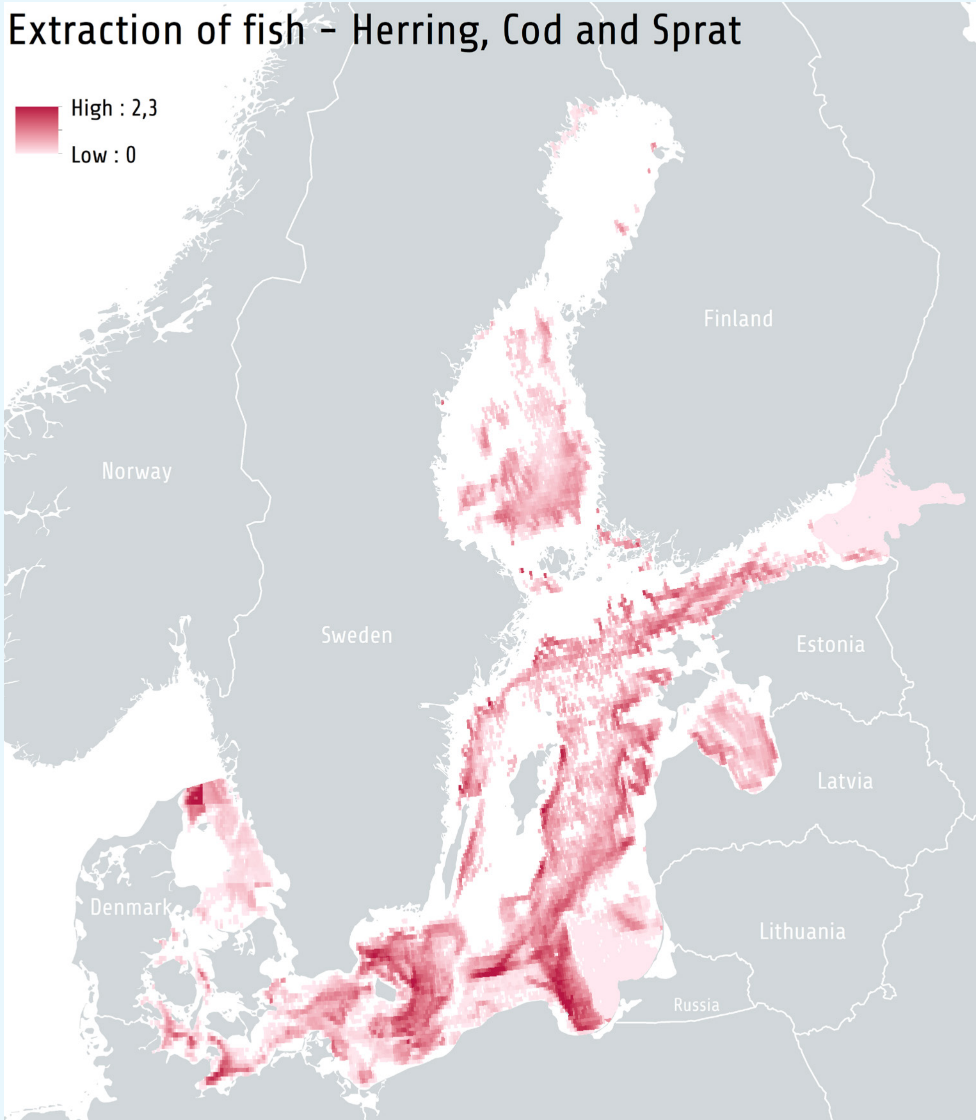

Figure Box 5.1. Spatial distribution and intensity of fishing efforts for the three main commercial fish species in the Baltic Sea, namely herring, sprat and cod, 2016-2021, all gear types. The layer is based on data on commercial during 2016-2020, available at the spatial scale of ICES statistical rectangles from the EU Joint Research Centre's data collection framework for fisheries data, for Contracting Parties which are part of the European Union. Data for Russia were obtained from ICES annual reports, and were only available at the scale of ICES sub-divisions. The Russian landings data were equally distributed over all ICES rectangles within the concerned sub-divisions. To obtain spatially more detailed information, the landings data were further redistributed within each ICES rectangle based on information on fishing effort (including all gears, c-squares) during 2016-2021. Information on effort was not available for Russia, and average values for the sub-basins were used. In the scaling, the maximum value of tons per square kilometre from the original ICES rectangles was used to scale the maximum pressure. The data set was log-transformed and normalized to produce the final pressure layer. For an overview of intensity of bottom trawling please see Figure 4.12 in Chapter 4.

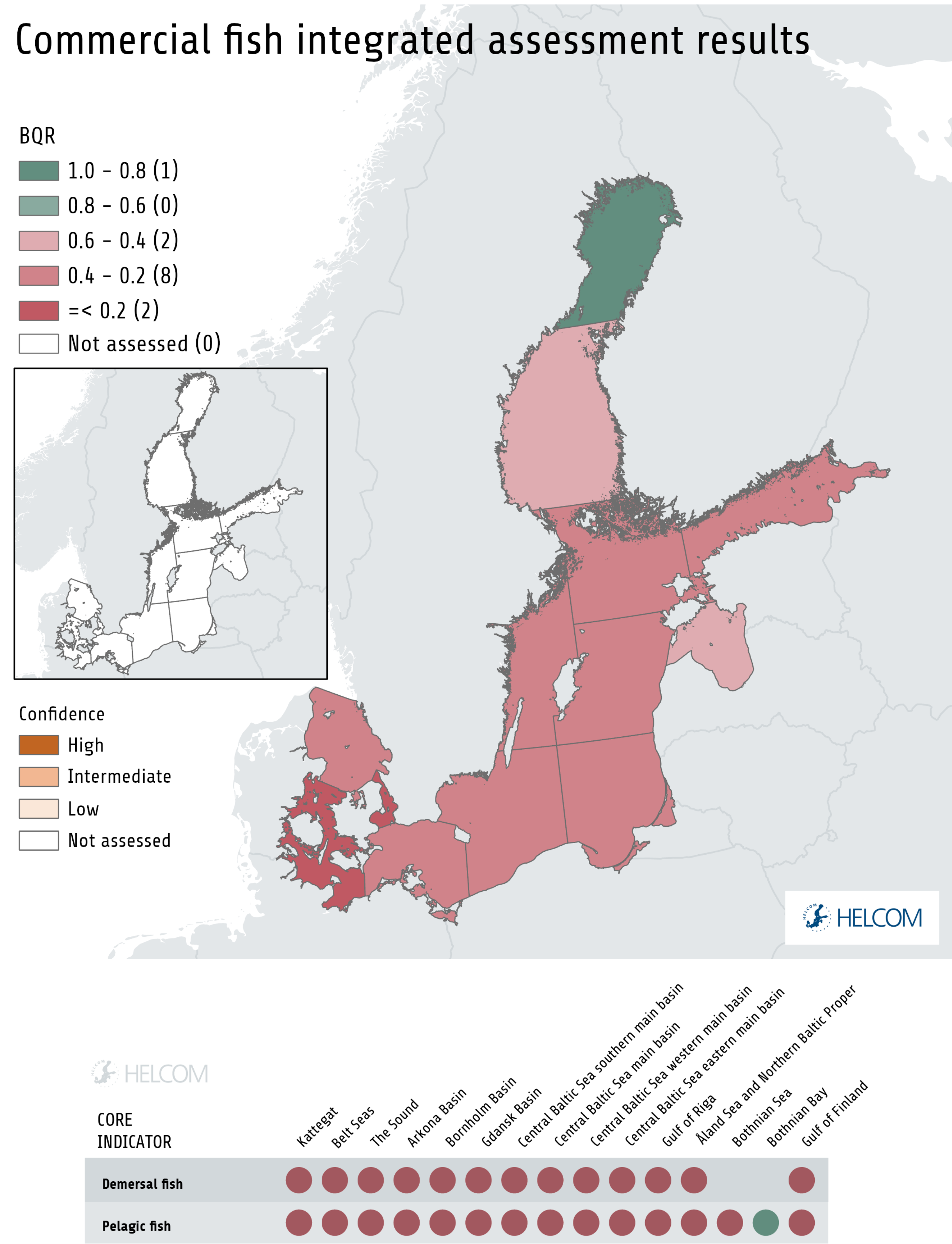

Figure 5.1 Integrated assessment results for commercial fish based on the BEAT tool. The displayed spatial assessment units are ICES sub-divisions, to align with the underlying indicators. Values >0.6 of at least 0.6 correspond to good status. Corresponding evaluation results for the groups of demersal and pelagic species, respectively, are presented in the bottom of the figure. The figure gives a general overview, while assessment results for each stock and indicator are given in Table 5.3 in Section 5.2.

Hence, a good status of fish is needed in order to ensure long term food provision in the region, but also to contribute to a healthy status of Baltic Sea foodwebs (Section 8). The evaluations presented in this chapter cover coastal and migratory fish assessed by HELCOM core indicators, and the status of commercial species evaluated based on data from fisheries stock assessments, mainly derived from the International Council for Exploration of the Sea (ICES 2021a, 2022b).

5.2. Assessment results for fish

5.2.1 Integrated assessment results for fish

The integrated status of fish was evaluated as not good in most assessment units. For commercial fish (Figure 5.1), the evaluation result reflected that only four out of fifteen stocks that could be fully evaluated with respect to fishing pressure and stock size showed good status. The integrated status of commercial fish was evaluated as good only in the Bothnian Bay, where herring and vendace (*Coregonus albula*) were included. In the other sub-basins, the results chiefly reflected a continued deterioration in the status of cod, although they were also affected by results for some pelagic stocks. The group of pelagic fish was represented by herring, sprat (*Sprattus sprattus*) and vendace. The group of demersal fish was represented by cod, plaice (*Pleuronectes platessa*), and sole (*Solea solea*). The status of demersal fish was not good in any sub-basin where it was assessed.

Based on HELCOM biodiversity core indicators, the integrated status of coastal fish (Figures 5.2 and 5.3) was evaluated as good in two out of twenty-two assessed coastal areas. 43 different species/species groups were included in the integrated assessment, distributed across the indicators which underpin the assessment (Table 5.1). Twenty coastal assessments units lacked assessment results for coastal fish, and several assessment units lacked results for at least some of the three HELCOM coastal fish indicators (Table 5.2).

The evaluation result for coastal fish reflects the application of the One-Out-All-Out aggregation rule across monitoring locations within one assessment unit, which gives conservative results, because the spatial variation for individual indicators was high. Good status was achieved in more than half of the monitoring locations for each of the key species except flounder (*Platichtys* spp), as well as for the indicators on functional groups and size structure (HELCOM 2023r, HELCOM 2023h).

Migratory fish were not included in the integrated assessment. Fourteen species of fish and lampreys have been evaluated as threatened according to the HELCOM Red List (Box. 5.2).

More information on the assessment methodology and approach can be found in Chapter 2 (BEAT methodology) and in Annex 1 (Methodology manuals).

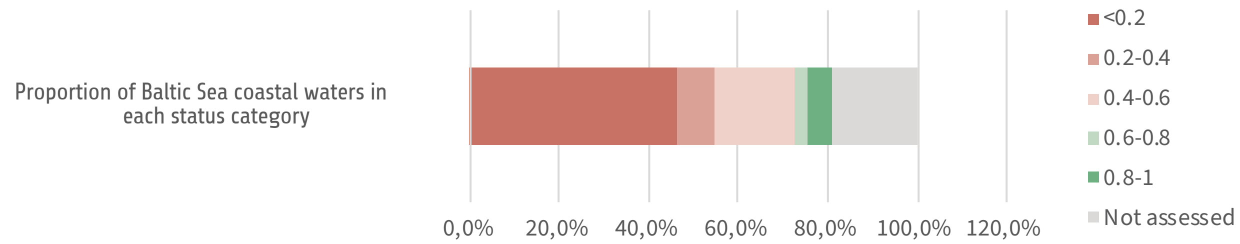

Figure 5.2. Proportion of the Baltic Sea coastal area in each status category based on the size of the coastal areas.

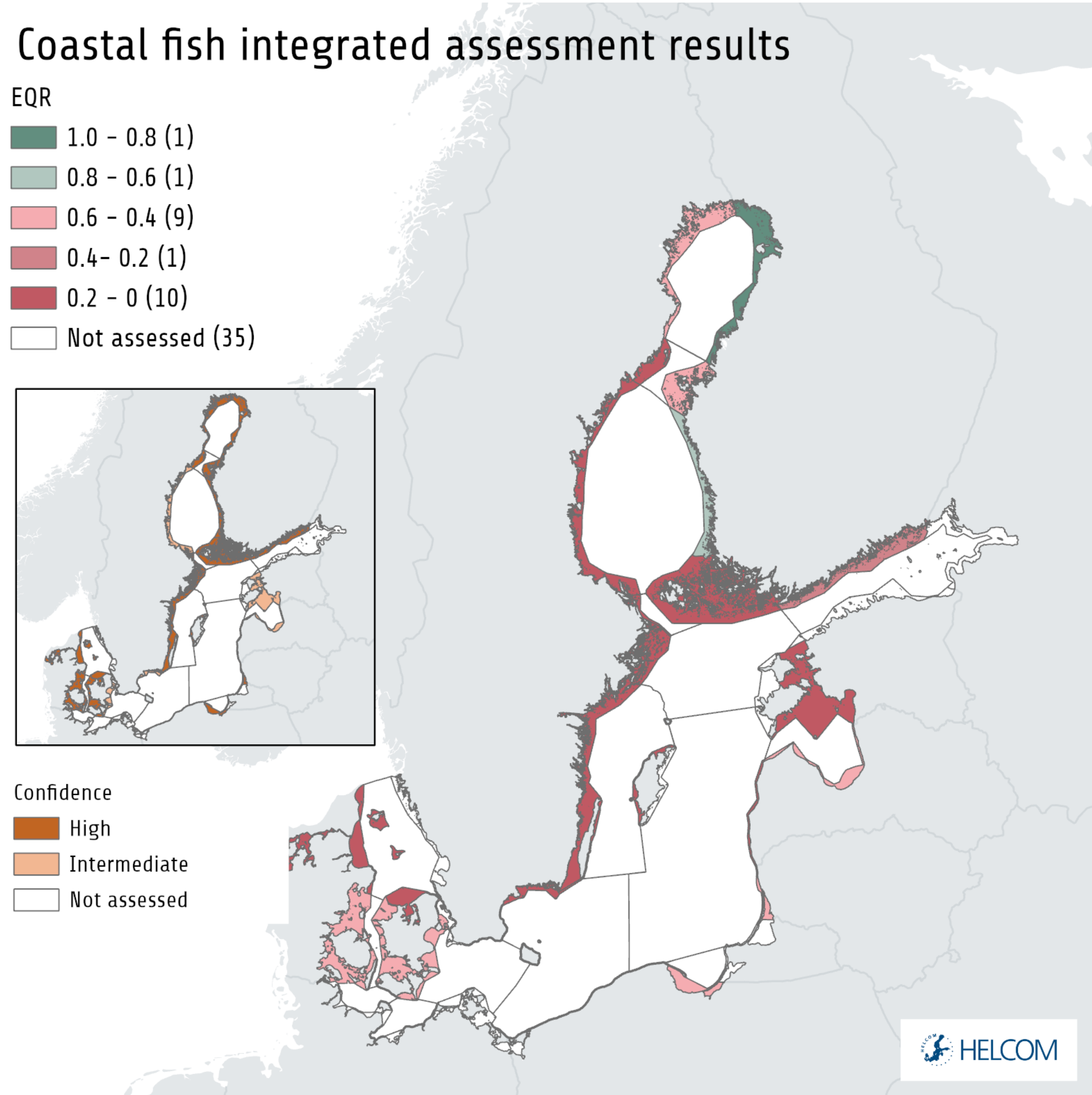

Figure 5.3 Integrated assessment results for coastal fish based on the BEAT tool. Values >0.6 correspond to good status. Corresponding indicator evaluation results for indicators included in the integrated assessment are presented in the right-hand side of the figure (page 87).

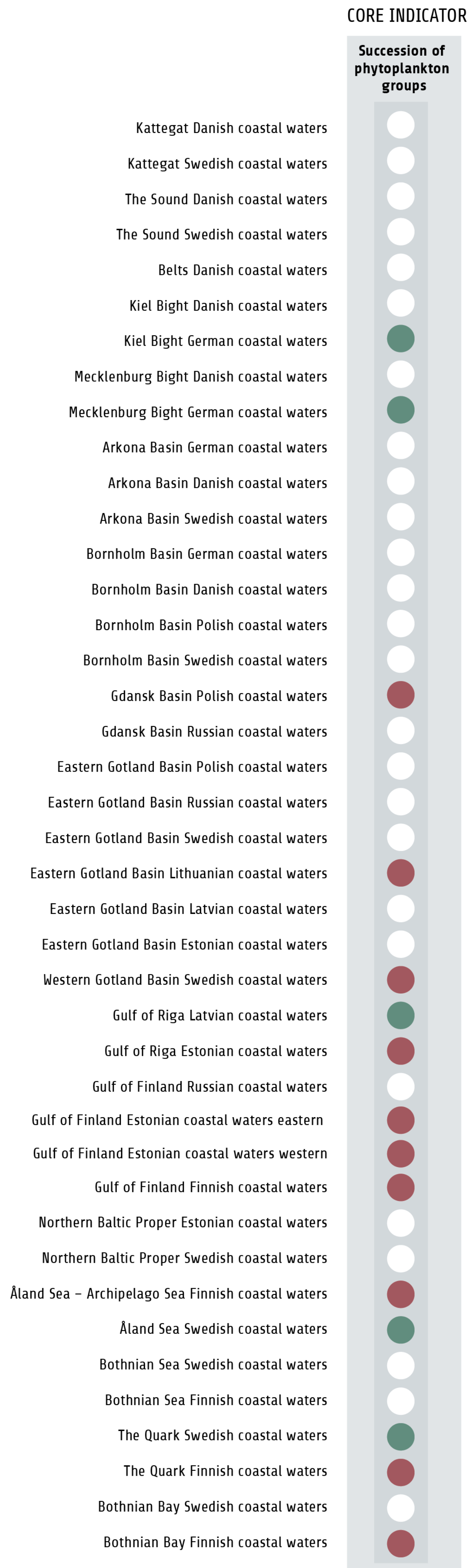

Table 5.1. Coastal fish species included in the integrated assessment. Columns 2-4 indicate in which indicator evaluation the species has been included. Presence is indicated according to the following; X: Occurs in monitoring in representative numbers, X*: Occurs in monitoring in representative numbers, but no identification of the different species is possible, x: Occurs in monitoring but in low and non-representative numbers, blank: Not applicable in the country. NB: Present, but stockings can confuse the abundance monitoring. Countries: FI: Finland, EE: Estonia, LV: Latvia, LT: Lithuania, PL: Poland, SE: Sweden, AX: Åland Islands (FI).

Species	Abundance of coastal fish key functional groups	Abundance of key coastal fish species	Size structure of coastal fish	Presence									
				FI	EE	LV	LT	RU	PL	DE	DK	SE	AX
Perch (*P. fluviatilis*)		x	x	X	X	X	X		X			X	X
Flounder (*P. flesus*)	x	x	x	x*	X	x*	x*		X		X	x*	x*
Whitefish (*C. maraena*)	x	x		X	X	X	X					X	X
Eelpout (*Z. viviparous*)	x	x		x	X	X	x		x		X	X	X
Pike (*E. lucius*)		x		x	X	X	X					X	X
Pikeperch (*S. lucioperca*)		x	x	X	X	X	X					X	X
Roach (*R. rutilus*)	x			X	X	X	X		x			X	X
Rudd (*S. erythrophthalmus*)	x			x	X	X	x		x			X	X
Bleak (*A. alburnus*)	x			x	X	X	X		x			X	X
Common bream (*A. brama*)	x			X	X	X	X		x			X	X
White bream (*A. bjoerkna*)	x			x	X	X	X					X	X
Zope (*A. ballerus*)	x			x					x			x	
Vimba bream (*V. vimba*)	x			x	X	X	X		x			x	
Ide (*L. idus*)	x			X	X	X	x		x			x	X
Dace (*L. leusicus*)	x			x	X	X	x		x			X	
Crucian carp (*C. carassius*)	x			x	X	X	x		x			x	
Gibel carp (*C. gibelio*)	x			x	X								
Tench (*T. tinca*)	x			x	X		x		x			x	
Minnow (*P. phoxinus*)	x			x	X								
Gudgeon (*G. gobio*)	x			x	X		x						
Chub (*S. cephalus*)	x			X	X	X	X		X			X	
Sichel (*P. cultratus*)	x			X	X	X	X		X			X	
Baltic flounder (*P. solemdali*)	x			x*	X	x*	x*					x*	x*
Ruffe (*G. cernuus*)	x			x	X	X	X		x			X	X
Eel (*A. anguilla*)	x			NB	X		X	x	x	x	X	X	
Herring (*C. harengus*)	x			X	X	X	X	x	x	x		X	X
Sprat (*S. sprattus*)	x			X	X	X	X		x			x	X
Smelt (*O. eperlanus*)	x			X	X	X	X		x			x	X
Plaice (*P. platessa*)	x										X	X	
Common dab (*L. limanda*)	x										X	X	
Common sole (*S. solea*)	x											x	
Vendace (*C. albula*)	x			X	X							x	
Labrids (*L. berggylta*, *L. mixtus*, *C. exoletus*, *S. melops*, *C. rupestris*)	x											X	
Sculpins (*C. poecilopus, T. quadricornis, T. bubalis, A. cataphractus, M. scorpius*)	x			x	X	X	X		x			X	X
Gobies (*G. niger, N. melanostomus*)	x			x	X	X	X		x			X	X
Sticklebacks (*G. aculeatus, P. pungiutus*)	x			X	X	X	x		x			x	X
Rocklings (*C. mustela, E. cimbrius*)	x											X	
Pipefishes (*E. aequoreus, S. acus, S. rostellatus, S. tyhple*)	x			X	X	X	x		x			x	X
Garfish (*B. belone*)	x				X		x		x			x	
Lumpfish (*C. lumpus*)	x				X		X					x	
Lesser sand-eel (*A. marinus*)	x				X		X		x			x	
Small sandeel (*A. tobianus*)	x			X	X	X	X		X		X	x	X
Great sandeel (*H. lanceolatus*)	x			X	X	X	X		X		X	x	X

Table 5.2. Results of the integrated assessment of coastal fish . The column "Assessment unit" referes to the agreed name of each individual assessment area. "Spatial assessment unit level" indicates at what spatial resolution the assessment was conducted (see Section 2.3.2 or the HELCOM Monitoring and Assessment Strategy for more information on the assessment units used for HELCOM assessments). "Biological Quality Ration" represents the quantitative results of the integrated assessment for the topic, with results >0.6 constituting Good Status (see Section 2.1.1 for more information on the BEAT tool). The column "Status" indicates whether the quantitative assessment results achieve of fail the threshold for good status. The columns "Confidence" and "Confidence Class", respectivey, provides a quantified value for confidence in the assessment and translates this value into a discreet confidence class, in line with the methodology outlined in Section 2.1.1.

Assesment unit	Spatial assessment unit level	Biological Quality Ratio	Status	Confidence	Confidence Class
Bothnian Bay Finnish Coastal waters	3	0.9	GES	0.88	High
Bothnian Bay Swedish Coastal waters	3	0.6	sub-GES	0.81	High
The Quark Finnish Coastal waters	3	0.5	sub-GES	0.88	High
The Quark Swedish Coastal waters	3	0.2	sub-GES	0.80	High
Bothnian Sea Finnish Coastal waters	3	0.7	GES	0.88	High
Bothnian Sea Swedish Coastal waters	3	0.2	sub-GES	0.72	Intermediate
Åland Sea Swedish Coastal waters	3	0.2	sub-GES	0.79	High
Archipelago Sea Coastal waters	3	0.2	sub-GES	0.90	High
Northern Baltic Proper Swedish Coastal waters	3	0.2	sub-GES	0.83	High
Gulf of Finland Finnish Coastal waters	3	0.3	sub-GES	0.82	High
Gulf of Riga Estonian Coastal waters	3	0.2	sub-GES	0.69	Intermediate
Gulf of Riga Latvian Coastal waters	3	0.4	sub-GES	0.56	Intermediate
Western Gotland Basin Swedish Coastal waters	3	0.2	sub-GES	0.76	High
Eastern Gotland Basin Latvian Coastal waters	3	0.2	sub-GES	0.69	Intermediate
Eastern Gotland Basin Lithuanian Coastal waters	3	0.5	sub-GES	0.92	High
Gdansk Basin Polish Coastal waters	3	0.4	sub-GES	0.90	High
Bornholm Basin Swedish Coastal waters	3	0.2	sub-GES	0.70	Intermediate
Arkona Basin Danish Coastal waters	3	0.5	sub-GES	0.63	Intermediate
Mecklenburg Bight Danish Coastal waters	3	0.5	sub-GES	0.84	High
Belts Danish Coastal waters	3	0.5	sub-GES	0.89	High
The Sound Danish Coastal waters	3	0.5	sub-GES	0.75	Intermediate
Kattegat Danish Coastal waters, including Limfjorden	3	0.2	sub-GES	0.96	High

Box 5.2 Threatened fish species in the Baltic Sea

Fourteen species of fish and lampreys have been evaluated as threatened according to the HELCOM Red List (HELCOM 2013c). 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 (*Anguilla anguilla*), which is also considered a commercial species, and grayling (*Thymallus thymallus*), which mainly occurs in coastal areas of the Gulf of Bothnia, and the sharks porbeagle (*Lamna nasus*) and spurdog (*Squalus acanthias*) in the Kattegat. The sharks have a wide distribution range and the populations occurring in the Kattegat are mainly influenced by pressures outside of the Baltic Sea region.

Three fish species are listed as endangered to the HELCOM red list, and seven are listed as vulnerable, including sea lamprey (*Petromyzon marinus*).

5.2.2 Indicator evaluation results for fish

The evaluation of coastal fish using core indicators shows that six out of twenty-two assessed coastal units achieved good status with regards to the indicator 'Abundance of coastal fish key species' (HELCOM 2023g), and four out of fourteen assessed units with regards to the "Abundance of coastal fish key functional groups' (HELCOM 2023r). Regarding size structure, four out of 15 assessed units achieved good status (Figure 5.4). Size structure was assessed for the key species perch using the new HELCOM indicator L90 (HELCOM 2023h), which focuses on the size of fish at the relatively higher end of the observed size distribution, by looking at the proportion of fish in different length classes and finding the fish length at the 90th Percentile of the size distribution. A deteriorated status for coastal fish could reflect unfavorable environmental conditions related to impacts from habitat loss, habitat deterioration, fishing (including commercial, recreational and subsistence fisheries), eutrophication, and climate change. In addition, cascading effects in the foodweb leading to release of predation on mesopredators and elevated natural mortality of fish (predation from birds or seals) is likely of importance in some of the evaluated locations.

The evaluation of migrating species using core indicators shows that, for salmon, good status was achieved in the Bothnian Bay, the Quark, the Bothnian Sea, and in the Western Main Basin (Including the Western Gotland Basin and Bornholm Basin) with regards to the indicator 'Salmon spawners and smolt'. In the Eastern Main Basin (Eastern Gotland Basin and Gulf of Riga) and Gulf of Finland, the status of salmon spawners and smolt was clearly below the threshold value. Hence, the situation in the northern Baltic rivers has improved significantly and many stocks have achieved the threshold, while most of the rivers in the Eastern Main Basin are far from reaching the threshold.

Salmon fishing has decreased in the whole Baltic Sea, which at least partly explains the improved status (HELCOM 2023s).

Evaluation results for the core indicator 'Abundance of sea trout spawners and parr' showed that twenty-two out of thirty-two assessed units achieved good status and seven units failed to achieve good status (with three units remaining unassessed; Figure 5.5), reflecting results aggregated to HELCOM spatial assessment unit level 3. In general, the status of sea trout stocks was not good in the northern Baltic Sea. (HELCOM 2023t) Threshold values were not achieved in the Bothnian Bay nor the Archipelago Sea. However, since 2016, a positive development in parr densities has been observed in some rivers in Finland (Gulf of Finland and Bothnian Sea) and Sweden (Bothnian Sea). In the eastern and south-western sub-basins of the Baltic Sea, most of the stocks reach production levels of parr that reflect good status (add ref to indicator report "Abundance of sea trout spawners and parr").

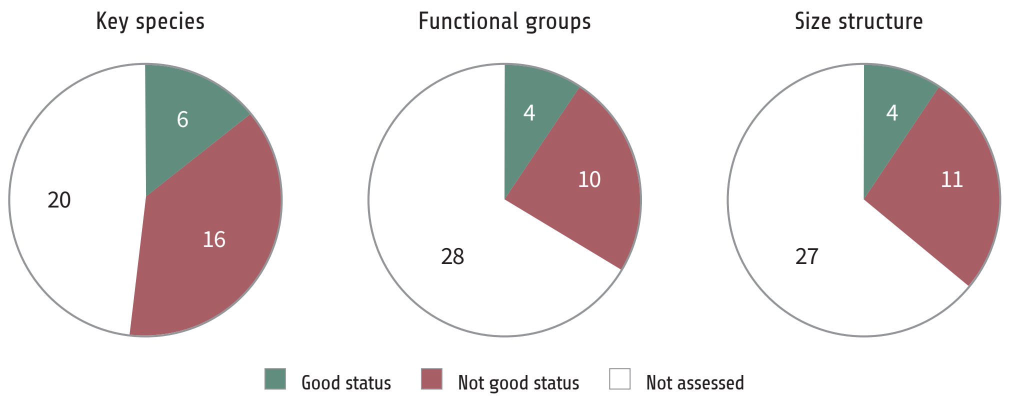

Figure 5.4. The status for coastal fish was assessed using three core indicators: 'Abundance of key coastal fish species', 'Abundance of coastal fish key functional groups', and 'Size structure of coastal fish'. Pie charts indicate the shares of all relevant spatial assessment units, 42 in total, achieving good status (green), not good status (red) or which were not assessed due to lack of data (white). Numbers give the number of assessment units within each category. See also Core indicator reports: HELCOM 2023g, HELCOM 2023h, HELCOM 2023r.

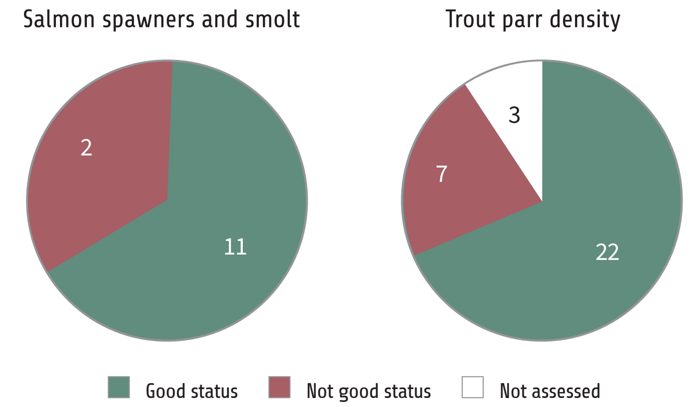

Figure 5.5. The status of migratory fish was assessed using two core indicators: 'Salmon spawners and smolt' and 'Abundance of sea trout spawners and parr'. The pie charts indicate the shares of all relevant spatial assessment units achieving good status (green), not good status (red) and not assessed due to lack of data (white). Numbers give the number of assessment units within each category. See also Core indicator reports: HELCOM 2023s and HELCOM 2023t).

5.2.3 Details on the core indicator evaluations

In all, the spatial coverage of the evaluation of coastal fish has expanded compared to the previous assessment, as more monitoring locations and assessment units were included this time. In addition, more species have been included under the indicator "Abundance of key coastal fish species' and the new HELCOM indicator 'Size structure of coastal fish' has been developed. Still, only 23 of in total 42 coastal assessment units were evaluated, and the indicator 'Abundance of key species' was the only indicator that was evaluated in all 23 assessment units. Quantitative threshold values are lacking for all species included in the indicator 'Size structure of coastal fish', except perch (Box 5.3).

The HELCOM indicator 'Abundance of key coastal fish species' (HELCOM 2023g) was evaluated based on data on the key species, namely perch, flounder, pike, pikeperch (*Sander lucioperca*), whitefish (*Coregonus maraena*), and/or eelpout (*Zoarces viviparus*), depending on the coastal area. When combining the evaluation results across species and monitoring locations, using the One-Out-All-Out principle, the indicator achieved good status in six out of 22 assessment units (Bothnian Bay Finnish and Swedish coastal waters, Bothnia Sea Finnish coastal waters, and the coastal waters of Estonia, and Latvia; Table 1). Looking at results for different species and monitoring locations, this reflects an overall good status for perch in 24 of 31 monitoring locations, and for flounder in eight of 26 locations. The other species were assessed at relatively fewer locations. For these, two of seven locations achieved good status for pike, six of nine for pikeperch, five of 11 for whitefish, and 10 of 14 for eelpout. In comparison to the previous assessment (HELCOM 2018d), the results indicate a deteriorating state. Only six out of 22 HELCOM assessment units achieved good status for the indicator 'Abundance of key coastal fish species' in the current assessment, compared to 13 out of 21 assessment units in HOLAS II. The decreased overall status partly reflects the inclusion of additional key species in the current assessment, namely pike, pikeperch, whitefish, and eelpout. Also, a stricter integration approach across monitoring locations was used this time (OOAO, while the majority rule was used in in HOLAS II). Pike and whitefish did not achieve good status in most of the monitoring locations. For perch and flounder, which are more comparable between assessment periods, differences between this and the previous assessment are rather small.

The HELCOM indicator 'Abundance of coastal fish key functional groups' (HELCOM 2023r) was evaluated based on data on the groups of cyprinids and/or mesopredators, depending on the coastal area. The spatial coverage for this indicator was lower compared to that of the key species indicator. When combining the evaluation results across groups and locations, only four out of 14 assessment units achieved the threshold value (Table 5.1). The indicator has both upper and lower threshold values because both very high and very low abundances of cyprinids and mesopredators may characterize an undesirable environmental state. In cases when good status was not achieved, this was generally due to too high abundances. Good status was achieved in the Swedish coastal waters of the Bothnian Bay, Bothnian Sea, and Bornholm basin, and in the Polish coastal waters of the Gdansk basin. Looking at results for different monitoring locations, good status was achieved in 20 out of 32 monitoring locations. In comparison to the previous assessment (HELCOM 2018d), there was a tendency for a slight decrease in the status of this indicator when considering cyprinids and mesopredators. In three of the assessment units also considered in the previous assessment,

Box 5.3 HELCOM indicators for fish assessment

Two HELCOM core indicators represent the status of characteristic Baltic Sea coastal fish species and functional groups:

— The 'Abundance of key coastal fish species' is based upon changes over time in typical key species of fish, such as perch (*Perca fluviatilis*), flounder (*Platichthys flesus*), pike (*Esox lucius*), pikeperch (*Sander lucioperca*), whitefish (*Coregonus maraena)*, and eelpout (*Zoarces viviparus)*, with the species chosen depending on the natural distribution of these species and the availability of data. Good status is achieved when the abundance is above a set site- and species-specific threshold value, determined through time-series analyses using the ASCETS method (Östman *et al.* 2020). Data from monitoring locations was integrated to HELCOM spatial assessment unit level 3 using the One-Out-All-Out principle. Overall, the assessment included between one and five key species per assessment unit (HELCOM 2023g)

— 'Abundance of coastal fish key functional groups' evaluates the abundance of selected functional groups of coastal fish in the Baltic Sea: cyprinids and mesopredators, which represent mid-trophic level fish. Changes in the long-term development of the abundance of coastal fish functional groups reflects the effects of increased water temperature and eutrophication in coastal areas, and/or changes in the level of human exploitation (mainly habitat degradation), natural predation pressure, and in some areas fishing. Good status is achieved when the abundance of cyprinids or mesopredators is within an acceptable range for the specific site. Data from monitoring locations was integrated to HELCOM spatial assessment unit level 3 using the One-Out-All-Out principle. (HELCOM 2023r)

The HELCOM 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:

— 'Abundance of salmon spawners and smolt' is based on the production of smolt in rivers with wild salmon (*Salmo salar*) stocks. It is applicable in all HELCOM countries except Denmark, Germany, Poland and Russia. For the Gulf of Riga, 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. For the remaining salmon stocks, smolt production at MSY (RMSY) and limit smolt production (Rlim), calculated using river-specific stock–recruitment parameters and vital rates, are used in evaluations of stock status. (HELCOM 2023s).

— 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 three years remains above 50% of the reference parr density (HELCOM 2023t).

Box 5.3.1 Role of stickleback in the Baltic Sea ecosystem

The temporal development of three-spined stickleback (*Gasterosteus aculeatus*) is a good indicator of the status of biodiversity in the Baltic Sea ecosystem, as it responds rapidly to changes in the configuration of the food web as a result of human impact (Olin *et al.* 2022).

The three-spined stickleback is a small short-lived fish that spends most of its life in the upmost water layer, typically at 0-20 meters. It occupies both coastal and open sea areas. Adults live in the open sea, and migrate to spawn in shallow coastal areas in spring at around two years of age. Most adults die after spawning, but juveniles and surviving adults migrate back to the open sea in the end of the summer (Bergström *et al.* 2015).

Stickleback does not show any pronounced spatial population structure (Olin *et al.* 2022), but there are spatial differences in size and condition. Fish in the Bothnian Sea have shown to be larger than in the Baltic Proper (Olsson *et al.* 2019). Based on their population development, stickleback could be divided into three different population entities, namely southern Baltic Sea, Baltic Proper and Bothnian Sea (corresponding to ICES Sub-divisions 25, 26-29, and 30, respectively; Olsson *et al.* 2019, Olin *et al.* 2022).

There is no targeted monitoring program for stickleback in the Baltic Sea, but data from the ICES-coordinated Baltic International Acoustic Survey (BIAS) can give estimates of stickleback abundance over time. These show that stickleback numbers have increased with a factor between two and four since the early 2000s, in all basins except for the southern Baltic Sea (Olin *et al.* 2022). Stickleback was estimated to represent around 10% of the pelagic fish biomass in the Baltic Proper during 2011–2014 (Olsson *et al.* 2019). In coastal areas, available coastal fish monitoring data suggest a concurrent increase mainly in Sweden and Finland, but with lower and sometimes decreasing abundances along the south-easternmost parts of the Baltic Proper (Olin *et al.* 2022).

Stickleback has been shown to impair the recruitment of coastal predatory fish when it occurs in high numbers in coastal areas, as stickleback predate on juveniles and eggs of for example perch (*Perca fluviatilis*) and pike (*Esox Lucius*; Olin *et al.* 2022). Along the Swedish coast, stickleback dominance has been linked to a loss of approximately 50% recruitment of pike and perch since the 1980s (Bergström & Erlandsson *et al.* 2022). Concurrently, mass occurrences of stickleback also induce trophic cascades that enhance eutrophication symptoms by lowering the water quality and spur blooms of ephemeral filamentous algae (reviewed in Olin *et al.* 2022). In offshore areas, stickleback competes for food with herring (*Clupea harengus*) and sprat (*Sprattus sprattus*), as they all feed on zooplankton. However, to what extent this affects the species needs further study (Olin *et al.* 2022).

Drivers behind the observed stickleback increases in the Baltic Sea remain to be firmly established. Recent evidence, however, indicates that declines in predatory and large fish (cod, pike, perch and herring) is likely of significance. In addition, temperature- and salinity-driven changes in zooplankton composition and reduced competition for food with declining clupeid stocks in the could have favored stickleback (reviewed in Olin *et al.* 2022). In all, the conditions observed in the Baltic Sea today with weak predatory fish populations, declining clupeid populations with smaller individual size, and warmer and eutrophic waters have likely created favorable conditions for the stickleback.

Dedicated monitoring and assessment tools are needed to follow the development of stickleback in the open sea and coastal areas, to also understand the drivers of its population expansion, effects on the ecosystem, and need of measures. Already today, measures that strengthen populations of predatory fish both at the coast and in the offshore Baltic are warranted. This includes reformulating management targets for commercial species beyond the principle of maximum-sustainable-yield (MSY) to rebuild populations towards a more natural size and age structure with higher abundance of large fish. For this, ecosystem-based approaches merging fisheries- and environmental management targets, where the role and effects of stickleback are considered, are essential.

Table 5.3. Summary of status evaluation for coastal fish in the Baltic Sea region. Status of coastal fish stocks in the Baltic Sea during the assessment period 2016–2021. The assessment is carried out using Scale 3 HELCOM assessment units (defined in the HELCOM Monitoring and Assessment Strategy Annex 4 (hyperlink/reference)) and 22 out of a total of 42 units could be assessed. The circle colors denote if the median indicator value during 2016–2020 achieves (green) or fails (red) to achieve good status. White circles denote that no status evaluation was available. Combined status is assessed by the condition that all indicators should achieve their reference points. The combined confidence is based on evaluation of the accuracy, temporal coverage, spatial representability, and methodology of the included indicators, integrated over all indicators).

Coastal area name (assessment unit)	Key species	Functional groups	size structure	Combined, status	Combined, confidence
Bothnian Bay Finnish Coastal waters	green	white	white	green	0,875
Bothnian Bay Swedish Coastal waters	green	green	red	red	0,8125
The Quark Finnish Coastal waters	red	white	green	red	0,875
The Quark Swedish Coastal waters	red	red	red	red	0,8021
Bothnian Sea Finnish Coastal waters	green	white	green	green	0,875
Bothnian Sea Swedish Coastal waters	red	green	green	red	0,724
Åland Sea Finnish Coastal waters					
Åland Sea Swedish Coastal waters	red	red	red	red	0,7875
Archipelago Sea Coastal waters	red	red	red	red	0,8958
Northern Baltic Proper Finnish Coastal waters					
Northern Baltic Proper Swedish Coastal waters	red	red	red	red	0,8304
Northern Baltic Proper Estonian Coastal waters					
Gulf of Finland Finnish Coastal waters	red	red	red	red	0,8194
Gulf of Finland Estonian Coastal waters					
Gulf of Finland Russian Coastal waters					
Gulf of Riga Estonian Coastal waters	green	red	green	red	0,6875
Gulf of Riga Latvian Coastal waters	green	red	red	red	0,5625
Western Gotland Basin Swedish Coastal waters	red	red	red	red	0,7589
Eastern Gotland Basin Estonian Coastal waters					
Eastern Gotland Basin Latvian Coastal waters	green	red	white	red	0,6875
Eastern Gotland Basin Lithuanian Coastal waters	red	red	red	red	0,9188
Eastern Gotland Basin Swedish Coastal waters					
Eastern Gotland Basin Russian Coastal waters					
Eastern Gotland Basin Polish Coastal waters					
Gdansk Basin Russian Coastal waters					
Gdansk Basin Polish Coastal waters	red	green	red	red	0,901
Bornholm Basin Swedish Coastal waters	red	green	red	red	0,7
Bornholm Basin Polish Coastal waters					
Bornholm Basin Danish Coastal waters					
Bornholm Basin German Coastal waters					
Arkona Basin Swedish Coastal waters					
Arkona Basin Danish Coastal waters	red	white	white	red	0,625
Arkona Basin German Coastal waters					
Mecklenburg Bight German Coastal waters					
Mecklenburg Bight Danish Coastal waters	red	white	white	red	0,8438
Kiel Bight Danish Coastal waters					
Kiel Bight German Coastal waters					
Belts Danish Coastal waters	red	white	white	red	0,8914
The Sound Swedish Coastal waters					
The Sound Danish Coastal waters	red	white	white	red	0,75
Kattegat Swedish Coastal waters, including Limfjorden					
Kattegat Danish Coastal waters, including Limfjorden	red	white	white	red	0,9625

the status has decreased, and in the remaining 10 assessment units there was no change in status. The differences partly reflect the inclusion of additional areas and functional groups (mesopredators) in some assessment units and areas, and the use of a stricter integrating approach across monitoring locations (majority rule was used in HOLAS II and the One-Out-All-Out principle in the current assessment).

The HELCOM indicator 'Size structure of coastal fish' (HELCOM 2023h) can be evaluated based on perch or flounder, but here all evaluation results reflect the size structure for the key species perch. Integration of monitoring results to the level of the spatial assessment unit showed that only four out of 15 assessed units achieved good status (The Quark Finnish coastal water, Bothnian Sea Finnish and Swedish coastal waters, and Gulf of Riga Estonian coastal waters; Table 5.3). In all, 28 monitoring locations were included, and half of these met the threshold value for good status. The indicator was used for the first time in the current assessment.

5.2.4 Details on the assessment results of commercial fish

Only four out of fifteen stocks that could be fully evaluated with respect to both fishing pressure and stock size (Box 5.4) showed good status over the assessment period 2016-2021 (plaice in the Baltic Sea, herring in the Gulf of Riga and the Gulf of Bothnia, vendace in the Swedish part of the Bothnian Bay). However, the stock size of Gulf of Bothnia herring shows a decreasing trend within the past decade and is reported as being close to the threshold value by ICES (2022; see also Figure 5.9). The remaining evaluated stocks failed their threshold values for either fishing mortality or stock size, or both. The stocks evaluated as not being in good status were distributed over four pelagic stocks (Western Baltic spring spawning herring, herring the Central Baltic Sea, sprat, and salmon in the Baltic Sea excluding Gulf of Finland), six demersal stocks (all three cod stocks, sole, plaice in the Kattegat, Belt Seas and the Sound, flounder in the north central and northern Baltic Sea), and one coastal stock (eel). The status of eighteen stocks could not be assessed (Figure 5.6). Three pelagic stocks (sandeel (*Hyperoplus* spp. and *Ammodytes* spp.), smelt (Osmeridae), and vendace in the Finnish side of the Bothnian Bay) and two demersal stocks (turbot (*Scophthalmus maximus)* and brill (*Scophthalmus rhombus*)) could not be assessed due to lack of data on both fishing mortality and stock size, as well as eight coastal species. Salmon in the Gulf of Finland could not be assessed due to lack of assessment results for fishing mortality and four demersal stocks (dab (*Limanda limanda*) and all three flounder stocks could not be evaluated due to lack of assessment results for stock size (Table 5.4). The presented results reflect the assessment period 2016-2021. Fishing mortality for Baltic commercial fish stocks have in some cases decreased over time since the early 2000s (See also Section 5.4). According to ICES (2022) one third of the commercially used Baltic fish stocks are analytically assessed and currently fished within or below the limits of F_{MSY}, and are in alignment with Good Environmental Status according to the MSFD. Five out of 17 fish stocks have good environmental status, six stocks do not achieve good status, and the MSFD status of the remaining six stocks is unknown (ICES 2022b). The majority of the commercial landings are driven by sprat and herring in the Gulf of Bothnia and Gulf of Riga which were reported by ICES (2022) to show full reproductive capacity. Some stocks, among them western Baltic cod, central Baltic herring and sprat were reported as currently being exploited above FMSY, showing a bad status.

In comparison to the previous assessment (HELCOM 2018a), three stocks had declined from good to not good status, one stock had improved to a good status, and for eight stocks the status remained unchanged (Table 5.3). An additional four stocks that could not be evaluated in the previous assessment could be evaluated this time. The status of salmon in the Gulf of Finland was evaluated as 'not good' in the previous assessment (HELCOM 2018a), due to indications of too low stock size, but the stock size has improved in recent years. In the current assessment, the status of salmon in the Gulf of Finland was however changed to 'not assessed', as information on fishing mortality was still lacking (For good status, reference values for both fishing mortality and stock size need to be achieved, see Annex 1).

With regards to fishing pressure, eight out of seventeen stocks that could be evaluated failed their threshold values. Stocks not reaching good status for fishing pressure were distributed over four pelagic stocks (Western Baltic spring spawning herring, herring in the Central Baltic Sea, sprat, and salmon in the Baltic excluding the Gulf of Finland) and four demersal stocks (the Western Baltic and Eastern Baltic cod stocks, plaice in Kattegat, Belt Seas and the Sound, as well as flounder in the North central and northern Baltic Sea). Four flatfish stocks (which could not be evaluated with regards to stock biomass, see below) achieved their threshold values for fishing pressure, namely dab and three flounder stocks. Sixteen stocks could not be assessed with regards to fishing pressure.

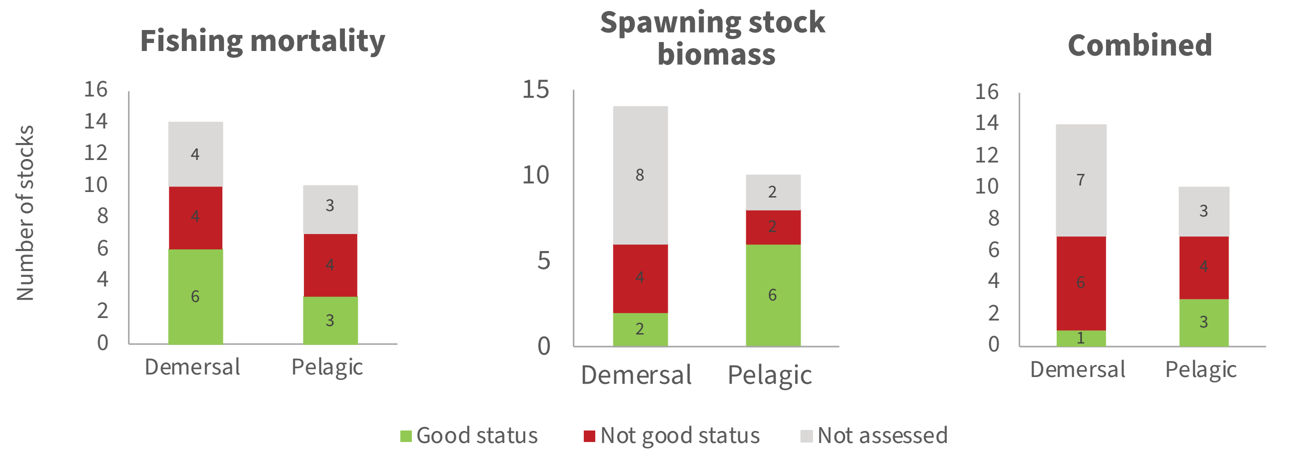

Figure 5.6. Numbers of commercial pelagic and demersal fish stocks in good and not good status, with respect to fishing mortality (left), stock size (spawning stock biomass; middle), and regarding both aspects combined (right). The colors denote if the average value during 2016–2021 achieves (green) or fails (red) the 2021 threshold value. The number of not assessed fish stocks in each case is indicated in grey.

Table 5.4. Summary of status evaluation for commercial fish in the Baltic Sea region. Status of internationally managed fish stocks in the Baltic Sea during 2016–2021. Commercial fish species are assessed by stocks, which are named by their areal distribution. The numbers give the corresponding ICES assessment units (Subdivisions, SD). Total status is assessed by the condition that indicators of fishing mortality and stock size should both achieve their reference points, on average during 2016–2021. The SYMBOLS denote if each stock achieves (green) or fails (red) the set conditions. In addition, trends over the last ten years are indicated by arrows. The applied assessment approach is indicated as: MSY = analytical stock assessment, evaluated in relation to the MSY objective, PA = precautionary approach. Size or age structure was not evaluated in relation to a threshold value, but changes over the last ten years are indicated based on available data, as denoted by subscripts (1 = age structure 2 = length structure, 3 = qualitative assessment based on ICES advice). The evaluations of salmon and sea trout are based on many stocks, which show variable status. White circles denote that no status evaluation is available. The final column gives red list status according to HELCOM (2013c), which is the currently most recent HELCOM red list assessment but which does not match the HOLAS3 assessment period.

Species name (23)	Scientific name	Stocks (33)	Assessment approach	Fishing pressure		Stock size		Age/Size structure	Total	HELCOM Red List Status
				Status	Trend	Status	Trend	Trend		
Pelagic species										
Atlantic herring*	*Clupea harengus*	Skagerrak, Kattegat, W Baltic Spring spawners (SD 20-24)	MSY	🔴	→	🔴	↓	↑1	🔴	LC
		Central Baltic Sea (SD25-29 & SD32)	MSY	🔴	↑	🟢	↓	→1	🔴	
		Gulf of Riga (SD28)	MSY	🟢	→	🟢	↑	→1	🟢	
		Gulf of Bothnia (SD30-31)	MSY	🟢	→	🟢	↓	→1	🟢	
Sprat*	*Sprattus sprattus*	Baltic Sea (SD22-32)	MSY	🔴	→	🟢	→	→1	🔴	NA
Vendace**	*Coregonus albula*	Bothnian Bay (SWE, SD30)	MSY	🟢	↓	🟢	↓	↑2	🟢	-
		Bothnian Bay (FIN, SD30)	-	⚪	-	⚪	-	⚪	⚪	
Salmon*	*Salmo salar*	Baltic Sea, excl. Gulf of Finland (SD22-31)	MSY+PA	🔴	↓	🔴	↑	-	🔴	VU
		Gulf of Finland (SD32)	PA	⚪	-	🟢	-	-	⚪	
Sandeels (=Sandlances)*	*Ammodytes spp + Gymnoammodytes spp*	Skagerrak, Kattegat and Belt Sea (SD21-22)	PA	⚪	-	⚪	-	-	⚪	
Smelt	*Osmerus eperlanus*		-	⚪	-	⚪	-	-	⚪	NA
Demersal species										
Atlantic cod*	*Gadus morhua*	Kattegat (SD21)	PA	⚪	↑	🔴	↓	-	🔴	VU
		Western Baltic (SD22-24)	MSY	🔴	↓	🔴	↓	→1	🔴	
		Eastern Baltic (SD24-32)	PA	🔴	↓	🔴	↓	↓3	🔴	
Sole*	*Coregonus albula*	Skagerrak, Kattegat, and W Baltic Sea (SD20-24)	MSY	🟢	→	🔴	↑	-	🔴	NA
Dab*	*Limanda limanda*	Baltic Sea (SD22-32)	PA	🟢	-	⚪	→	→2	⚪	NA
Turbot*	*Scophthalmus maximus*	Baltic Sea (SD22-32)	PA	⚪	-	⚪	→	-	⚪	NT
Brill*	*Scophthalmus rhombus*	Baltic Sea (SD22-32)	PA	⚪	-	⚪	↑	-	⚪	
Plaice*	*Pleuronectes platessa*	Kattegat, Belt Sea, and the Sound (SD21-23)	MSY	🔴	↓	🟢	↑	↑1	🔴	NA
		Baltic Sea excl. Sound and Belt Sea (SD24-32)	MSY	🟢	→	🟢	↑	→2	🟢	
Baltic flounder*	*Platichthys solemdalii*	N Central and Northern Baltic Sea (SD 27, 29–32)	PA	🔴	-	⚪	→	-	🔴	
Flounders (European and Baltic)*	*Platichthys flesus + P.solemdalii*	Belt Sea and Sound (SD 22, 23)	PA	🟢	-	⚪	→	↓2	⚪	NA
		West of Bornholm, S Central Baltic (SD 24-25)	PA	🟢	-	⚪	→	→2	⚪	
		East of Gotland, Gulf of Gdansk (SD 26, 28)	PA	🟢	-	⚪	→	↓2	⚪	
Coastal species										
Eel*	*Anguilla anguilla*	Baltic Sea (SD22-32)	PA	⚪	-	🔴	-	-	🔴	CR
Sea trout*	*Salmo trutta*	Baltic Sea (SD22-32)	PA	⚪	-	⚪	-	-	⚪	VU
Whitefish	*Coregonus maraena*	-	-	⚪	-	⚪	-	-	⚪	EN
Perch	*Perca fluviatilis*	-	-	⚪	-	⚪	-	-	⚪	-
Roach	*Rutilus rutilus*	-	-	⚪	-	⚪	-	-	⚪	NA
Pikeperch	*Sander lucioperca*	-	-	⚪	-	⚪	-	-	⚪	NA
Pike	*Esox lucius*	-	-	⚪	-	⚪	-	-	⚪	NA
Bream	*Abramis brama*	-	-	⚪	-	⚪	-	-	⚪	NA
Blue mussel	*Mytilus edulis*	-	-	⚪	-	⚪	-	-	⚪	-

* Included in ICES advice, ** national data from Sweden

With regards to stock size, eight out of fifteen stocks that could be evaluated failed their threshold values. Stocks not reaching good status for stock size included two pelagic stocks (the Western Baltic spring spawning herring, salmon in the Baltic Sea excluding the Gulf of Finland), four demersal stocks (all three cod stocks, and sole), as well as one coastal stock (eel). Herring stocks in the central Baltic Sea, Gulf of Riga and Gulf of Bothnia, sprat, vendace on the Swedish side of the Bothnian Bay, salmon in the Gulf of Finland, as well as both plaice stocks were evaluated as achieving their threshold values for stock size.

The age/size structure was evaluated for changes over time, without applying threshold values for good status (Box 5.4). This analysis could be applied to fourteen stocks, while suitable data for the concerned approach were not available for the remaining nine stocks (For details on the approach, see Annex 1). Three out of evaluated stocks showed a decreasing age or size structure, namely Eastern Baltic cod, flounder in the Belt Seas and the sound, and flounder East of Gotland and the Gulf of Gdansk. The other stocks showed an increasing or no significant trend over time, which however in several cases reflecting them being at constant but low levels. The status of fish stocks regarding age/structure was not addressed due to the lack of regionally agreed threshold values, which remains an important development need for future assessments. Further, aspects of age/size structure are relevant to address from several perspectives and complementing the evaluation with additional approaches to the one applied here would be motivated to give a more complete picture (ICES 2022b).

Among coastal species identified as commercially important, only eel and sea trout are addressed by ICES, partially using qualitative information (ICES 2021b, 2022c). The status of the widely distributed European eel remains critical. Glass-eel recruitment remains at a very low level since the 1980s, and while stock size reference points are undefined, it is considered likely that the stock size is well below potential biological limit reference points (ICES 2022c). The status of sea trout was concluded to be within safe limits in the Baltic Sea by ICES (ICES 2021c), who noted that the sea trout populations around the Baltic Sea showed a positive development in general in 2015-2017, followed by a general slight decline in 2018-2019, which levelled out in 2020.

Commercially important coastal fish are partly included under the section on HELCOM core indicators, as several species included in these are also commercially important. However, the HELCOM core indicators on coastal and migratory fish are developed in relation to biodiversity criteria (D1 in MSFD) and do not specifically address changes in relation to fishing, for example. Two coastal fish (roach, bream), and blue mussel could not be addressed at all.

5.3. Changes over time for fish

5.3.1 Trends between assessments

Abundance of key coastal fish species (Coastal fish key species)

Overall, the status of coastal fish in the Baltic Sea has deteriorated between this and the HOLAS II, conducted in 2018 including data until 2016 (Results Table 2). However, the decreased overall status partly reflects the inclusion of additional key species in the current evaluation, namely pike, pikeperch, whitefish, and eelpout, and applying a stricter integrating approach across monitoring locations (majority rule in HOLAS II vs One-Out-All-Out principle in the current evaluation). Pike and whitefish do not achieve good status in the majority of the monitoring locations. Thus, only 6 out of 22 HELCOM assessment units achieve good status in the current evaluation, compared to 13 out of 21 assessment units achieving good status in HOLAS II. Focussing on the comparable key species perch and flounder, differences between this and the previous evaluation are only minor. The status of perch has decreased in 2 and increased in 1 out of 23 comparable monitoring locations, and the status of flounder has decreased in 1 out of 14 comparable monitoring locations since 2018. When the status is integrated over HELCOM assessment units, the status of perch has increased in the Gulf of Riga, decreased in the Finnish Quark, while in the Swedish Northern Baltic proper, the status of both perch and flounder have decreased. The integrated status remains unchanged in the remaining 17 assessment units when considering perch and flounder only.

Abundance of coastal fish key functional groups (Coastal fish key groups)

There is a tendency for a slight decrease in the status of coastal fish in the Baltic Sea when considering cyprinids and mesopredators between this assessment and HOLAS II, conducted in 2018 including data until 2016 (Results Table 2). In three of the assessment units also considered in HOLAS II, the status has decreased, and in the remaining ten assessment units there is no change over time in status. However, the decreased overall status partly reflects the inclusion of additional areas and functional groups (mesopredators) in some assessment units and areas (see comments in Results Table 2). The use of a more strict integrating approach across monitoring locations (majority rule in HOLAS II vs One-Out-All-Out principle in the current assessment), might also contribute to the pattern observed.

Size structure of coastal fish (Coastal fish size)

The size distribution of coastal fish was not included in the previous status assessment, HOLAS II. Available data dating back to the late 1990s and early 2000s do, however, suggest that L90 in perch have been rather stable over time with no strong temporal trends (Bolund et al. in prep; Results figure 1). L90 in flounder and pikeperch have likewise tended to remain stable over time in terms of L90 in most monitoring locations (Bolund et al. in prep; Results figure 1). Despite that no previous assessment has been undertaken, this lack of consistent regional trends over time indicates that there does not seem to be a general worsening of the situation regarding size distribution of key species in the Baltic Sea. However, current data only allows for an evaluation of three species with a rather limited spatial coverage. Moreover, L90 in perch did not meet the threshold for good environmental status in 11 out of 15 HELCOM assessment units (Results table 2), suggesting that the environmental status in terms of L90 for perch in the Baltic Sea is consistently not good in the majority of assessed coastal areas.

Table 5.5 shows an overview of the changes in status between the 2011-2016 and 2016-2021 assessments across commercial species in the Baltics Sea.

Table 5.5. Overview of differences between the 2016-2021 status assessment and the 2011-2016 assessment (HELCOM 2018a), for commercial fish in the Baltic Sea region.

Species name	Scientific name	Stock	Assessment approach	Status 2011-2016	Status 2016-2021	Comparison of outcomes
Pelagic species						
Atlantic herring*	*Clupea harengus*	Skagerrak, Kattegat, W Baltic Spring spawners (SD 20-24)	MSY	🔴	🔴	no change
		Central Baltic Sea (SD25-29 & SD32)	MSY	🟢	🔴	declined status due to too high F
		Gulf of Riga (SD28)	MSY	🔴	🟢	improved status due to lower F
		Gulf of Bothnia (SD30-31)	MSY	🟢	🟢	no change
Sprat*	*Sprattus sprattus*	Baltic Sea (SD22-32)	MSY	🔴	🔴	no change
Vendace**	*Coregonus albula*	Bothnian Bay (SWE, SD30)	MSY	⚪	🟢	not included in HOLAS II
		Bothnian Bay (FIN, SD30)	-	⚪	⚪	no change
Salmon*	*Salmo salar*	Baltic Sea, except Gulf of Finland (SD22-31)	PA	partially	🔴	deteriorating status despite some improving trends
		Gulf of Finland (SD32)	PA	🔴	⚪	not fully evaluated in HOLAS 3
Sandeels (=Sandlances)*	*Ammodytes spp + Gymnoammodytes spp*	Skagerrak, Kattegat and Belt Sea (SD21-22)	PA	⚪	⚪	not assessed
Smelt	*Osmerus eperlanus*	-	-	⚪	⚪	not assessed
Demersal species						
Atlantic cod*	*Gadus morhua*	Kattegat cod (SD21)	PA	⚪	🔴	not assessed in HOLAS II
		Western Baltic (SD22-24)	MSY	🔴	🔴	no change
		Eastern Baltic (SD24-32)	PA	🔴	🔴	no change
Sole*	*Solea solea*	SD20-24	MSY	🔴	🔴	no change
Dab*	*Limanda limanda*	Baltic Sea (SD22-32)	PA	⚪	⚪	not assessed
Turbot*	*Scophthalmus maximus*	Baltic Sea (SD22-32)	PA	⚪	⚪	not assessed
Brill*	*Scophthalmus rhombus*	Baltic Sea (SD22-32)	PA	⚪	⚪	not assessed
Plaice*	*Pleuronectes platessa*	SD21-23	MSY	🟢	🔴	declined status due to too high F
		SD24-32	MSY	⚪	🟢	not assessed in HOLAS II
Baltic flounder*	*Platichthys solemdalii*	SD 27, 29–32	PA	⚪	🔴	not assessed in HOLAS II
Flounders (European and Baltic)*	*Platichthys flesus + P.solemdalii*	SD 22, 23	PA	⚪	⚪	not assessed
		SD 24-25	PA	⚪	⚪	not assessed
		SD 26, 28	PA	⚪	⚪	not assessed
Coastal species						
Eel*	*Anguilla anguilla*	Baltic Sea (SD22-32)	PA	🔴	🔴	no change
Sea trout*	*Salmo trutta*	Baltic Sea (SD22-32)	PA	⚪	⚪	
Whitefish	*Coregonus maraena*	-	-	⚪	⚪	not assessed
Perch	*Perca fluviatilis*	-	-	⚪	⚪	not assessed
Roach	*Rutilus rutilus*	-	-	⚪	⚪	not assessed
Pikeperch	*Sander lucioperca*	-	-	⚪	⚪	not assessed
Pike	*Esox lucius*	-	-	⚪	⚪	not assessed
Bream	*Abramis brama*	-	-	⚪	⚪	not assessed
Blue mussel	*Mytilus edulis*	-	-	⚪	⚪	not assessed

5.3.2 Long term trends

Long term trends in the assessed indicators are summarized in Figure 5.6, and outlined in Figures 5.8-5.13 Over the past ten years, fishing pressure had increased on one pelagic stock (herring in the Central Baltic Sea) and one demersal stock (Kattegat cod), while fishing pressure had decreased on two pelagic stocks (vendace in the Bothnian Bay and salmon in the Baltic excluding the Gulf of Finland) and three demersal stocks (Western Baltic cod, Eastern Baltic cod, as well as plaice in Kattegat, Belt Seas and the Sound). Despite decreasing trends, the fishing pressure remained too high during the assessment period on both Western and Eastern Baltic cod, plaice in the Kattegat, Belt seas and the Sound, and salmon in the Baltic Sea excluding the Gulf of Finland.

The fishing mortality on Eastern Baltic cod decreased steeply, but due to a large decline in productivity, the stock size also decreased, and the stock is not estimated to recover in the medium term, even with no fishing (ICES 2022d). In fact, all three cod stocks showed a decreasing stock size over the assessed ten recent years. Four demersal flatfish stocks (both plaice stocks, sole, and brill) showed an increasing trend in stock size, as did salmon in the Baltic excluding the Gulf of Finland and herring in the Gulf of Riga. The remaining three herring stocks showed a decreasing stock size. The stock size of vendace also decreased, although it still achieved its threshold value. The remaining evaluated stocks (all four flounder stocks, turbot, and sprat) did not show a decreasing or increasing trend in stock size.

With respect to the here presented assessment of age/size structure, decreasing trends were seen in three demersal stocksnamely Eastern Baltic cod and two flounder stocks (SD 22-23, and SD 26 and 28), indicating a worsening situation. The other assessed stocks showed either no change or an increase over the ten assessed years. As the status of the age/size structure was not evaluated in relation to any threshold value, the results could reflect either a good or an undesired state.

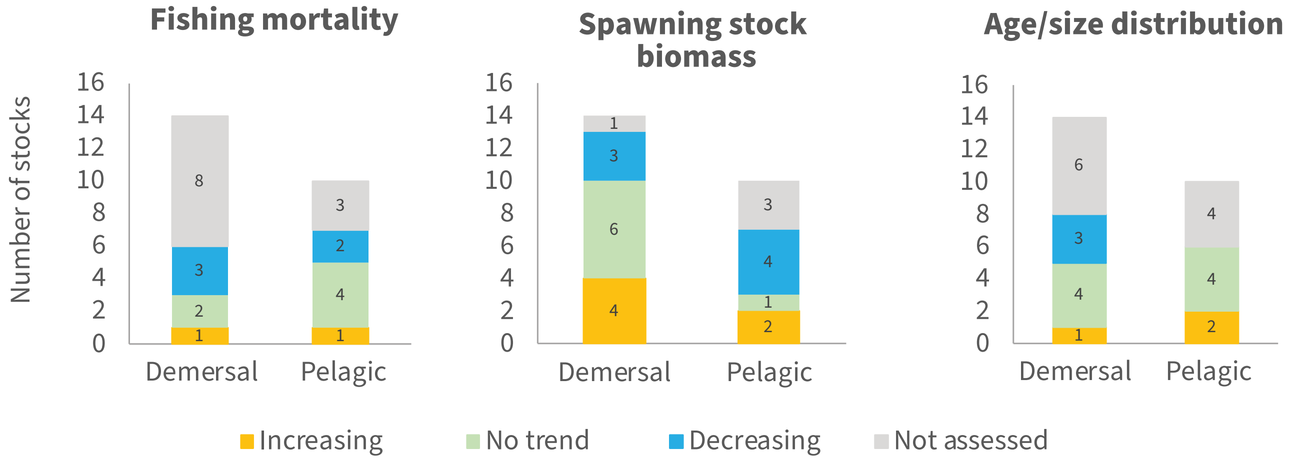

Figure 5.7. Number of commercial pelagic and demersal stocks that show an increasing trend, a decreasing trend, or no trend, with respect to Fishing mortality (left), Stock size (spawning stock biomass; middle), and Age/size structure (right). The colors denote the prevalence of improving, deteriorating or unchanged trends during the years 2012-2021. The number of species/stocks that could not be assessed are indicated in grey.

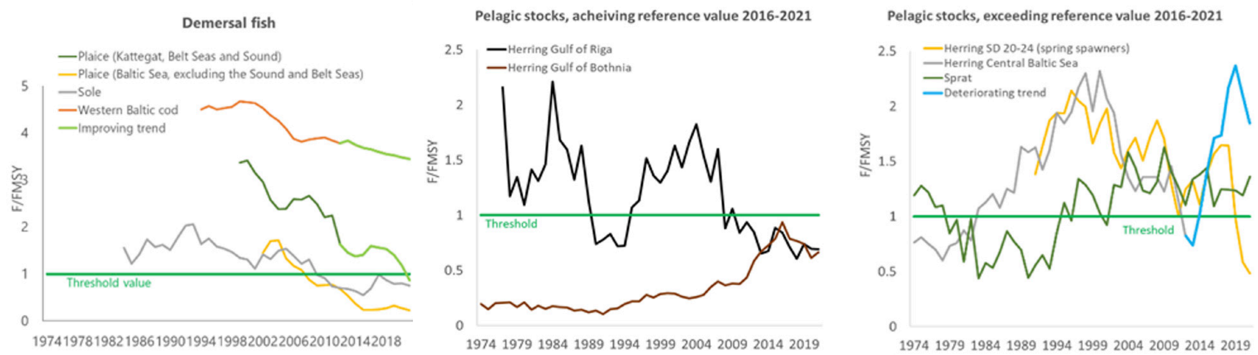

Figure 5.8. Temporal development in fishing mortality for internationally assessed demersal and pelagic stocks, evaluating in relation to Maximum Sustainable Yield. Left: Demersal stocks. Middle: pelagic stocks currently achieving the threshold value. Right: pelagic stocks with currently too high fishing mortality. Values below 1 mean that the reference value for fishing mortality is achieved. Source: ICES.

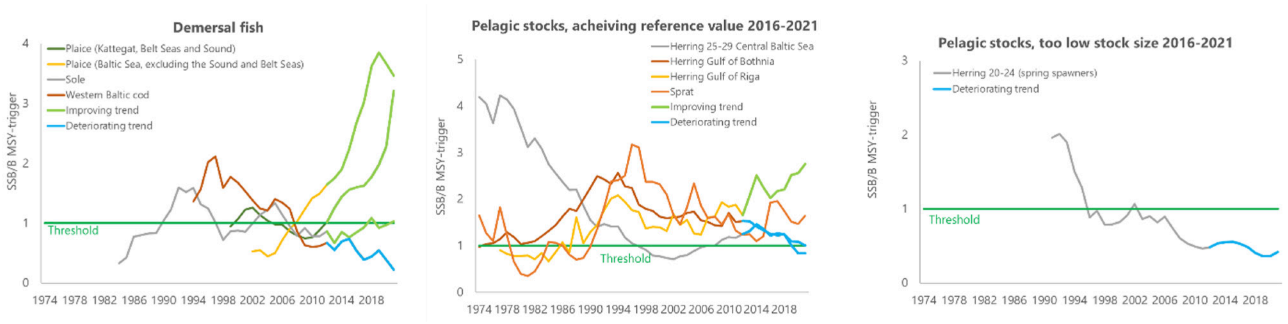

Figure 5.9. Development over time in the stock size (spawning stock biomass) of internationally assessed fish stocks. Left: Demersal fish including cod, plaice, and sole. Middle: pelagic stocks currently achieving the reference value. Right: pelagic stocks with too low stock size. Values above 1 mean that the reference value for stock size, as indicated by the green line, is achieved. Source: ICES.

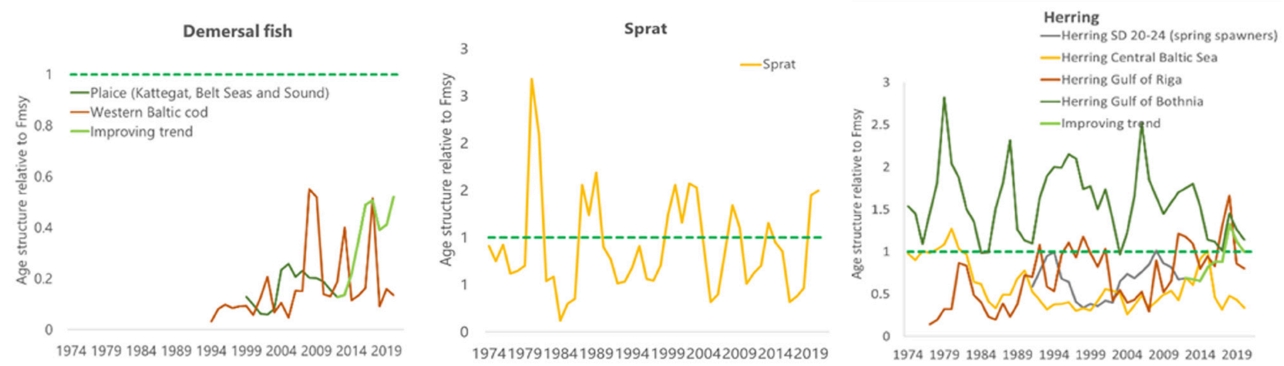

Figure 5.10. Development over time in the relative age structure of selected commercial fish stocks. Left: Demersal fish including plaice and sole. Middle: Sprat. Right: herring. Status was not assessed. The green hatched line signifies equivalence to the age structure at equilibrium under FMSY. Source: Griffiths *et al.* (in review).

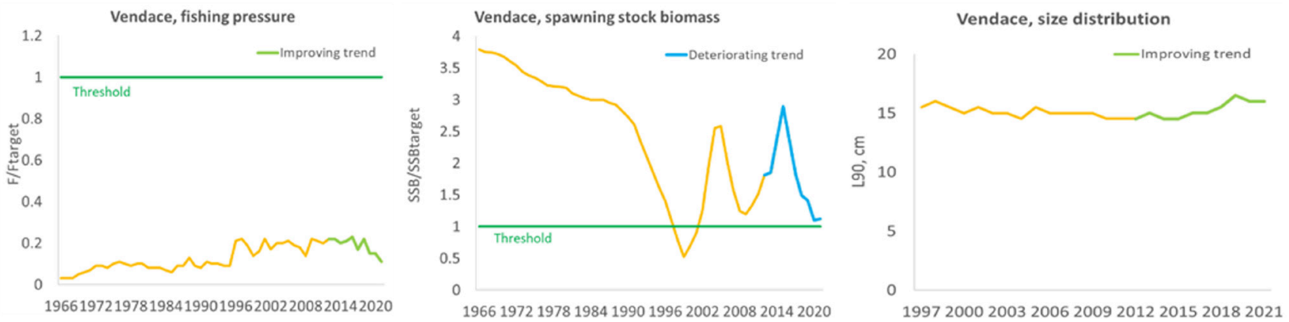

Figure 5.11. Assessment results for vendace. Left: Development over time of fishing pressure (Values below 1 mean that the reference value for fishing pressure is achieved), middle: spawning stock biomass (Values above 1 mean that the reference value for stock size is achieved), and right: trend in size distribution. Source: Gilljam et al. 2022 (SLU.aqua.2022.5.5-275).

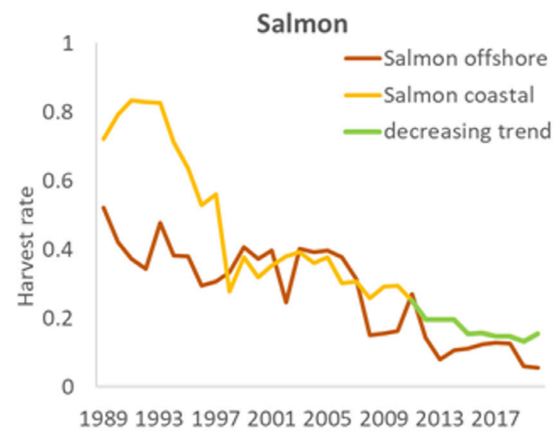

Figure 5.12. Development over time of harvest rates (a relative estimate of fishing mortality) for coastal and offshore salmon. Source: ICES.

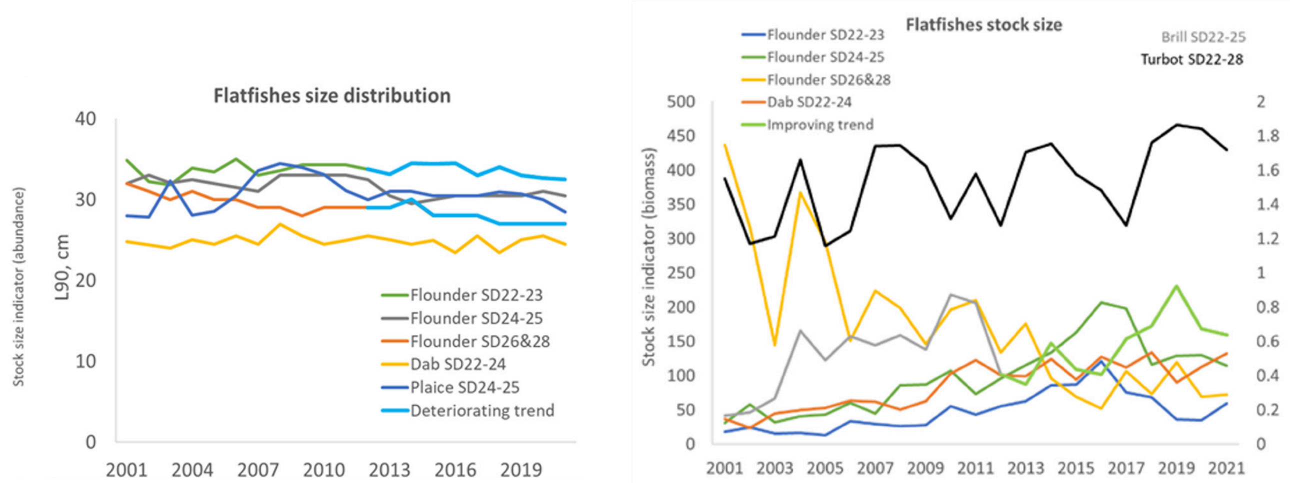

Figure 5.13. Development over time of stock biomass and size distribution in commercial flatfish species that currently lack full analytical assessment by ICES due to data limitations. Source: ICES.

5.4. Relationship of fish to drivers and pressures

5.4.1 Human activities and associated pressure

Impacts of overfishing include depleted fish stocks and reduced biomass. Since fisheries typically target certain species and larger fishes, they may also cause structural changes to populations and the foodweb. 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 8). Overfishing, and the associated changes at population and ecosystem level, affect long term fishing opportunities and food provisioning, since the changes in population or foodweb structure make the depleted stocks less productive and more vulnerable to environmental pressures (Berkeley *et al.* 2004, Stige *et al.* 2017, Bryhn *et al.* 2022). Several societal drivers are directly related to fishing, as presented in the HOLAS 3 Thematic assessment of Economic and Social analyses (HELCOM 2023b).

The status of fish is, further, influenced by several concurrently acting pressures and ongoing changes in the ecosystem, and influences on the susceptibility of the ecosystem to these (see for example Froese et al. 2022). Overfishing has had a widely extended impact on fish stocks and foodwebs in the Baltic Sea and is still ongoing for several stocks. It is very likely that effects of climate change are already affecting Baltic stocks, and will do so even more in the future. Other pressures affecting fish include eutrophication, which is linked to for example effects on habitat quality and feeding opportunities, and modification or loss of key habitats, causing impacts on recruitment, spawning and feeding areas (Olsson *et al.* 2012, Bergström *et al.* 2016, 2019, Östman *et al.* 2017, Olsson 2019, Snickars *et al.* 2015, Moyano *et al.* 2022, HELCOM 2018a).

A gradual but continued deterioration of coastal shallow areas is a particular concern in coastal areas and river mouths, as areas of importance for development and construction often coincide with important areas for recruitment (Seitz *et al.* 2014, Sundblad and Bergström 2014, Kraufvelin *et al.* 2018). In the open sea, the currently most important spawning area for Eastern Baltic cod, the Bornholm Basin, has been reduced to only a fraction of its historical area due to increasing oxygen deficiency. The Gdansk Basin and the Gotland Basin have had a very limited contribution to cod recruitment since the 1990s (Köster *et al.* 2017).

5.4.2 Climate change

Climate change is already having an impact on fish and this impact is expected to increase in the futureexpected to have an increasing influence on fish in the future. Climate change can cause changes to fish directly, by effects on recruitment success and growth (Huss *et al.* 2019, 2021, Lindmark *et al.* 2022, Polte et al. 2021, van Dorst *et al.* 2019), or it may influence the distribution range of species, prey availability, or the strength of 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 juvenile fish are dependent on these for food (Polte *et al.* 2022). Any decreases in salinity could also have a strong effect on fish community composition in the Baltic Sea, if marine species are disadvantaged and habitats suitable for freshwater species expand (Olsson *et al.* 2012, Koehler *et al.* 2022).

5.5. Assessment methodological details

The assessment methodologies are explained in short in Boxes 5.3 and 5.4, and in more detail in Annex 1.

5.6. Follow up and needs for the future with regards to fish

5.6.1 HELCOM actions

The HELCOM Baltic Sea Action Plan (HELCOM 2021a) stresses that the achievement of good environmental status for the Baltic Sea will require major efforts and transformational change in all sectors of the economy affecting the sea, including fisheries. One of the central management objectives of the Baltic Sea Action Plan is that 'Human induced mortality, including hunting, fishing, and incidental bycatch, does not threaten the viability of marine life' (Table 5.6).

A central target of the UN Sustainable Development Goals, encompassed by HELCOM, is to effectively regulate harvesting and end overfishing, illegal, unreported and unregulated fishing and destructive fishing practices, as well as to implement science-based management plans, to restore fish stocks in the shortest time feasible, and at least to levels that can produce maximum sustainable yield as determined by their biological characteristics (SDG 14.4).

5.6.2 Other international commitments

Baltic Sea fisheries is managed under the EU's Common Fisheries Policy (CFP) and Russian Federation legislation. The fisheries for cod, herring, sprat, salmon, and plaice are managed using catch limits (Total Allowable Catches, TAC). In addition, technical measures, such as restrictions on the types of fishing gear that can be used and specifications to reduce catches of undersized fish, are in place for some fisheries. Some temporal and spatial closures are implemented to protect spawning cod, salmon, flounder, and plaice, and preserve benthic habitats (ICES 2021a). Fisheries advice is provided by the International Council for the Exploration of the Sea (ICES) and the European Commission's Scientific Technical and Economic Committee for Fisheries (STECF). Coastal fisheries and some more spatially limited other fisheries are managed nationally. Examples of national fishing regulations are gear and catch limits, protected areas and temporal fishing closures. The degree to which recreational and subsistence fisheries are regulated varies between countries (HELCOM 2020c).

5.6.3 Needs for future assessment

The evaluation of commercial fish uses predominantly data from ICES, while one stock (vendace) was evaluated based on national assessment data. Stocks and indicators that lack established reference values were evaluated descriptively based on trends over time. Consequently, method developments to be able to determine threshold values for good status for these stocks, and for ad-

Box 5.4. Summary of the assessment approach for commercial fish

The evaluations were based on estimates representing fishing mortality and stock size. In addition, trends in age or size structure of fish stocks are presented. Data for internationally assessed stocks were provided by the International Council for the Exploration of the Sea (ICES 2021, ICES 2022b).

Status was evaluated separately for each stock against the condition that the average assessment ratio during 2016-2021 should achieve the reference values for indicators of both fishing mortality and stock size (See also Annex 1). For all stocks where data allowed, including stocks that could not be evaluated in relation to a threshold value, trends over the last ten years in estimates representing fishing mortality and stock size were assessed using non-parametric Mann-Kendall tests for monotonic trends.

Trends in age or size structure were considered as supporting information. For stocks assessed using age-based analytical assessments (Classified as category 1), the proportion of older fish in the population relative to a theoretical age structure under FMSY conditions was considered (Griffiths *et al.* In review, see also Annex 1). Data were taken from ICES stock assessment inputs and outputs (ICES 2022e), spanning the last ten years. For the other internationally assessed fish stocks, trends in size structure over the last ten years (2012-2021) were evaluated, when possible, based on data from the ICES DATRAS database.

Incidental bycatches of birds and mammals in connection to the fisheries are evaluated in Chapter 9.

Table 5.6. 2021 Baltic Sea Action Plan actions of relevance for fish.

Code	Action
B5	Develop, implement and share information on effective management measures, including measures to ensure compliance/control measures, to reduce the impact of fisheries inside marine protected areas (MPAs) in order to contribute to achieving their conservation objectives
B15	Develop and coordinate monitoring and assessment methods, where ecologically relevant, for specified representative coastal fish species, populations and communities, by 2023. Based on these assessment methods, to regularly assess the state of the coastal fish community through selected coastal fish species and groups, including threatened species, by at latest 2023. Based on the results of the assessment, develop and implement management measures with the ambition to maintain or improve the status of coastal fish species, including migratory species by 2027
B16	To strengthen native strains and to reinstate migratory fish species: — By 2023 identify rivers where management measures for migratory fish species, including eel, would have the greatest positive impact. — Starting from 2023, in line with relevant international commitments, iteratively review and prioritize effective mitigation measures in the identified rivers and/or dams, including removal of dams and migration barriers where relevant and possible, especially in small waterways. — Develop and implement habitat restoration plans of spawning sites for anadromous species in relevant rivers by 2025
B17	With the aim to protect and restore eel populations, determine which measures set out in the Convention on the Conservation Migratory Species of Wild Animals (CMS), EU Eel Regulation and other relevant instruments would benefit from regional cooperation on a Baltic-wide level. Finalize by 2024 and implement by 2025 a Baltic coordinated programme of such measures.
B18	Restore functional populations of Baltic sturgeon by 2029 implementing the HELCOM Baltic Sea Sturgeon Action Plan
S39	Develop guidance by 2026 in cooperation with the Regional Coordination Groups within the EU Data Collection Framework and the International Council for the Exploration of the Sea (ICES) on how to improve data collected on recreational fisheries in a cost-effective way, with a view to evaluating the impacts of recreational fisheries on the marine environment, where there is a need
S40	Identify by 2024 fish species for which there is a need for better data for identified purposes, such as setting threshold levels. Utilise dedicated programmes and projects to facilitate recording and reporting of data for these species by 2025 to support the identification and implementation of measures to achieve good environmental status.
S41	Further elaborate cooperation between the Baltic Sea Fisheries Forum (BALTFISH) and relevant HELCOM working groups by 2023 to facilitate a wide range of actions to achieve good environmental status.
S42	Update and harmonize by 2024 the 2016 BALTFIMPA decision support tool approach with ongoing initiatives e.g. in the International Council for the Exploration of the Sea (ICES) on a seafloor assessment framework for the Baltic Sea. This tool should also provide options on how to reduce the possible negative impact of fisheries on conservation values in the most cost-effective way, including in marine protected areas (MPAs).
S50	Competent authorities to jointly further develop protective measures for Baltic Sea salmon to support the development of a new regional salmon management plan, and nationally establish salmon management plans by 2023, where appropriate. These management plans should be implemented by 2025 to achieve the set targets, including but not limited to smolt production, genetic diversity and distribution throughout the river habitat. In addition, nationally ensure that granting permits for activities in and near rivers does not compromise the ability to reach set river-specific fish population targets
S51	Competent authorities to improve data related to sea trout stocks and to improve populations of sea trout stocks by implementing national measures at the latest by 2025 with a view to achieving good ecological condition in sea trout streams.
S52	Define necessary complementary measures by 2024 in relevant policy (fisheries, environment etc.) areas to improve the size/age structure for fish stocks, including cod
S53	Implement measures to restore coastal fish communities, including establishment of no-take areas, seasonal closures and catch regulations, as appropriate by 2026 for the specific coastal area.
S54	Share information among Contracting Parties, the Baltic Sea Fisheries Forum (BALTFISH) and Baltic Sea Advisory Council (BSAC) on non-lethal mitigation measures or other ways to manage seals-fisheries interactions and implement those measures by 2025, as appropriate

ditional data limited stocks, would be needed. Currently, the status of 18 species/stocks identified as commercially important in the Baltic Sea region could not be evaluated based on the criteria for Fishing mortality and Stock size taken together, as requested by (European Commission 2022).

With regards to age and size structure, no regionally agreed threshold values are available in HELCOM and only trends over time were assessed. For species with full age-based analytical stock assessment models, this was achieved by comparing age structure data (described by the proportion of older fish) on a relative scale to a theoretical age structure under FMSY (Griffiths *et al.* in review). For species without full analytical stock assessment models, data on the size distribution from ICES database DATRAS were assessed. However, threshold values are lacking to determine the desired state of age or size indicators. Regionally agreed approaches to establish threshold values for good status with regards to fish age and size structure are imperative for achieving sufficient confidence in the status evaluation of commercial fish.

With regards to coastal fish, enhanced spatial coverage of monitoring would be needed to improve the confidence of the evaluation, due to the presence of natural environmental gradients and the typically local population structure of coastal fish species. As the current evaluation is mainly based on data from sites with relatively low levels of direct human impact, an increased monitoring network should also cover more heavily affected sites. Moreover, the current monitoring in the northern and eastern parts of the Baltic Sea is designed to target coastal fish species that prefer higher water temperatures and predominate in coastal areas during warmer parts of the year (typically species of freshwater origin, such as perch). Monitoring of species that predominate in more exposed parts of the coast and during colder parts of the year are, however, rather poorly represented (such as whitefish, herring, flounder and cod).

With regards to migratory fish, the integration of salmon status across river stocks to the level of HELCOM assessment units could be modified to better reflect the status of small river stocks. Further, establishing one index river in each evaluation area should be given high priority. Currently, only a few rivers in the Baltic provide the full set of information (monitoring of spawning runs, smolt runs and river catches, and parr densities) required of an index river. The monitoring of sea trout parr partially takes place in connection with monitoring salmon populations, which results in less precise estimates of sea trout recruitment because of differences in habitats used by the two species. Thus, more electrofishing sites should be established in smaller rivers and streams, e.g., tributaries of salmon rivers, to ensure sufficient coverage of sea trout nursery areas.

The general accuracy of the status assessment of fish is expected to benefit from implementation of ecosystem-based assessments, which consider interactions between species and changes in the external environment. This would enable identification of reference levels and threshold values that take such interactions and external environmental changes into account and thus more accurately reflect good status in the environment.

Understanding of species interactions, foodwebs and ecosystem aspects is expected to support more reliable measures to recover deteriorated stocks (Chapter 8). A multitude of pressures, species interactions and environmental drivers impact on fish, and the magnitude of importance of different factors and their interactions should be understood to be able to take relevant measures to improve the status and halt ongoing declining trends.

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Third HELCOM holistic assessment 2016–2021

Biodiversity
5. Fish

6. Results for the waterbirds assessment

Assessment results in short

- The overall status of waterbirds in the Baltic Sea region is not good, although there is some variability for waterbirds within different feeding behaviour.
- Benthic feeders and waders do not have good status in any part of the region.
- Surface-feeders are assessed as having good status in the Bothnian Sea, The Quark and the Bothnian Bay (birds assessments were conducted on subdivisions consisting of subbasin aggregations). All of the species included in this functional group reach good status in these areas. For the central and southern Baltic Sea, the status is assessed as not good.
- Pelagic feeders achieve the threshold value for good status in the Kiel Bay, Bay of Mecklenburg, Arkona Basin, Bornholm Basin, Gdansk Basin, Eastern Gotland Basin, Western Gotland Basin, Gulf of Riga, Northern Baltic Proper, Gulf of Finland, Åland Sea, where around 80-90% of the pelagic-feeding species included in the assessment are assessed to be in good status. For the remaining subbasins status is assessed as not good.
- Grazing feeders fail to reach the threshold value for good status in Kattegat, the Northern Baltic Proper, and the Åland Sea, but achieve the threshold value in all other subbasins.

6.1. Introduction to waterbirds in the Baltic Sea

The Baltic Sea is one of the most important areas for seabirds and coastal birds in the Western Palaearctic. It functions as an important resting, feeding, moulting, breeding and wintering area for around 80 bird species. 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, many species use the Baltic Sea only during specific seasons.

Some species migrate to the area for breeding and, due to the high diversity of coastal habitats, a variety of species groups with different habitat preferences can be found during the breeding period. These include grebes and dabbling ducks breeding on inland lakes and pools or in brackish lagoons, sea ducks favouring rocky and shrubby archipelago areas, waders and terns preferring open sand or gravel habitats or low grass vegetation, auks and gulls breeding on rocky islands and skerries, the latter also occupying roofs of buildings.

Just as many breeding birds winter outside the Baltic Sea, many birds may winter in the Baltic Sea region but do not breed there. In winter, the avifauna of the Baltic Sea is dominated by species that breed in (arctic) freshwater habitats but occur in marine or brackish habitats outside the breeding season such as divers, grebes and sea ducks, the most characteristic bird species of the Baltic Sea. Waterbirds use all ice-free areas of the Baltic Sea as a wintering areas and therefore the distribution varies between years depending on ice conditions. The HELCOM supporting parameter 'Ice season' provides insight into the highly variable coverage of ice in the Baltic Sea during the past few centuries.

In the Baltic Sea truly marine, species are only represented by northern fulmars (*Fulmarus glacialis*), black legged kittiwakes (*Rissa tridactyla*), and northern gannet (*Morus bassanus*) (only in the Kattegat region and in the Sound) and by auks (Alcidae).

6.1.1 Importance of waterbirds for the Baltic Sea ecosystem

Waterbirds are an integral part of the Baltic marine ecosystem. They are predators of fish and macroinvertebrates, scavengers of carcasses and fishery discards and herbivores of littoral vegetation. The waterbirds connect foodwebs in water with those on land, and by migration they also link the Baltic Sea with other marine regions.

Waterbirds can be assigned to functional species groups, as has been done in this assessment and in the associated evaluations related to waterbird abundance (HELCOM 2023i, HELCOM 2023j) (Table 6.1), meaning that different prey types are taken from different compartments of the marine environment. Further, most species are specialized in certain species and/or size classes of prey. By dividing the species into species groups the assessment provides a more functional perspective on status, and allows for more management relevant conclusions. Regardless of degree of specialization, their abundance is affected by the availability of prey.

The assessment covers 47 species, over half of all the species which utilize the Baltic Sea. The species group surface feeders makes up 10 species, the majority of which are occuring during the breeding season, followed by 12 species of pelagic feeders, where the number of species are almost evenly distributed across the two seasons. Amongst the seven species of wading feeders included, all but one represent species occurring in the breeding season only. Benthic and grazing feeders are represented by 9 species each, with both groups predominantly represented by species using the Baltic Sea as a wintering ground although this is more pronounced for the grazers (Table 6.2).

6.1.2 Waterbirds and Baltic Sea environmental management

As they cannot survive without a sufficient food supply, changes in the number of waterbirds reflect conditions in the foodweb of the Baltic Sea. However, this means that a high number of breeding waterbirds may not automatically indicate a good status, because for instance piscivorous species benefit from a high availability of small fish, which in turn may point to a disorder of the foodweb owing to overfishing of large fish species.

As many of them are predators at or close to the top of the foodweb, waterbirds also accumulate contaminants and their numbers, and even more their breeding success, may indicate the degree of contamination. Through the link between contamination and breeding success the contaminants ingested in winter may have carry-over effects on breeding success in spring and summer. Moreover, several waterbird species are predated by white-tailed eagles (*Haliaeetus albicilla*), transferring the loads of contaminants to a higher level in the foodweb.

As waterbirds are long-lived species with delayed maturity, changes in their breeding success are expected to reflect changes in environmental conditions long before environmental changes are evident in population size. Breeding success is one of the demographic determinants of population growth rate. Therefore, changes in breeding success should be viewed as an early warning of changes in population status, and thus complement the evaluation of waterbird abundance. At the same time, annual breeding success of marine birds is a sensitive indicator of the ability of marine ecosystems to support higher trophic levels that feed on key lower trophic level production.

Table 6.1. Species groups of waterbirds as defined by JWGBIRD (ICES 2015).

Species group	Typical feeding behaviour	Typical food types	Additional guidance
Wading feeders	Walk/wade in shallow waters	Invertebrates (molluscs, polychaetes, etc.)	
Surface feeders	Feed within the surface layer (within 1–2 m of the surface)	Small fish, zooplankton and other invertebrates	"Surface layer" defined in relation to normal diving depth of plunge-divers (except gannets)
Pelagic feeders	Feed at a broad depth range in the water column	Pelagic and demersal fish and invertebrates (e.g. squid, zooplankton)	Include only spp. that usually dive by actively swimming underwater; but including gannets. Includes species feeding on benthic fish (e.g. flatfish)
Benthic feeders	Feed on the seafloor	Invertebrates (e.g. molluscs, echinoderms)	
Grazing feeders	Grazing in intertidal areas and in shallow waters	Plants (e.g. eelgrass, saltmarsh plants), algae	Geese, swans and dabbling ducks, coot

Table 6.2. Species included in the assessment, and their division across wintering and breeding season as well as by the five species groups based on feeding behaviour.

	Species	Breeding/wintering	Species group
1	Arctic skua (*Stercorarius parasiticus*)	Breeding	surface feeders
2	Common gull (*Larus canus*)	Breeding/wintering	
3	Great black-backed gull (*Larus marinus*)	Breeding/wintering	
4	Herring gull (*Larus argentatus*)	Breeding/wintering	
5	Lesser black-backed gull (*Larus fuscus*)	Breeding	
6	Little tern (*Sternula albifrons*)	Breeding	
7	Caspian tern (*Hydroprogne caspia*)	Breeding	
8	Sandwich tern (*Sterna sandvicensis*)	Breeding	
9	Common tern (*Sterna hirundo*)	Breeding	
10	Arctic tern (*Sterna paradisaea*)	Breeding	
11	Smew (*Mergellus albellus*)	Wintering	pelagic feeders
12	Goosander (*Mergus merganser*)	Breeding/wintering	
13	Red-breasted merganser (*Mergus serrator*)	Breeding/wintering	
14	Great crested grebe (*Podiceps cristatus*)	Breeding/wintering	
15	Slavonian grebe (*Podiceps auritus*)	Wintering	
16	Red-necked grebe (*Podiceps grisegena*)	Wintering	
17	Red-throated diver (*Gavia stellata*)	Wintering	
18	Black-throated diver (*Gavia arctica*)	Wintering	
19	Great cormorant (*Phalacrocorax carbo*)	Breeding/wintering	
20	Razorbill (*Alca torda*)	Breeding	
21	Common guillemot (*Uria aalge*)	Breeding	
22	Black guillemot (*Cepphus grylle*)	Breeding	
23	Common pochard (*Aythya ferina*)	Wintering	benthic feeders
24	Tufted duck (*Aythya fuligula*)	Breeding/wintering	
25	Greater scaup (*Aythya marila*)	Breeding/wintering	
26	Common eider (*Somateria mollissima*)	Breeding/wintering	
27	Steller's eider (*Polysticta stelleri*)	Wintering	
28	Long-tailed duck (*Clangula hyemalis*)	Wintering	
29	Common scoter (*Melanitta nigra*)	Wintering	
30	Velvet scoter (*Melanitta fusca*)	Breeding/wintering	
31	Common goldeneye (*Bucephala clangula*)	Wintering	
32	Common shelduck (*Tadorna tadorna*)	Breeding	wading feeders
33	Eurasian oystercatcher (*Haematopus astralegus*)	Breeding	
34	Pied avocet (*Recurvirostra avosetta*)	Breeding	
35	Ringed plover (*Charadrius hiaticula*)	Breeding	
36	Turnstone (*Arenaria interpres*)	Breeding	
37	Dunlin (*Calidris alpina*)	Breeding	
38	Eurasian teal (*Anas crecca*)	Wintering	
39	Mute swan (*Cygnus olor*)	Breeding/wintering	grazing feeders
40	Whooper swan (*Cygnus cygnus*)	Wintering	
41	Bewick's swan (*Cygnus columbianus*)	Wintering	
42	Eurasian wigeon (*Anas penelope*)	Wintering	
43	Mallard (*Anas platyrhynchos*)	Wintering	
44	Northern pintail (*Anas acuta*)	Wintering	
45	Eurasian coot (*Fulica atra*)	Wintering	
46	Barnacle goose (*Branta leucopsis*)	Breeding/wintering	
47	Greylag goose (*Anser anser*)	Breeding/wintering	

6.2. Assessment results for waterbirds

6.2.1 Integrated assessment results for waterbirds

Overall waterbirds in the Baltic Sea did not achieve the threshold value and status is therefore assessed to be not good, with only the species groups grazing birds, surface-feeding birds and pelagic feeding birds achieving the threshold value (Figure 6.1, 6.2 and 6.3). The waterbird indicators underpinning the integrated assessment are evaluated using the 18 scale two HELCOM assessment units aggregated to form 7 subdivisions (see Section 6.5.2). This means that the indicators underpinning the integrated assessment are evaluated at a coarser scale than the integrated assessment results are presented at. However, also in the subdivisions of aggregated scale 2 assessment unit, the overall status of waterbirds was poor. The confidence of the overall assessment was high at both spatial levels. All assessments in chapter 6 are building on waterbird abundance (breeding and wintering season and in one case on breeding success. Waterbird by-catch assessments are presented in Chapter 9.

The confidence of the assessment was high in all subdivisions, apart from the Belt group where not all species groups were assessed. Confidence, both quantitative and categorical for each functional group and sub-basin is presented together with the results in Table 6.3-6.8. To further elucidate the results the tables 6.3-6.8 also present a column outlining proportion of waterbirds in a given functional group which achieve the threshold value for good status gives an indication of how close or distant a given area is to reaching good status. The agreed threshold value for waterbirds is that 75% of species included in the assessment need to achieve good status for the area itself to be considered in good status.

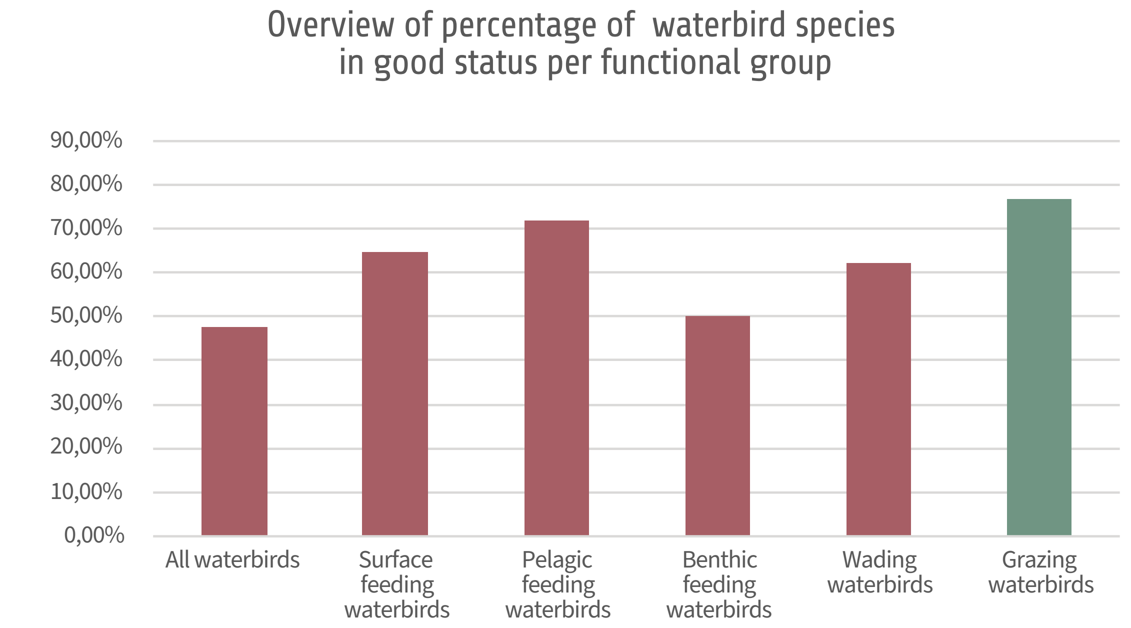


Figure 6.1. Percentage of Baltic Sea waterbird species in good status, across all functional groups (first column from the left) and within each functional group. Good status is achieved when 75% of the species in each functional group reach good status.

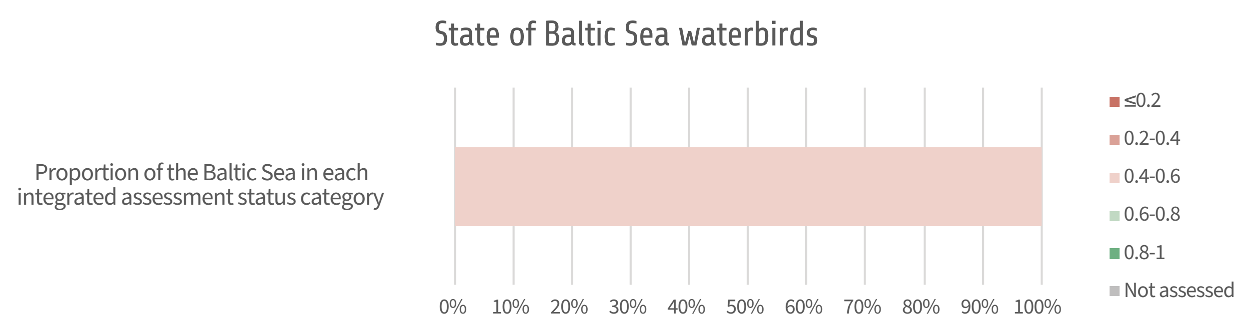


Figure 6.2. Proportion of Baltic Sea in each of the five status categories used for integrated status assessment (three categories representing poor status and two categories representing good status).

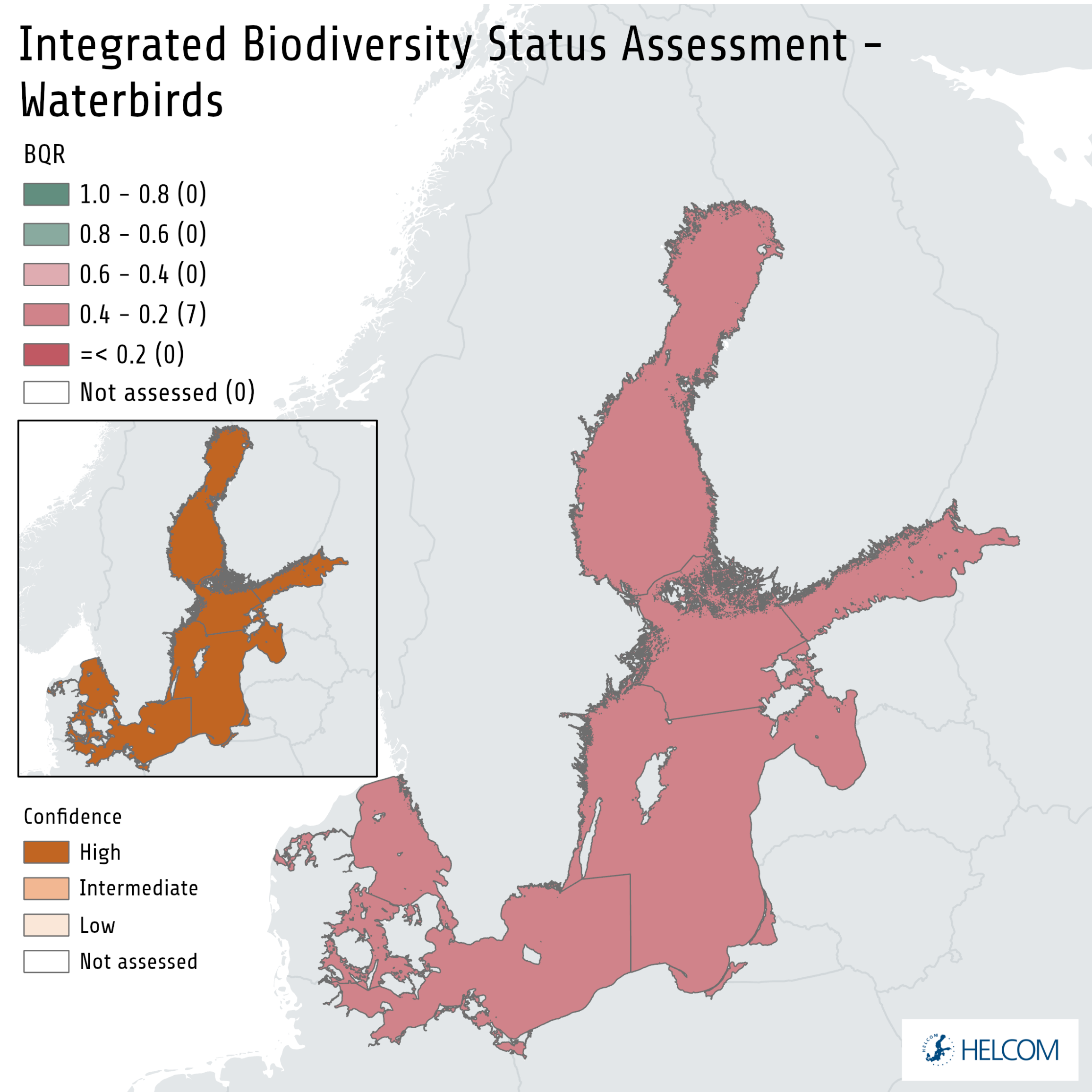


Figure 6.3. Integrated biodiversity status assessment results for waterbirds, as generated by the BEAT tool, based on the indicator evaluations for abundance of breeding and wintering waterbirds as well as the indicator evaluation on breeding success (currently only relevant for pelagic feeders) (HELCOM 2023i, HELCOM 2023j and HELCOM 2023u). Values >0.6 correspond to good status. Confidence is presented in the map insert. Corresponding indicator evaluation results for indicators included in the integrated assessment are presented in the right hand side of the figure.

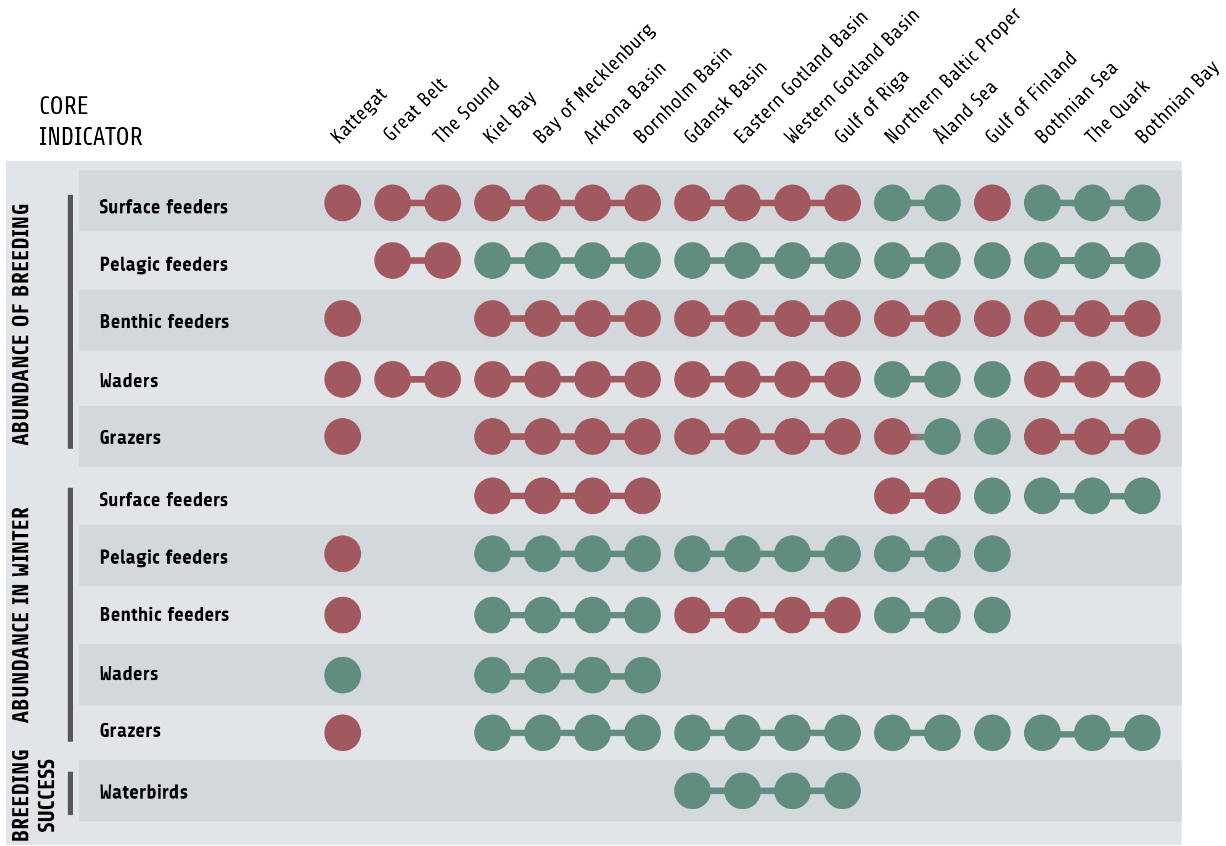


Figure 6.3. (Continued). Integrated biodiversity status assessment results for waterbirds, as generated by the BEAT tool, based on the indicator evaluations for abundance of breeding and wintering waterbirds as well as the indicator evaluation on breeding success (currently only relevant for pelagic feeders) (HELCOM 2023i, HELCOM 2023j and HELCOM 2023u). Values >0.6 correspond to good status. Confidence is presented in the map insert. Corresponding indicator evaluation results for indicators included in the integrated assessment are presented in the right hand side of the figure.

Table 6.3. BEAT output from the integrated assessment of waterbirds. The assessment includes the entire populations the waterbirds in the Baltic Sea region, as listed in Table 6.2. The column "Sub-division" referes to the agreed name of each individual assessment area. "Spatial assessment unit level" indicates at what spatial resolution the assessment was conducted (see Section 2.3.2 or the HELCOM Monitoring and Assessment Strategy for more information on the assessment units used for HELCOM assessments). "Biological Quality Ratio" represents the quantitative results of the integrated assessment for the topic, with results >0.6 constituting Good Status (see Section 2.1.1 for more information on the BEAT tool). The following column indicates the proportion of the species included in the integrated assessment for this area which achieve the threshold of 75% of species being in good condition in order to indicate good status. The column "Status" indicates whether the quantitative assessment results achieve of fail the threshold for good status. The columns "Confidence" and "Confidence Class", respectivey, provides a quantified value for confidence in the assessment and translates this value into a discreet confidence class, in line with the methodology outlined in Section 2.1.1.

Sub-division	Spatial assessment unit level	Biological Quality Ratio	Proportion of species in good status across all feeding groups	Status	Confidence	Confidence Class
A: Kattegat (Kattegat)	2	0.3	0.2	not good	0.9	High
B: Belt Group (Great Belt, The Sound)	2	0.3	0.5	not good	1.0	High
C: Bornholm Group (Kiel Bay, Bay of Mecklenburg, Arkona Basin, Bornholm Basin)	2	0.3	0.5	not good	0.9	High
D: Gotland Group (Gdansk Basin, Eastern Gotland Basin, Western Gotland Basin, Gulf of Riga)	2	0.3	0.5	not good	0.9	High
E: Åland Group (Northern Baltic Proper, Åland Sea)	2	0.3	0.7	not good	1.0	High
F: Gulf of Finland (Gulf of Finland)	2	0.3	0.6	not good	1.0	High
G: Bothnian Group (Bothnian Sea, The Quark, Bothnian Bay).	2	0.3	0.3	not good	1.0	High

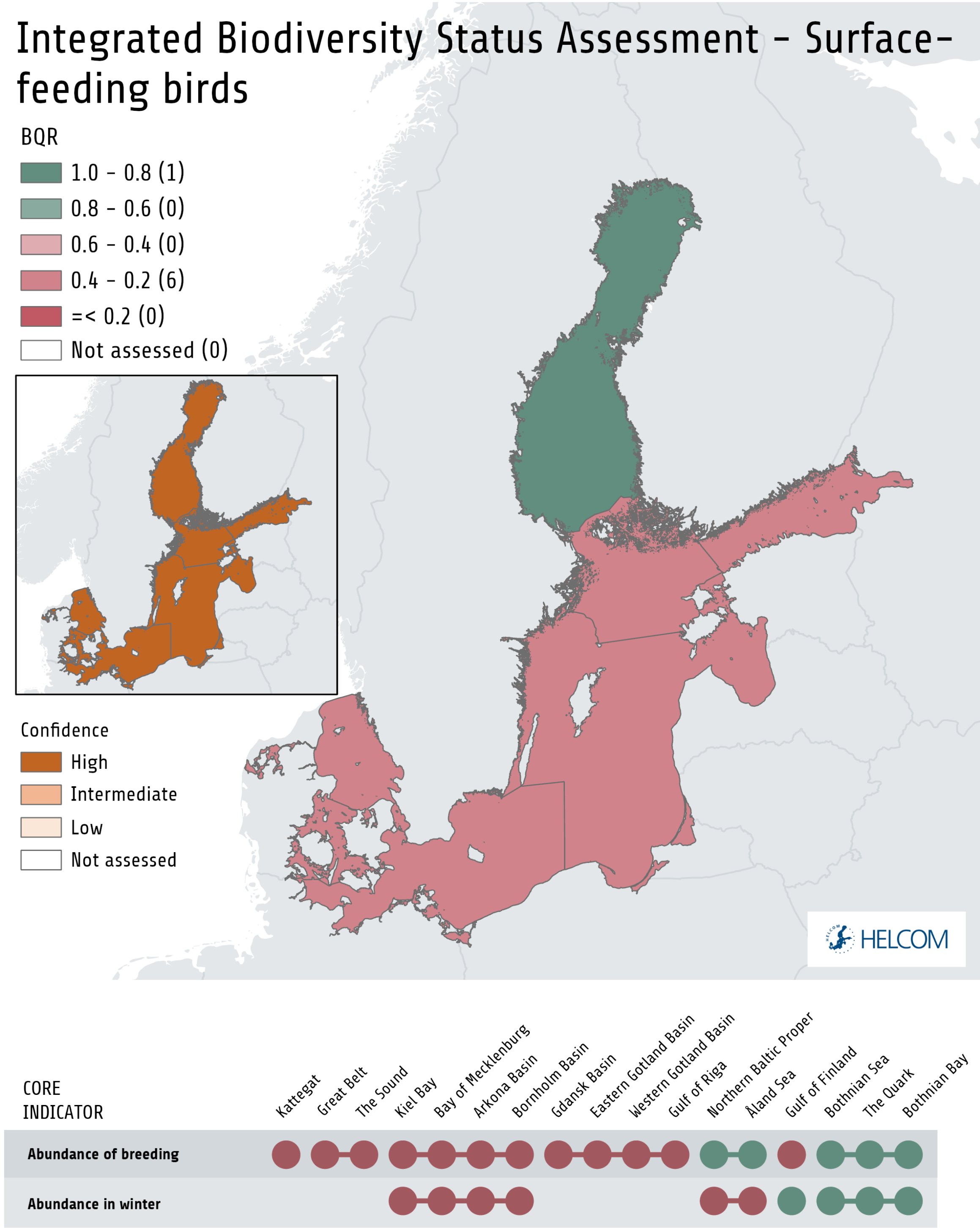


Figure 6.4. Integrated biodiversity status assessment results for surface-feeding birds, as generated by the BEAT tool, based on the indicator evaluations for abundance of breeding and wintering waterbirds birds (HELCOM 2023i, HELCOM 2023j and HELCOM 2023u). Values >0.6 correspond to good status. Confidence is presented in the map insert Corresponding indicator evaluation results for indicators included in the integrated assessment are presented in the bottom of the figure.

The assessment presented in this chapter should be considered together with other relevant biodiversity assessments in order to achieve an overall overview of the status of biodiversity. More information on the assessment methodology and approach can be found in Chapter 2 (BEAT methodology) and in Annex 1 (Methodology manuals).

At the species group level, grazing birds achieved the threshold in most subdivisions (exceptions: Åland group and Kattegat) and reach the threshold value of 75% of species in good status when averaged across the all areas, whereas benthic-feeding birds and wading birds were below the threshold in all areas. Pelagic-feeding birds achieved the threshold in the Åland group, Bornholm group, Gotland group and Gulf of Finland. Surface-feeding birds achieved the threshold only in the Bothnian group. Result across functional groups are presented in Figures 6.4-6.8. The confidence of the assessment of species groups was high for all species groups in all areas, except for the pelagic-feeding birds in Kattegat where the confidence was intermediate.

None of the species groups achieved the threshold in Kattegat or in the Belt group. In the Belt group, no assessment was done for grazing birds and benthic-feeding birds. In the Bornholm group, Gotland group and Gulf of Finland grazing birds and pelagic feeding birds achieved good status, whereas in the Åland group only pelagic feeding birds achieved good status. In the Bothnian group grazing birds and surface feeding birds achieved good status.

Table 6.4. BEAT output from the integrated assessment of surface feeding waterbirds. The assessment includes the entire populations of the pelagic feeding waterbirds in the Baltic Sea region, as listed in Table 6.2. The column "Sub-division" referes to the agreed name of each individual assessment area. "Spatial assessment unit level" indicates at what spatial resolution the assessment was conducted (see Section 2.3.2 or the HELCOM Monitoring and Assessment Strategy for more information on the assessment units used for HELCOM assessments). "Biological Quality Ratio" represents the quantitative results of the integrated assessment for the topic, with results >0.6 constituting Good Status (see Section 2.1.1 for more information on the BEAT tool). The following column indicates the proportion of the species included in the integrated assessment for this area which achieve the threshold of 75% of species being in good condition in order to indicate good status. The column "Status" indicates whether the quantitative assessment results achieve of fail the threshold for good status. The columns "Confidence" and "Confidence Class", respectivey, provides a quantified value for confidence in the assessment and translates this value into a discreet confidence class, in line with the methodology outlined in Section 2.1.1.

Sub-division	Spatial assessment unit level	Biological quality ratio	Proportion of species in good status in this feeding group	Status	Confidence	Confidence Class
A: Kattegat (Kattegat)	2	0.3	0.5	not good	1.00	High
B: Belt Group (Great Belt, The Sound)	2	0.3	0.7	not good	1.00	High
C: Bornholm Group (Kiel Bay, Bay of Mecklenburg, Arkona Basin, Bornholm Basin)	2	0.3	0.5	not good	0.99	High
D: Gotland Group (Gdansk Basin, Eastern Gotland Basin, Western Gotland Basin, Gulf of Riga)	2	0.3	0.6	not good	1.00	High
E: Åland Group (Northern Baltic Proper, Åland Sea)	2	0.3	0.7	not good	1.00	High
F: Gulf of Finland	2	0.3	0.6	not good	0.96	High
G: Bothnian Group (Bothnian Sea, The Quark, Bothnian Bay) Bothnian Sea	2	0.8	1.0	good	1.00	High

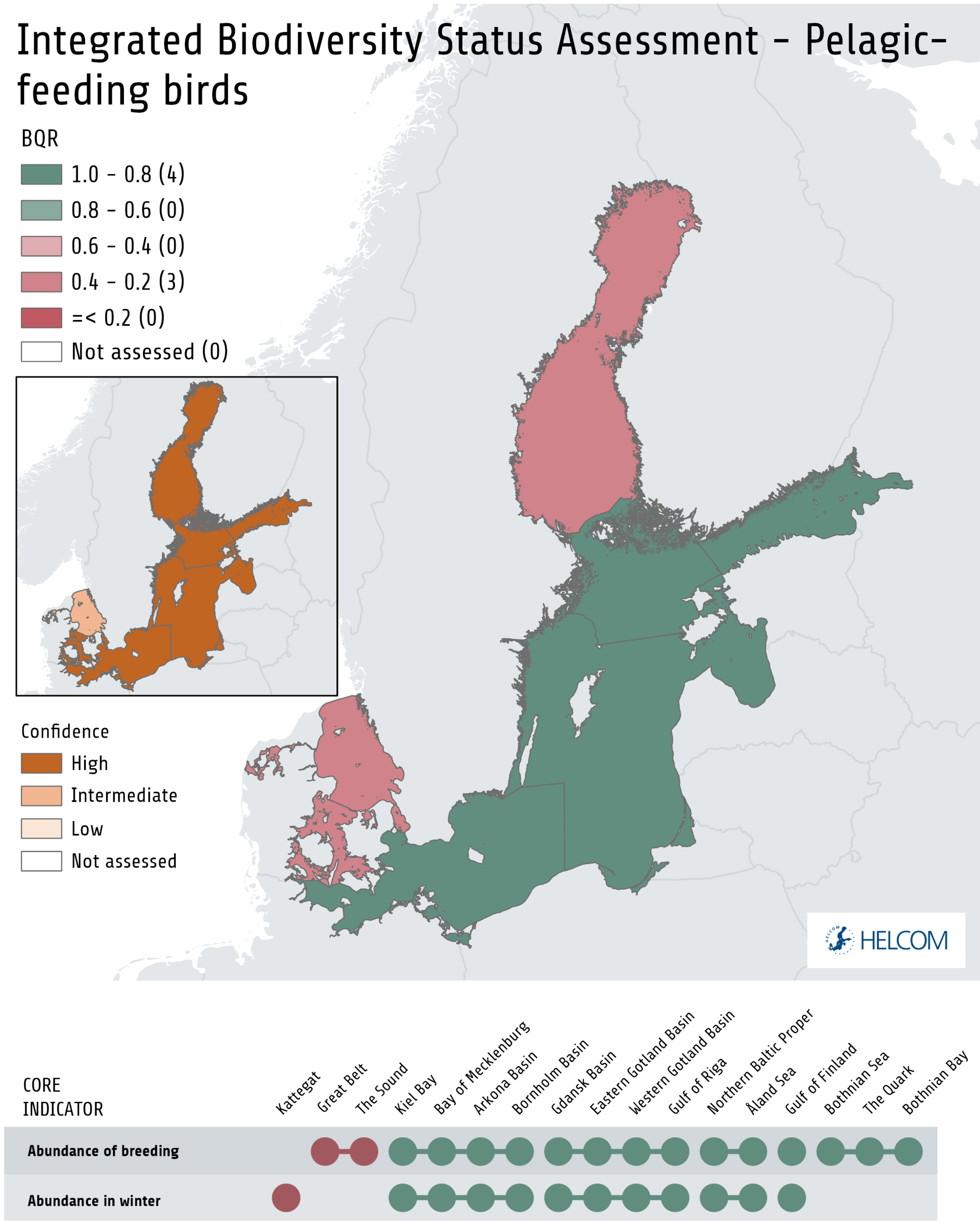


Figure 6.5. Integrated biodiversity status assessment results for pelagic feeding birds, as generated by the BEAT tool, based on the indicator evaluations for abundance of breeding and wintering waterbirds birds as well as breeding success (HELCOM 2023i, HELCOM 2023j and HELCOM 2023u). Values >0.6 correspond to good status. Confidence is presented in the map insert. Corresponding indicator evaluation results for indicators included in the integrated assessment are presented in the bottom of the figure.

Table 6.5. BEAT output from the integrated assessment of pelagic feeding waterbirds. The assessment includes the entire populations of the pelagic feeding waterbirds in the Baltic Sea region, as listed in Table 6.2. The column "Sub-division" referes to the agreed name of each individual assessment area. "Spatial assessment unit level" indicates at what spatial resolution the assessment was conducted (see Section 2.3.2 or the HELCOM Monitoring and Assessment Strategy for more information on the assessment units used for HELCOM assessments). "Biological Quality Ratio" represents the quantitative results of the integrated assessment for the topic, with results >0.6 constituting Good Status (see Section 2.1.1 for more information on the BEAT tool). The following column indicates the proportion of the species included in the integrated assessment for this area which achieve the threshold of 75% of species being in good condition in order to indicate good status. The column "Status" indicates whether the quantitative assessment results achieve of fail the threshold for good status. The columns "Confidence" and "Confidence Class", respectivey, provides a quantified value for confidence in the assessment and translates this value into a discreet confidence class, in line with the methodology outlined in Section 2.1.1.

Sub-division	Spatial assessment unit level	Biological quality ratio	Proportion of species in good status in this feeding group	Status	Confidence	Confidence Class
A: Kattegat (Kattegat)	2	0.3	0.5	not good	0.75	Intermediate
B: Belt Group (Great Belt, The Sound)	2	0.3	0.5	not good	1.00	High
C: Bornholm Group (Kiel Bay, Bay of Mecklenburg, Arkona Basin, Bornholm Basin)	2	0.8	0.8	good	0.89	High
D: Gotland Group (Gdansk Basin, Eastern Gotland Basin, Western Gotland Basin, Gulf of Riga)	2	0.8	0.9	good	0.92	High
E: Åland Group (Northern Baltic Proper, Åland Sea)	2	0.8	0.9	good	1.00	High
F: Gulf of Finland (Gulf of Finland)	2	0.8	0.8	good	0.96	High
G: Bothnian Group (Bothnian Sea, The Quark, Bothnian Bay)	2	0.3	0.7	not good	1.00	High

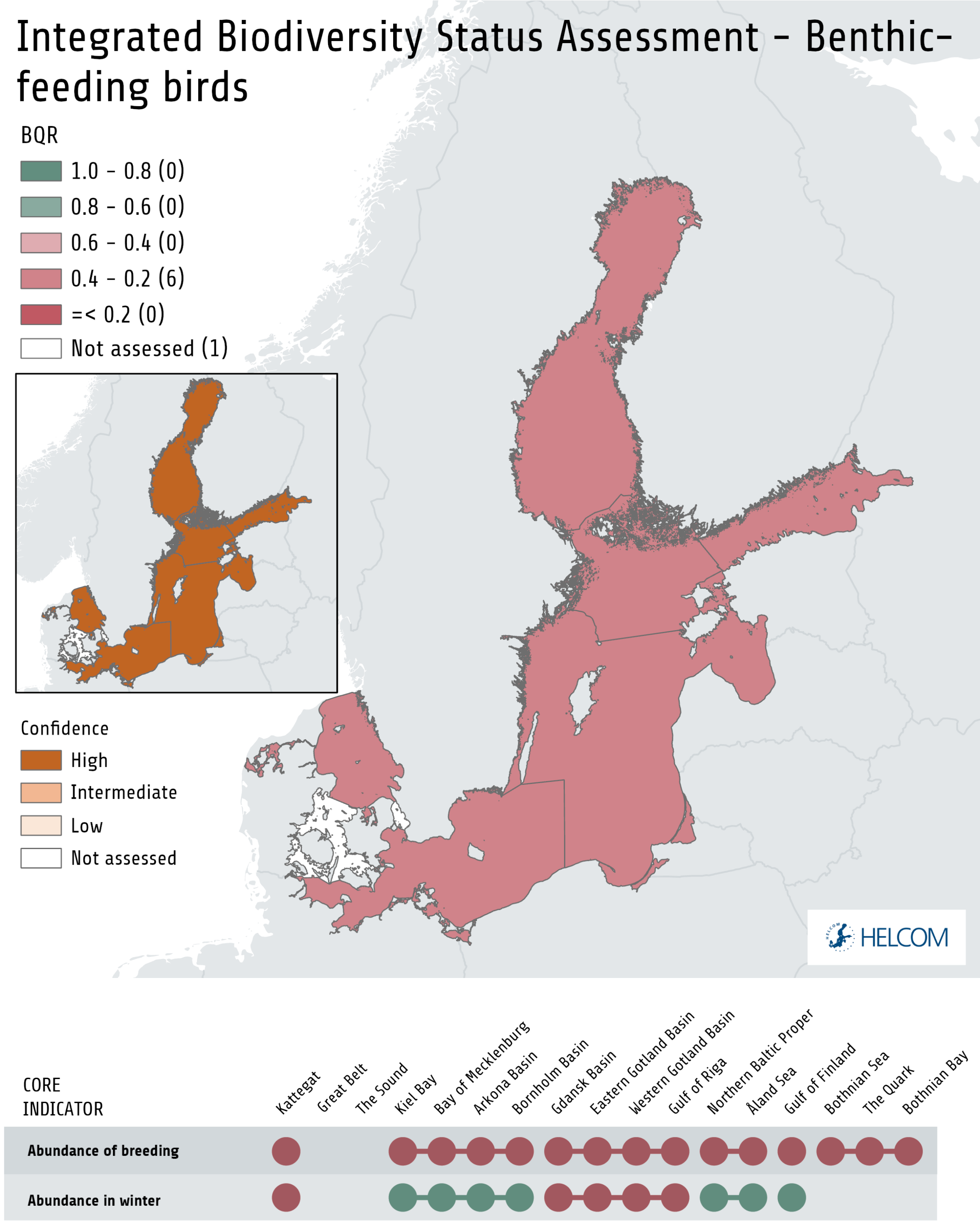


Figure 6.6. Integrated biodiversity status assessment results for benthic-feeding birds, as generated by the BEAT tool, based on the indicator evaluations for abundance of breeding and wintering waterbirds (HELCOM 2023i, HELCOM 2023j). Values >0.6 correspond to good status. Confidence is presented in the map insert. Corresponding indicator evaluation results for indicators included in the integrated assessment are presented in the bottom of the figure.

Table 6.6. BEAT output from the integrated assessment of bethic feeding waterbirds. The assessment includes the entire populations of the benthic feeding waterbirds in the Baltic Sea region, as listed in Table 6.2. The column "Sub-division" referes to the agreed name of each individual assessment area. "Spatial assessment unit level" indicates at what spatial resolution the assessment was conducted (see Section 2.3.2 or the HELCOM Monitoring and Assessment Strategy for more information on the assessment units used for HELCOM assessments). "Biological Quality Ratio" represents the quantitative results of the integrated assessment for the topic, with results >0.6 constituting Good Status (see Section 2.1.1 for more information on the BEAT tool). The following column indicates the proportion of the species included in the integrated assessment for this area which achieve the threshold of 75% of species being in good condition in order to indicate good status. The column "Status" indicates whether the quantitative assessment results achieve of fail the threshold for good status. The columns "Confidence" and "Confidence Class", respectivey, provides a quantified value for confidence in the assessment and translates this value into a discreet confidence class, in line with the methodology outlined in Section 2.1.1.

Sub-division	Spatila assessment unit level	Biological quality ratio	Proportion of species in good status in this feeding group	Status	Confidence	Confidence Class
Kattegat	2	0.3	0.2	not good	0.80	High
C: Bornholm Group (Kiel Bay, Bay of Mecklenburg, Arkona Basin, Bornholm Basin)	2	0.3	0.6	not good	0.86	High
D: Gotland Group (Gdansk Basin, Eastern Gotland Basin, Western Gotland Basin, Gulf of Riga)	2	0.3	0.5	not good	0.89	High
E: Åland Group (Northern Baltic Proper, Åland Sea)	2	0.3	0.7	not good	0.91	High
F: Gulf of Finland (Gulf of Finland)	2	0.3	0.6	not good	0.93	High
G: Bothnian Group (Bothnian Sea, The Quark, Bothnian Bay)	2	0.3	0.3	not good	1.00	High

State of the Baltic Sea
Third HELCOM holistic assessment 2016-2021
Biodiversity
6. Waterbirds

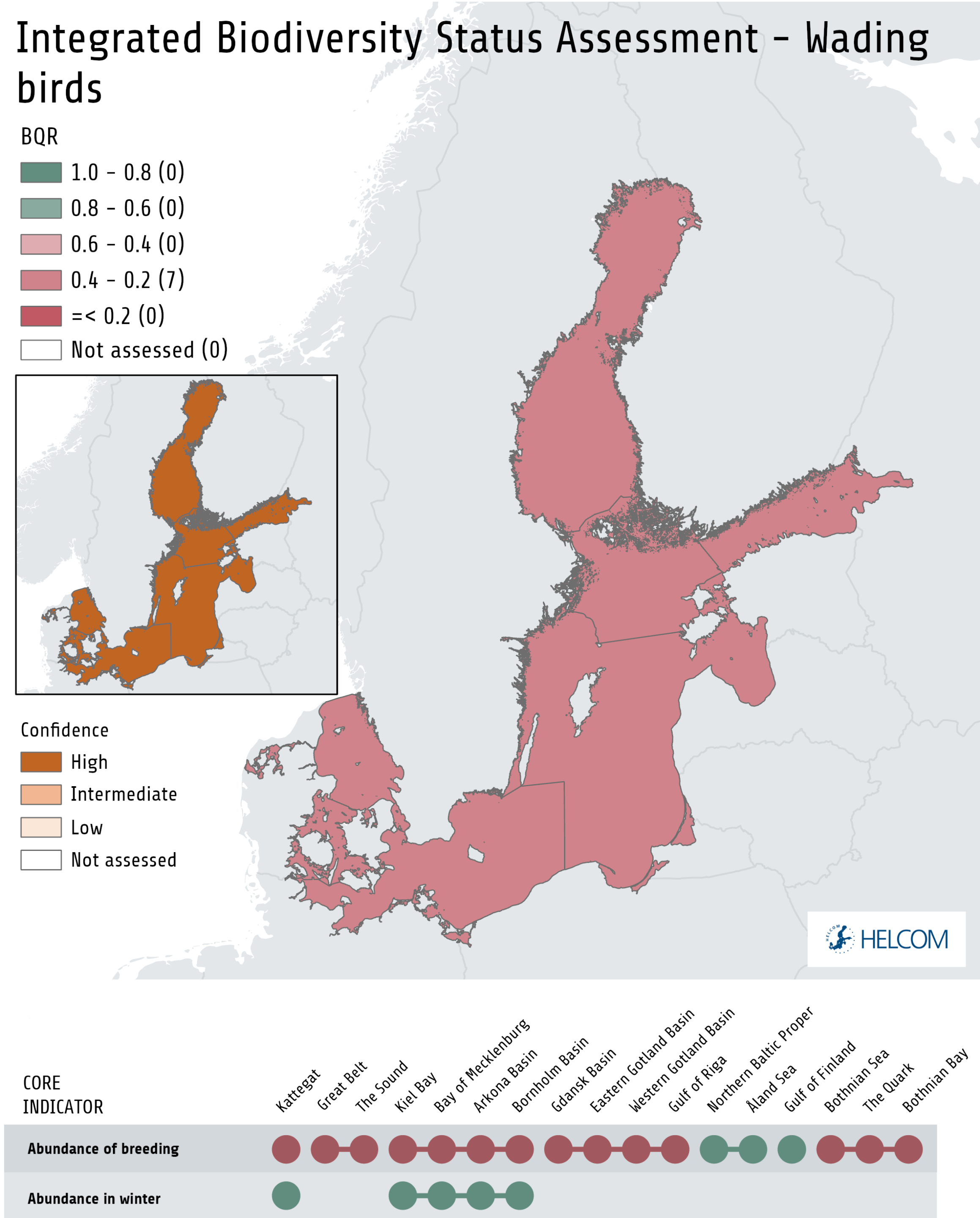


Figure 6.7. Integrated biodiversity status assessment results for wading birds, as generated by the BEAT tool, based on the indicator evaluations for abundance of breeding and wintering waterbirds (HELCOM 2023i, HELCOM 2023j). Values >0.6 correspond to good status. Confidence is presented in the map insert. Corresponding indicator evaluation results for indicators included in the integrated assessment are presented in the bottom of the figure.

Table 6.7. BEAT output from the integrated assessment of wading waterbirds. The assessment includes the entire populations of the wading waterbirds in the Baltic Sea region, as listed in Table 6.2. The column "Sub-division" referes to the agreed name of each individual assessment area. "Spatial assessment unit level" indicates at what spatial resolution the assessment was conducted (see Section 2.3.2 or the HELCOM Monitoring and Assessment Strategy for more information on the assessment units used for HELCOM assessments). "Biological Quality Ratio" represents the quantitative results of the integrated assessment for the topic, with results >0.6 constituting Good Status (see Section 2.1.1 for more information on the BEAT tool). The following column indicates the proportion of the species included in the integrated assessment for this area which achieve the threshold of 75% of species being in good condition in order to indicate good status. The column "Status" indicates whether the quantitative assessment results achieve of fail the threshold for good status. The columns"Confidence" and "Confidence Class", respectivey, provides a quantified value for confidence in the assessment and translates this value into a discreet confidence class, in line with the methodology outlined in Section 2.1.1.

Sub-division	Spatial assessment unit level	Biological quality ratio	Proportion of species in good status in this feeding group	Status	Confidence	Confidence Class
A: Kattegat (Kattegat)	2	0.3	0.4	not good	0.95	High
B: Belt Group (Great Belt, The Sound)	2	0.3	0.5	not good	1.00	High
C: Bornholm Group (Kiel Bay, Bay of Mecklenburg, Arkona Basin, Bornholm Basin)	2	0.3	0.7	not good	0.98	High
D: Gotland Group (Gdansk Basin, Eastern Gotland Basin, Western Gotland Basin, Gulf of Riga)	2	0.3	0.6	not good	1.00	High
E: Åland Group (Northern Baltic Proper, Åland Sea)	2	0.3	0.8	not good	1.00	High
F: Gulf of Finland (Gulf of Finland)	2	0.3	0.8	not good	1.00	High
G: Bothnian Group (Bothnian Sea, The Quark, Bothnian Bay).	2	0.3	0.7	not good	1.00	High

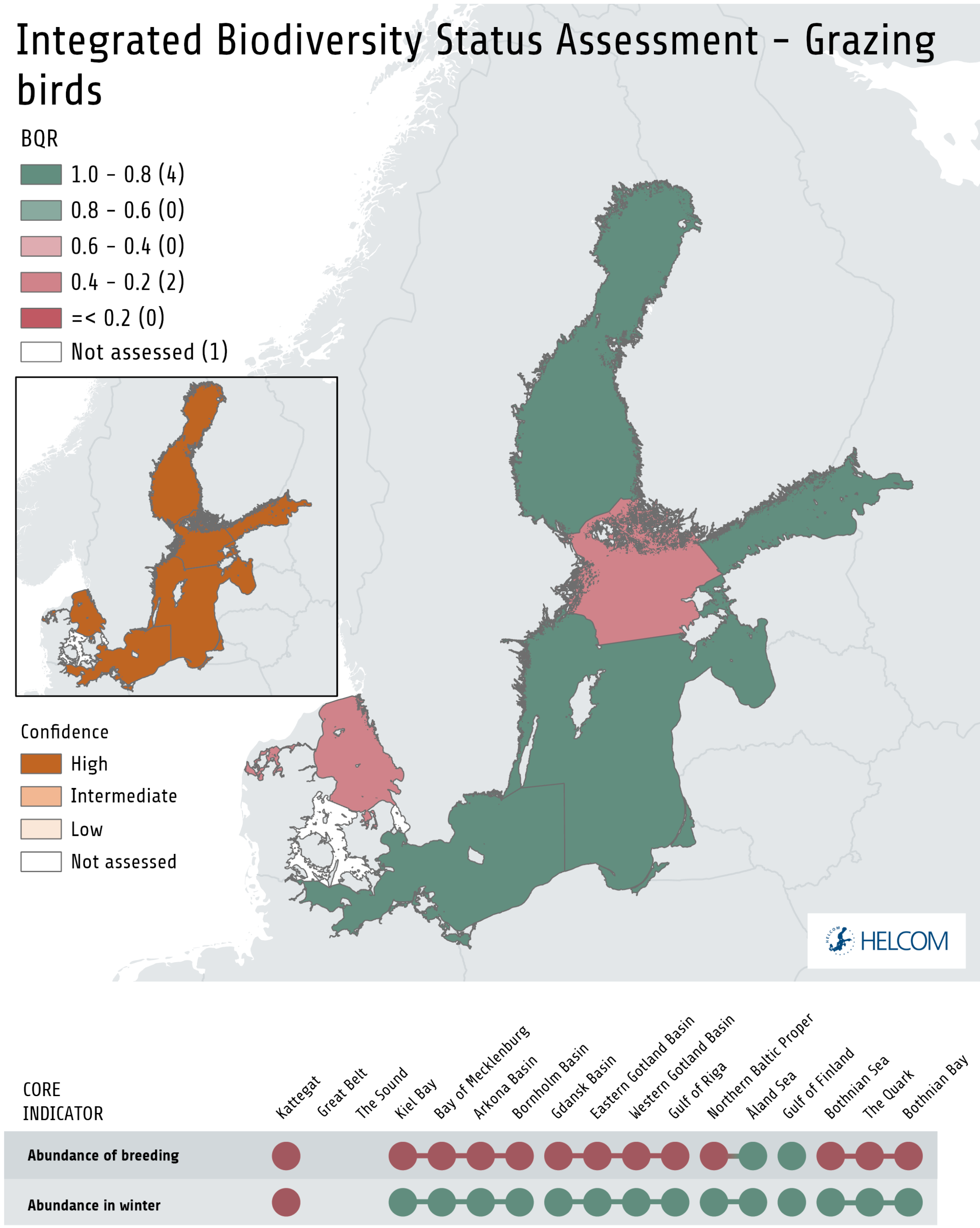


Figure 6.8. Integrated biodiversity status assessment results for grazing birds, as generated by the BEAT tool, based on the indicator evaluations for abundance of breeding and wintering waterbirds birds (HELCOM 2023i, HELCOM 2023j). Values of >0.6 correspond to good status. Confidence is presented in the map insert. Corresponding indicator evaluation results for indicators included in the integrated assessment are presented in the bottom of the figure.

The assessment results show that there are some differences between the various functional groups as well as 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 (*Clangula hyemalis*), others are restricted to smaller parts of the Baltic or only selected sites, for example breeding pied avocets (*Recurvirostra avosetta*) and wintering Steller's eiders (*Polysticta stelleri*). 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 season are currently primarily based on land-based survey data, whilst species in the open sea are not adequately covered. While this does not directly affect the results, it affects the overall robustness of the assessment, which should therefore be taken into consideration when interpreting the results. Many open sea species are known to show strongly declining trends in the Baltic Sea (Skov *et al.* 2011) , and this negative trend was maintained for some of these species.

6.2.2 Indicator evaluation results for waterbirds

The status assessment of waterbirds presented in the previous section is underpinned by indicators. Subsequent indicator evaluation results, as presented in Annex 2, section on waterbirds, provide more detailed information on the status of waterbirds in the Baltic Sea for the assessment period 2016-2021. These indicator results are integrated to achieve a status assessment for waterbird overall and by functional group as presented in the previous section. For maps showing the status, as well as brief summaries of the evaluation results, please see the section for the indicator in question further down in this chapter.

Table 6.8. BEAT output from the integrated assessment of grazing waterbirds. The assessment includes the entire populations of the grazing waterbirds in the Baltic Sea region, as listed in Table 6.2. The column "Sub-division" refers to the agreed name of each individual assessment area. "Spatial assessment unit level" indicates at what spatial resolution the assessment was conducted (see Section 2.3.2 or the HELCOM Monitoring and Assessment Strategy for more information on the assessment units used for HELCOM assessments). "Biological Quality Ratio" represents the quantitative results of the integrated assessment for the topic, with results >0.6 constituting Good Status (see Section 2.1.1 for more information on the BEAT tool). The following column indicates the proportion of the species included in the integrated assessment for this area which achieve the threshold of 75% of species being in good condition in order to indicate good status. The column "Status" indicates whether the quantitative assessment results achieve of fail the threshold for good status. The columns"Confidence" and "Confidence Class", respectivey, provides a quantified value for confidence in the assessment and translates this value into a discreet confidence class, in line with the methodology outlined in Section 2.1.1.

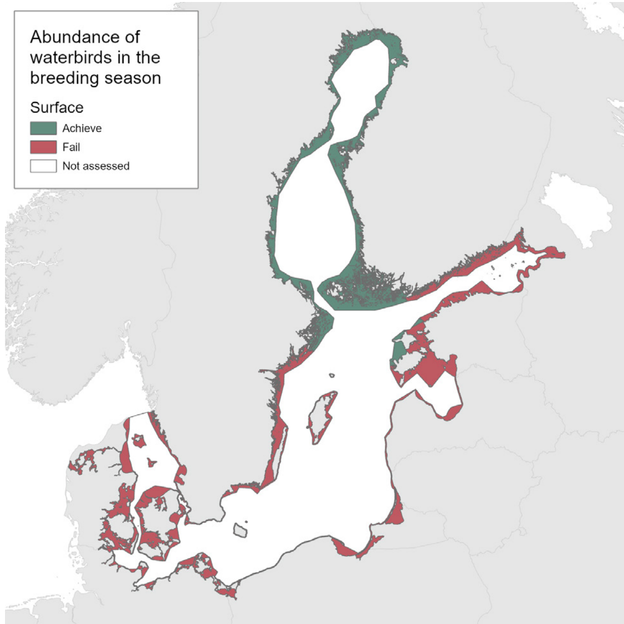
Sub-division	Spatial assessment unit level	Biological quality ratio	Proportion of species in good status in this feeding group	Status	Confidence	Confidence Class
A: Kattegat (Kattegat)	2	0.3	0.3	not good	0.86	High
C: Bornholm Group (Kiel Bay, Bay of Mecklenburg, Arkona Basin, Bornholm Basin)	2	0.8	0.8	good	0.90	High
D: Gotland Group (Gdansk Basin, Eastern Gotland Basin, Western Gotland Basin, Gulf of Riga)	2	0.8	0.9	good	0.93	High
E: Åland Group (Northern Baltic Proper, Åland Sea)	2	0.3	0.7	not good	1.00	High
F: Gulf of Finland (Gulf of Finland)	2	0.8	1.0	good	0.95	High
G: Bothnian Group (Bothnian Sea, The Quark, Bothnian Bay)	2	0.8	1.0	good	1.00	High

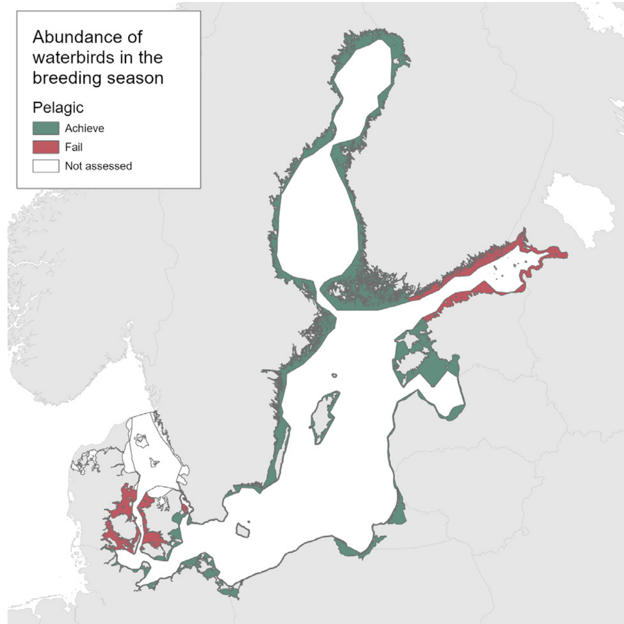
Abundance of breeding birds

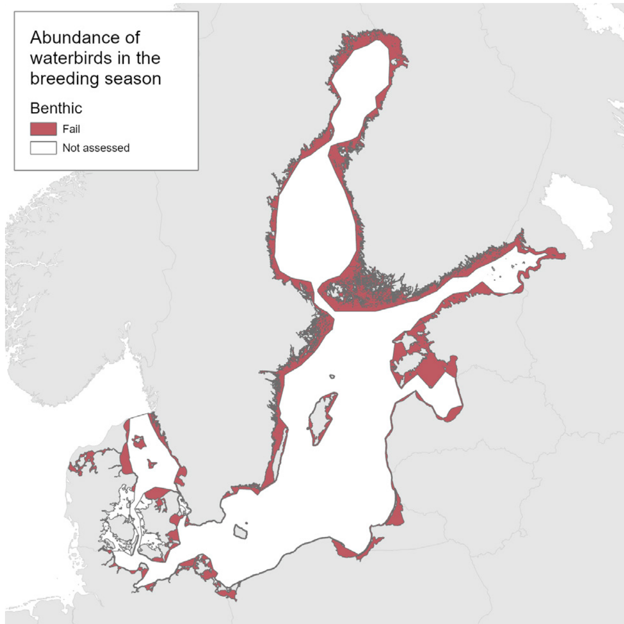
On the scale of the entire Baltic Sea the evaluation of the indicator 'Abundance of breeding birds' for the assessment period 2016-2021 showed a good status for all breeding waterbird species when considered together, but diverging results for the species groups (Figure 6.9). While surface feeders, pelagic feeders and grazing feeders achieved the threshold value indicating a good status, wading feeders and benthic feeders failed to achieve the threshold value and do not indicate good status.

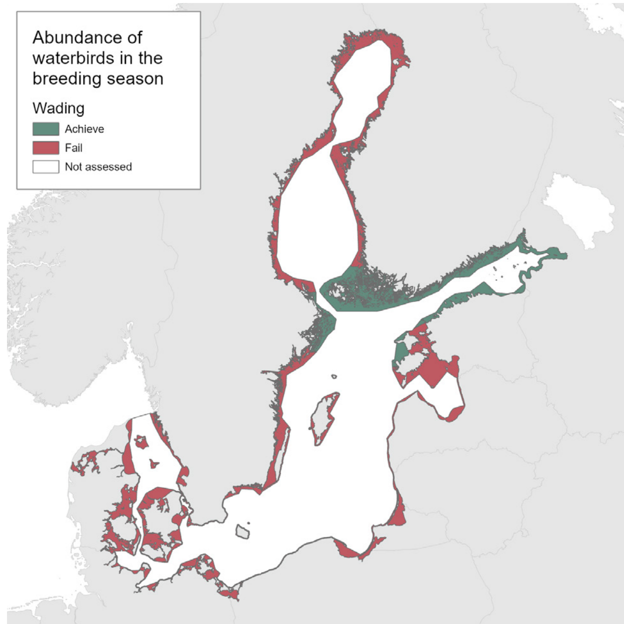
On a finer spatial scale, the status for breeding waterbirds was evaluated in seven subdivisions of the Baltic Sea (Figure 6.7). The results define a different perspective and diverging evaluations between the spatial subdivisions. More information on the indicator evaluation and results can be found in the indicator report (HELCOM 2023j).

Figure 6.9. Status of the indicator 'abundance of waterbirds in the breeding season'. The current evaluation is presented for coastal areas. The evaluation is for the entire Baltic Sea – including all species currently evaluated and for seven sudivisions of the Baltic Sea. Results for the species groups are based on the trends of individual species: surface feeders (top row, left), pelagic feeders (top row, right), benthic feeders (middle row, left), wading feeders (middle row, right) and grazing feeders (bottom row, left). (Source: HELCOM 2023j).









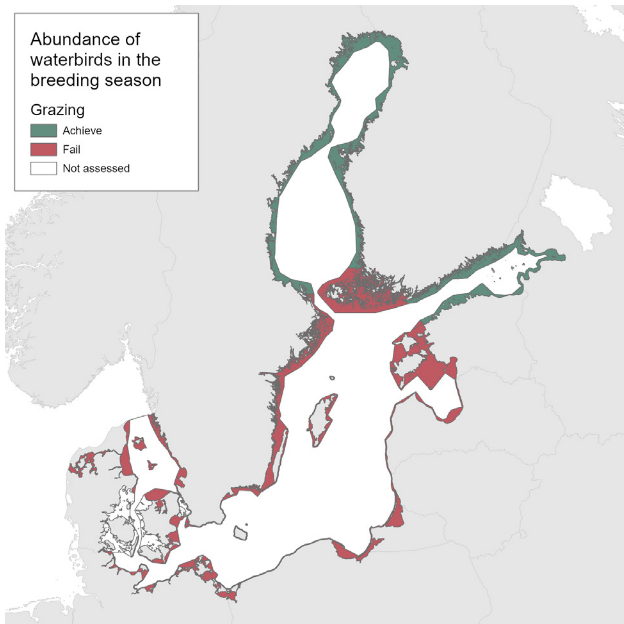


Figure 6.9. (continued). Status of the indicator 'abundance of waterbirds in the breeding season'. The current evaluation is presented for coastal areas. The evaluation is for the entire Baltic Sea – including all species currently evaluated and for seven sudivisions of the Baltic Sea. Results for the species groups are based on the trends of individual species: surface feeders (top row, left), pelagic feeders (top row, right), benthic feeders (middle row, left), wading feeders (middle row, right) and grazing feeders (bottom row, left). (Source: HELCOM 2023j).

Abundance of wintering birds

The abundance of wintering waterbirds in the Baltic Sea was not in good status during the HOLAS 3 assessment period 2016-2021, because 69% of the species assessed achieved the threshold value (at least 75% of species meeting threshold value indicates good status). Two species groups, namely pelagic feeders and wading feeders, achieved good status (≥75% of species meeting threshold value), whereas surface feeders, benthic feeders and grazing feeders did not reach the threshold value. These evaluations only reflect the status of coastal waters, because waterbirds wintering predominantly in the open sea and therefore too far offshore to be monitored by land-based surveys are not considered.

A good status of wintering waterbirds was observed in four of the subdivisions (Bornholm Group, Gotland Group, Gulf of Finland, Bothnian Group), but could not be achieved in the other two (Kattegat, Åland Group). The subdivision Belt Sea (Great Belt, The Sound) could not be evaluated. Subdivision evaluations for species groups mostly reflect the same pattern as the overall evaluation, but showed more variation (Figure 6.10). In Bornholm Group subdivision, data from offshore surveys could enter the evaluation of one species for the first time. More information on the indicator evaluation and results can be found in the indicator specific report (HELCOM 2023i).

Figure 6.10. Status of the indicator 'abundance of waterbirds in the wintering season'. The current evaluation is presented for coastal areas. The evaluation is for the entire Baltic Sea – including all species currently evaluated and for seven subdivisions of the Baltic Sea. Results for the species groups are based on the trends of individual species: surface feeders (top row, left), pelagic feeders (top row, right), benthic feeders (middle row, left), wading feeders (middle row, right) and grazing feeders (bottom row, left). (Source: HELCOM 2023i).

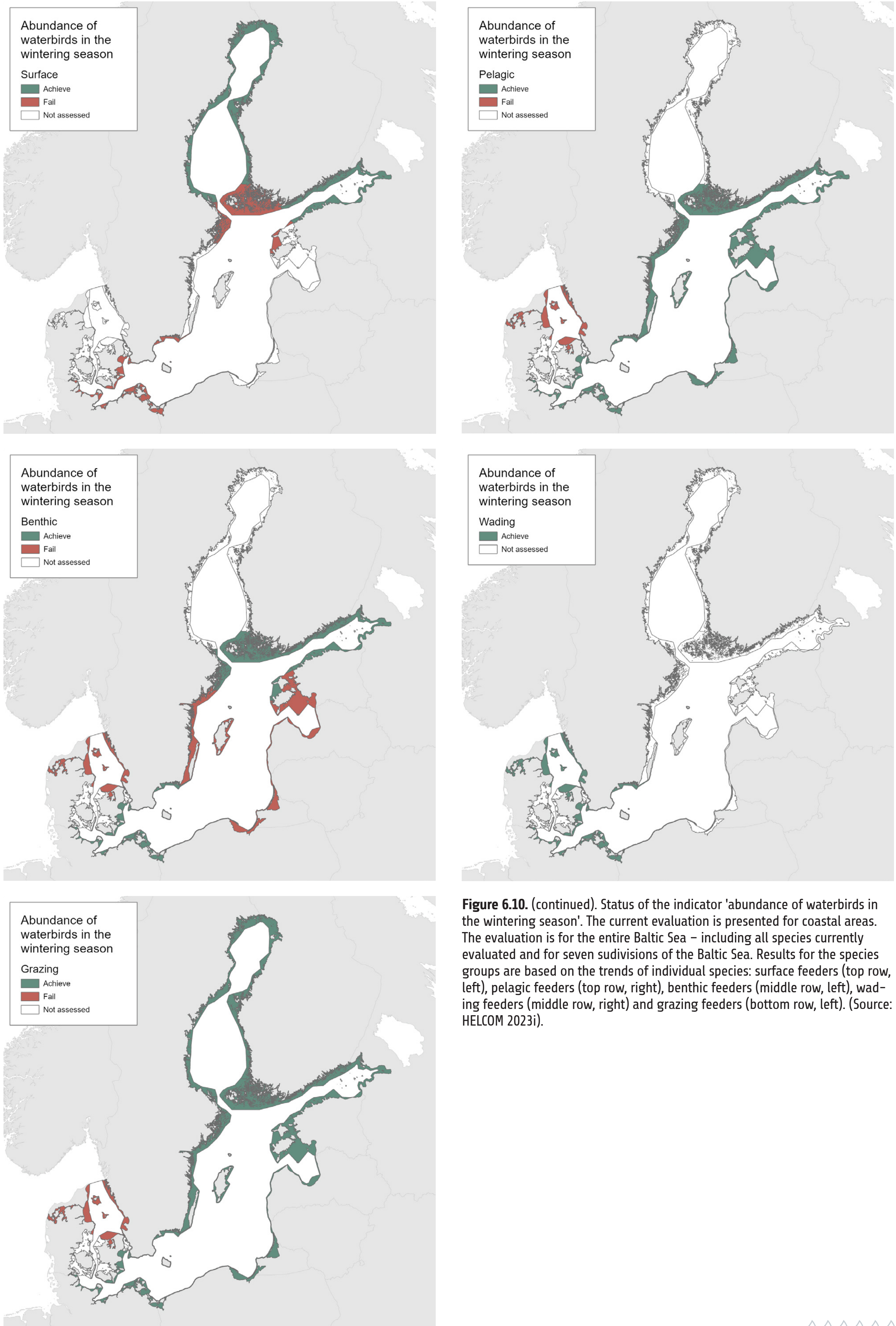


Figure 6.10. (continued). Status of the indicator 'abundance of waterbirds in the wintering season'. The current evaluation is presented for coastal areas. The evaluation is for the entire Baltic Sea – including all species currently evaluated and for seven sudivisions of the Baltic Sea. Results for the species groups are based on the trends of individual species: surface feeders (top row, left), pelagic feeders (top row, right), benthic feeders (middle row, left), wading feeders (middle row, right) and grazing feeders (bottom row, left). (Source: HELCOM 2023i).

Breeding success of waterbirds

Waterbird breeding success (also known as breeding productivity) is a highly informative parameter for assessing the state of waterbirds and thereby the status of the marine environment. Problems in the marine environment are reflected rapidly in such a parameter, in contrast to abundance (as presented above), which can show response time lags of several years between effects of disturbance and impact on the population size.

In the third holistic assessment breeding success was included as a candidate indicator, in other words the evaluation represents a pilot example showing how the indicator works. The results therefore cover only one species, common guillemot (*Uria aalge*), at one location, near Gotland. The results indicate that the species is in good condition with regard to breeding success (Figure 6.11). The population growth rate indicates an increase in population size over three generations, which is equal to 74.4 years in the case of this species. The good status regarding breeding success points in particular to favourable feeding conditions. With regard to the state of the Baltic Sea, on the other hand, it must be taken into account that the common guillemot benefits from an imbalance in the ecosystem. Presently, the abundance of small fish populations, which constitute the common guillemot favourite preys, is favoured by the collapse of cod (*Gadus morhua*) in the region, which is itself a consequence of detrimental human activities, including past overfishing of the cod stocks. More information on the indicator evaluation and results can be found in the indicator specific report (HELCOM 2023u).

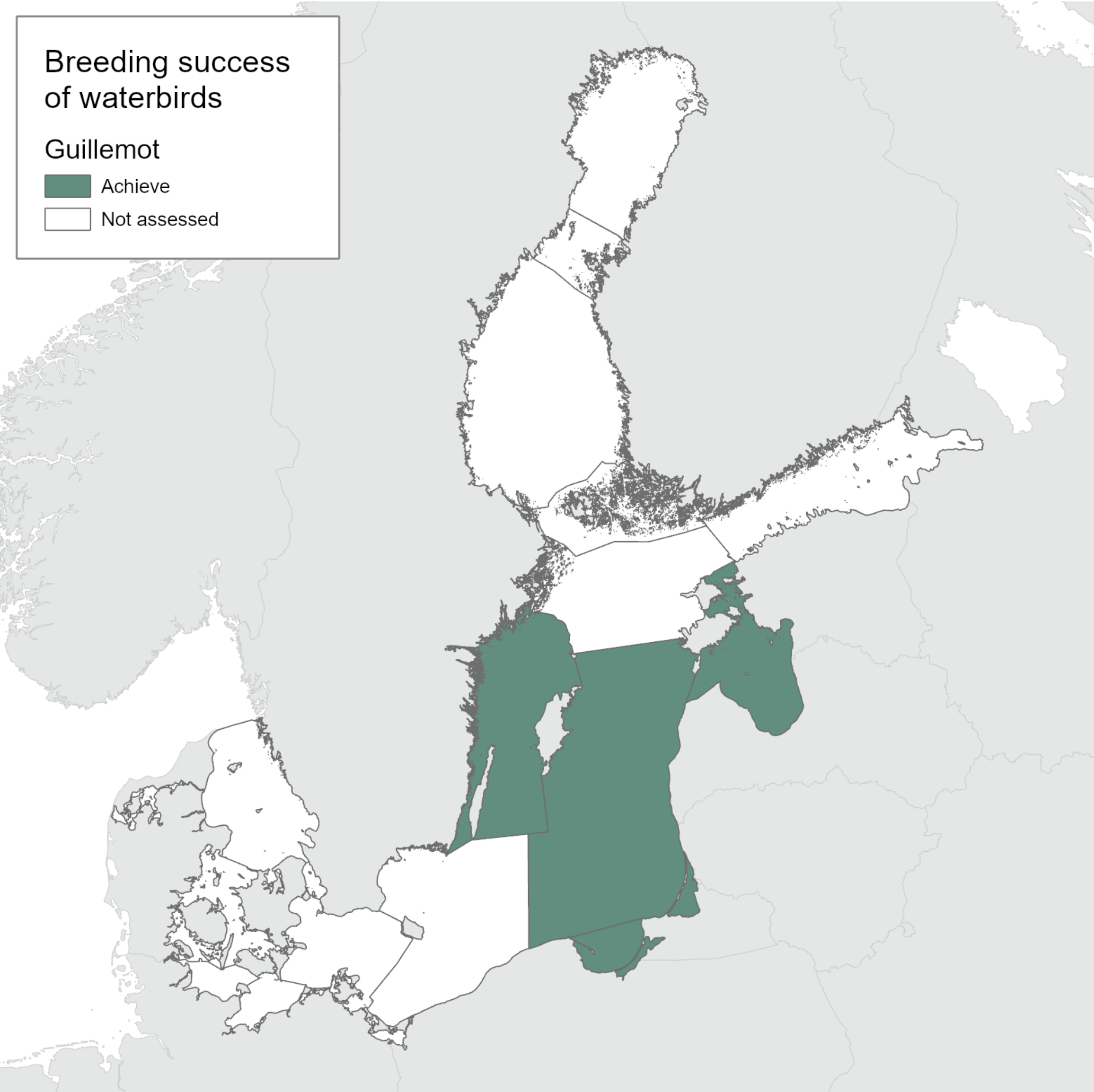


Figure 6.11. Status assessment results based on evaluation of the indicator 'Breeding success of waterbirds'. The assessment is carried out using open sea areas of Baltic Sea subdivisions. This pilot assessment is based on the breeding success of one species (common guillemot) in one subdivision (Gotland Group). (Source: HELCOM 2023u).

Box 6.1. Habitat quality of waterbirds

The Baltic Sea Action Plan aspires to viable populations of the species as well as thriving and balanced communities of plants and animals. Both goals can only be achieved if species are not restricted in the use of their habitats. This is also true for waterbirds. In more detail, the HELCOM Recommendation 34E/1 Safeguarding important bird habitats and migration routes in the Baltic Sea from negative effects of wind and wave energy production at sea recommends (among other things) to

— apply the precautionary principle by undertaking measures to avoid or minimize negative effects of wind energy facilities on birds in the Baltic Sea, such as disturbance during and after construction, including barrier effects and hampering of migration, habitat modification or loss, and collisions with turbines, through the application of ecosystem-based approach in strategic planning for wind energy facility developments in the Baltic Sea;
— enable appropriate planning of the use of marine space that incorporates conservation need of seabirds in the Baltic-wide context thus contributing to reaching their favourable conservation status;
— avoid that wind energy facilities and wave energy installations are sited in areas important for birds, and that the loss of off-shore staging habitats will be halted.

Towards this end HELCOM is exploring the possibility of establishing an indicator which would target water bird habitat quality, directly addressing human activities disturbing waterbirds and their habitats. Methodology and test assessments towards this end were prepared as part of the development phase of HOLAS 3.

Although other features of habitat quality can be incorporated in future, the current candidate indicator measures how much of a species' habitat cannot be used or can be used to only a limited degree owing to disturbance from human activities. This is indicated by a considerable proportion of the population inhabiting habitats which are disturbed or possibly even lost because of human activities (see pilot assessment by Mercker *et al.* 2021). The intention in establishing a threshold for this indicator is thus for the threshold to identify if a species not achieving good status is a consequence of restrictions in the use of its habitat. If good status is not achieved, the indicator results clearly show where the problems for the species concerned can be found.

In the future such an indicator could contribute to overall waterbird status assessments by identifying the habitat available for a species and thus providing important supporting information for the assessment of abundance in the HELCOM Core Indicator *Abundance of waterbirds in the wintering season*. It also has a high potential to inform programmes of measures, for example under MSFD Article 13 or in the Baltic Sea Action Plan. Thus, assessing the quality of waterbird habitats has the potential to become a valuable component of bird assessments in the Baltic Sea.

6.3.3 Waterbirds threatened with extinction

The red-listing provides additional information on the status of waterbirds in the Baltic Sea. Twenty-three out of 58 bird species defined as breeding in the Baltic Sea were listed in the HELCOM Red List (HELCOM 2013c). 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 47 water bird species wintering in the Baltic Sea are red-listed. The red-throated diver (*Gavia stellata*) and the black-throated diver (*Gavia arctica*), 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 seven species that are also included in the core indicator for breeding birds, and nine species that are included in the core indicator for wintering birds. In some instances, the core indicator evaluations may show a good status and an increasing trend for a red-listed species (Table 6.9).

Table 6.9. Summary results for waterbirds included as vulnerable (VU), endangered (EN) or critically endangered (CR) on the HELCOM Red List (HELCOM 2013c). Index values, status, trend slopes and trends as in 6.4 Changes over time for waterbirds.

Species	Season	Red List status	Index 2016-2021	Status	Trend slope	Trend
lesser black-backed gull	Breeding	VU	0.995	good	1.0006	no trend
Caspian tern	Breeding	VU	1.948	good	1.0268	moderate increase
greater scaup	Breeding	VU	0.571	not good	0.9724	uncertain
common eider	Breeding	VU	0.196	not good	0.9320	strong decrease
velvet scoter	Breeding	VU	0.499	not good	0.9699	moderate decrease
turnstone	Breeding	VU	0.345	not good	0.9541	moderate decrease
dunlin	Breeding	EN	0.071	not good	0.8941	strong decrease
red-breasted merganser	Wintering	VU	0.768	good	0.9886	moderate decline
red-necked grebe	Wintering	EN	0.951	good	0.9974	no change
red-throated diver	Wintering	CR	2.043	good	0.9794	moderate decline
black-throated diver	Wintering	CR	0.849	good	0.9919	no trend
common eider	Wintering	EN	0.243	not good	0.9638	moderate decline
Steller's eider	Wintering	EN	0.080	not good	0.8909	steep decline
long-tailed duck	Wintering	EN	0.666	not good	0.9877	uncertain
common scoter	Wintering	EN	3.192	good	1.0575	moderate increase
velvet scoter	Wintering	EN	1.584	good	1.0224	moderate increase

6.3. Changes over time for seabirds

6.3.1 Trends in status between assessments

The integrated assessment of waterbirds in HOLAS II was done at assessment scale 1 (one result for the entire Baltic Sea) whereas the assessment in HOLAS 3 is done at the more precise and ecologically relevant resolution of aggregated assessment level 2 units. This means that a side by side comparison between the 2011-2016 and 2016-2021 assessment is not possible. However, at the indicator level the evaluations were done at sub-basin level already for the 2011-2026 evaluation and hence it is possible to present information on the trend between the 2011-2016 and 2016-2021 indicator evaluations. These are presented by indicator in Annex 3, Section 3.3 on Trends in indicator evaluations for waterbirds.

6.3.2 Long term trends in abundance

Many characteristic bird species have decreased over the last few decades, for example the surface feeding great black-backed gull (*Larus marinus*), which scouts the sea surface for fish, and the common eider (*Somaterial mollissima*) which feeds on invertebrates at the sea floor. Other species have increased, such as the greylag goose (*Anser anser*). Changes can be attributed to factors such as disruptions of foodweb structure, climate change and habitat alteration. Table 6.10 provides an overview of the overall long term (1991-2021) trends per species and season, whereas Figure 6.12 illustrates the long term trend graphs per species and season.

Table 6.10. Trends observed in breeding and wintering waterbirds in the Baltic 1991–2021. For breeding birds the trend slopes and standard errors result from TRIM analyses. For wintering birds the trend slopes and standard errors result from GAM analyses. In species marked (wt) the GAM was calculated without air temperature as a covariate.

Group	Species		Number of sites	Trend slope	Standard Error	P	Status
SURFACE FEEDERS	Arctic skua	Breeding	1004	1.0084	0.0037	<0.05	moderate increase
	common gull	Breeding	8527	0.9851	0.0016	<0.01	moderate decrease
	common gull	Wintering	561	1.0288	0.0051		moderate increase
	great black-backed gull	Breeding	4380	0.9871	0.0017	<0.01	moderate decrease
	great black-backed gull	Wintering	611	1.0022	0.0038		no trend
	herring gull	Breeding	4357	0.9984	0.0011		no trend
	herring gull	Wintering	691	0.9949	0.0032		no trend
	lesser black-backed gull	Breeding	1784	1.0006	0.0035		no trend
	little tern	Breeding	382	0.9987	0.0028		no trend
	Caspian tern	Breeding	651	1.0268	0.0037	<0.01	moderate increase
	sandwich tern	Breeding	166	1.0139	0.0056	<0.05	moderate increase
	common tern	Breeding	3567	1.0372	0.0058	<0.01	moderate increase
	Arctic tern	Breeding	6069	1.0111	0.0023	<0.01	moderate increase

Table 6.10. (Continued). Trends observed in breeding and wintering waterbirds in the Baltic 1991–2021. For breeding birds the trend slopes and standard errors result from TRIM analyses. For wintering birds the trend slopes and standard errors result from GAM analyses. In species marked (wt) the GAM was calculated without air temperature as a covariate.

PELAGIC FEEDERS	smew	Wintering	1009	1.0488	0.0035		moderate increase
	red-necked grebe	Wintering	319	0.9974	0.0058		no trend
	Slavonian grebe	Wintering	250	1.0626	0.0089		uncertain
	red-throated diver	Wintering	420	0.9794	0.0087		moderate decrease
	black-throated diver	Wintering	367	0.9919	0.0053		no trend
	goosander	Breeding	4751	0.9949	0.002	<0.05	moderate decrease
	goosander	Wintering	1927	0.9873	0.0014		moderate decrease
	red-breasted merganser	Breeding	4632	0.9927	0.0015	<0.01	moderate decrease
	red-breasted merganser	Wintering	1121	0.9886	0.0016		moderate decrease
	great crested grebe	Breeding	994	1.0735	0.0058	<0.01	strong increase
	great crested grebe	Wintering	859	1.0424	0.0029		moderate increase
	great cormorant	Breeding	747	1.0049	0.0026		stable
	great cormorant	Wintering	1304	1.0149	0.0021		moderate increase
	razorbill	Breeding	471	1.032	0.0128	<0.05	moderate increase
	common guillemot	Breeding	57	1.0401	0.0011	<0.01	moderate increase
	black guillemot	Breeding	1520	1.0031	0.0014	<0.05	moderate increase
BENTHIC FEEDERS	common pochard	Wintering	576	0.9524	0.0023		moderate decrease
	tufted duck	Breeding	4560	0.9891	0.0027	<0.01	moderate decrease
	tufted duck	Wintering	1352	0.9841	0.0019		moderate decrease
	greater scaup	Breeding	249	0.9724	0.0171		uncertain
	greater scaup	Wintering	734	0.982	0.0027		moderate decrease
	common eider	Breeding	4980	0.932	0.0014	<0.01	strong decrease
	common eider	Wintering	796	0.9638	0.0019		moderate decrease
	Steller's eider	Wintering	98	0.8909	0.0107		steep decrease
	long-tailed duck	Wintering	1090	0.9877	0.0023		uncertain
	common scoter	Wintering	499	1.0575	0.0054		moderate increase
	velvet scoter	Breeding	2615	0.9699	0.0022	<0.01	moderate decrease
	velvet scoter	Wintering	553	1.0224	0.0024		moderate increase
	common goldeneye	Wintering	1922	1.0026	0.0012		uncertain
WADING FEEDERS	common shelduck	Breeding	532	0.9981	0.0021		stable
	Eurasian oystercatcher	Breeding	3870	1.0063	0.0014	<0.01	moderate increase
	pied avocet	Breeding	444	0.9847	0.0025	<0.01	moderate decrease
	ringed plover	Breeding	1156	0.9986	0.0016		stable
	turnstone	Breeding	2205	0.9541	0.0016	<0.01	moderate decrease
	dunlin	Breeding	127	0.8941	0.0077	<0.01	strong decrease
	Eurasian teal	Wintering	468	1.0226	0.0078		uncertain
GRAZING FEEDERS	mute swan	Breeding	4187	1.0151	0.001	<0.01	moderate increase
	mute swan	Wintering	1960	0.9896	0.001		moderate decrease
	barnacle goose	Breeding	1310	1.1127	0.0079	<0.01	strong increase
	greylag goose	Breeding	2732	1.0166	0.002	<0.01	moderate increase
	whooper swan	Wintering	1115	1.0021	0.0021		stable
	Bewick's swan	Wintering	111	0.9906	0.0169		stable
	Eurasian wigeon	Wintering	512	1.0201	0.0033		moderate increase
	mallard	Wintering	1793	0.9933	0.0011		moderate decrease
	northern pintail	Wintering	249	1.0045	0.0079		stable
	Eurasian coot	Wintering	805	0.9582	0.0015		moderate decrease

Surface feeders

Breeding

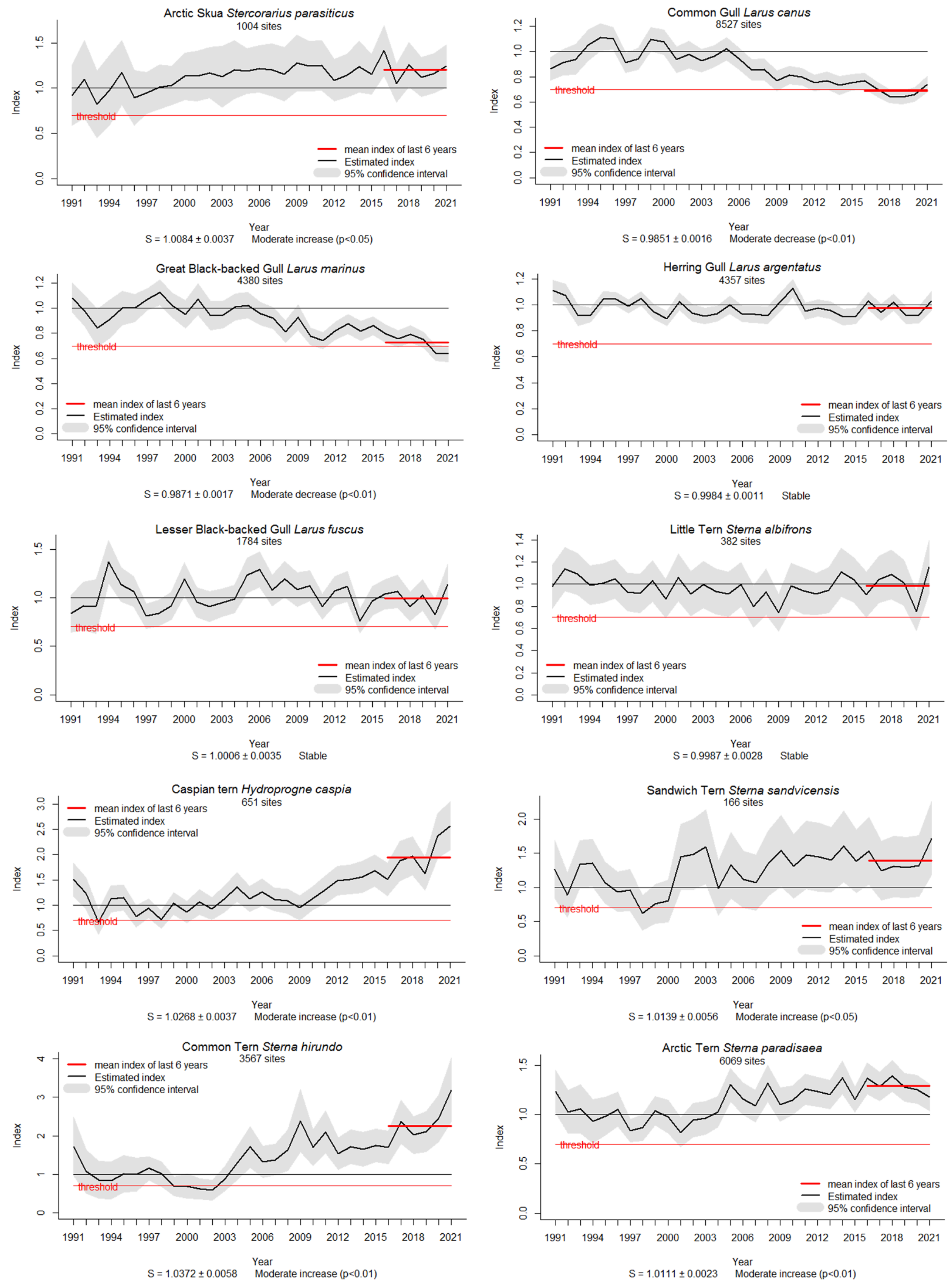
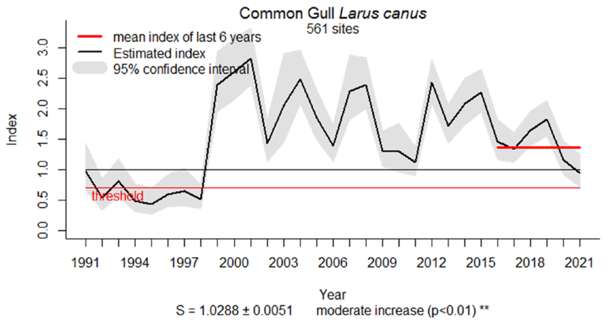
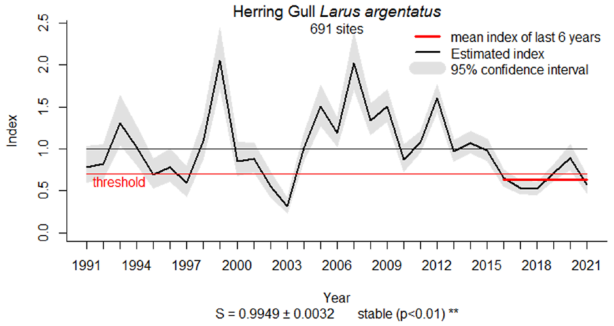


Figure 6.12. Index graphs showing annual index values for breeding and wintering waterbirds in the entire Baltic (black line) and 95% confidence intervals (grey shading). The threshold value indicated in the graphs refers to the threshold value for the abundance indicators for breeding and wintering birds respectively. For breeding waterbirds the trends result from TRIM analyses after rescaling the annual indices to reference level where average of index values 1991–2000 is 1 (thin black line). Further, the threshold values for good status are shown (70% of baseline, 80% of baseline in species laying only one egg per year, thin red line) and the average index values 2016–2021 (geometric mean) used for the evaluation (red line). In addition, trend slopes and s.e. as well as the status of the species are given below the graphs.

Surface feeders

Wintering





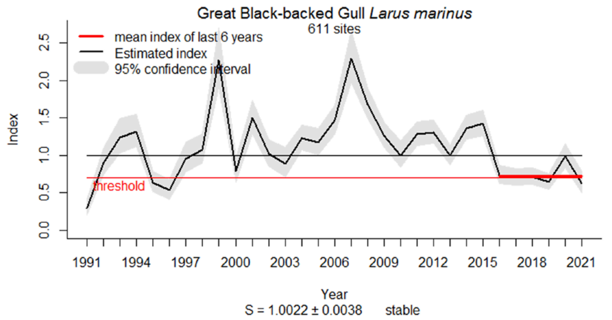


Figure 6.12. (Continued). Index graphs showing annual index values for breeding and wintering waterbirds in the entire Baltic (black line) and 95% confidence intervals (grey shading). The threshold value indicated in the graphs refers to the threshold value for the abundance indicators for breeding and wintering birds respectively. For breeding waterbirds the trends result from TRIM analyses after rescaling the annual indices to reference level where average of index values 1991–2000 is 1 (thin black line). Further, the threshold values for good status are shown (70% of baseline, 80% of baseline in species laying only one egg per year, thin red line) and the average index values 2016–2021 (geometric mean) used for the evaluation (red line). In addition, trend slopes and s.e. as well as the status of the species are given below the graphs. For wintering waterbirds the trends result from GAM analyses with reference level where average of index values 1991–2000 is 1 (thin black line). Further, the threshold values for good status are shown (70% of baseline, 80% of baseline in species laying only one egg per year, thin red line) and the average index values 2016–2021 (geometric mean) used for the evaluation (red line). In addition, trend slopes and s.e. as well as the status of the species are given below the graphs. Models for Slavonian grebe, red-throated diver, black-throated diver, common pochard, greater scaup, common scoter, Bewick's swan and Eurasian coot do not include temperature as a covariate. (Source: HELCOM 2023i, HELCOM 2023j).

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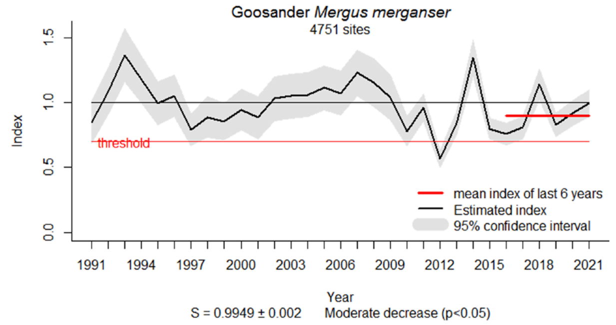
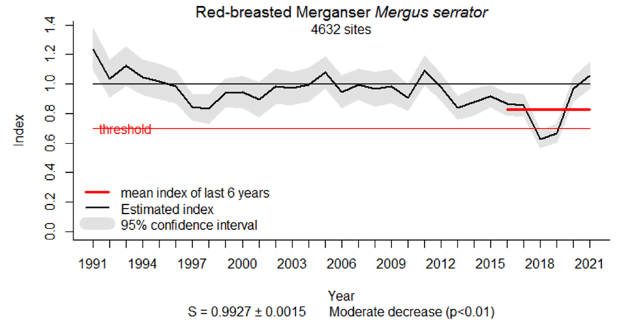
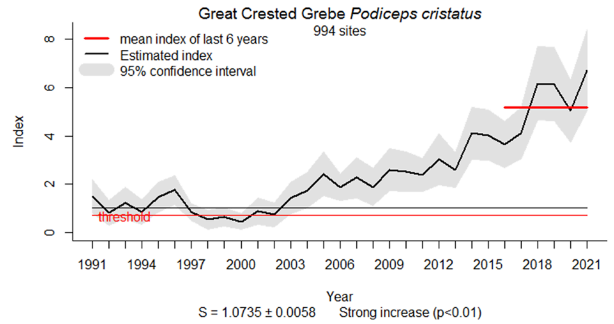
Biodiversity
6. Waterbirds

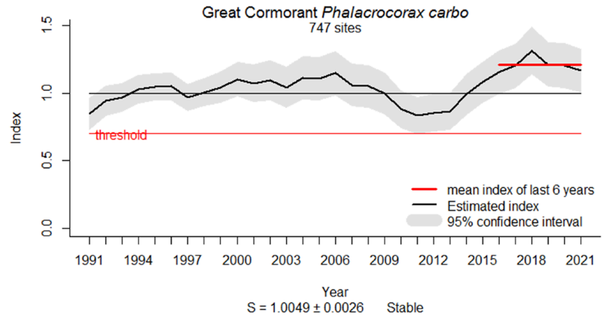
Pelagic feeders

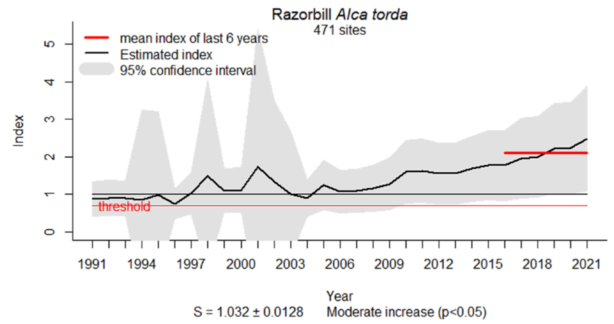
Breeding

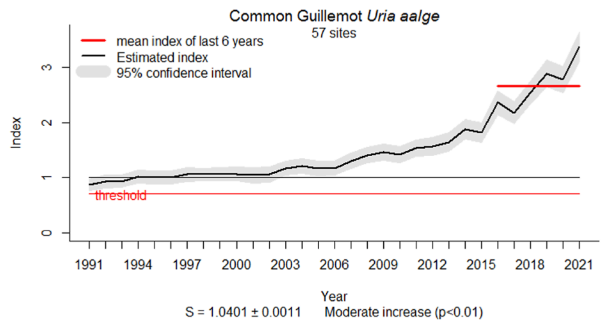












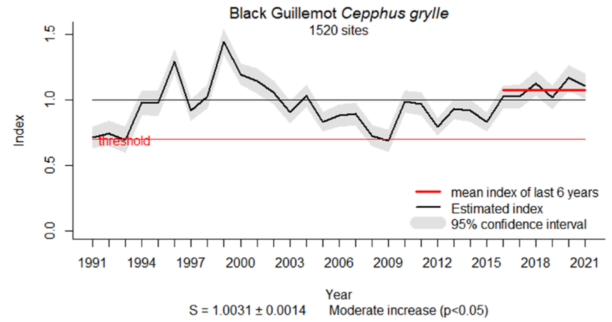


Figure 6.12. (Continued). Index graphs showing annual index values for breeding and wintering waterbirds in the entire Baltic (black line) and 95% confidence intervals (grey shading). The threshold value indicated in the graphs refers to the threshold value for the abundance indicators for breeding and wintering birds respectively. For breeding waterbirds the trends result from TRIM analyses after rescaling the annual indices to reference level where average of index values 1991–2000 is 1 (thin black line). Further, the threshold values for good status are shown (70% of baseline, 80% of baseline in species laying only one egg per year, thin red line) and the average index values 2016–2021 (geometric mean) used for the evaluation (red line). In addition, trend slopes and s.e. as well as the status of the species are given below the graphs. For wintering waterbirds the trends result from GAM analyses with reference level where average of index values 1991–2000 is 1 (thin black line). Further, the threshold values for good status are shown (70% of baseline, 80% of baseline in species laying only one egg per year, thin red line) and the average index values 2016–2021 (geometric mean) used for the evaluation (red line). In addition, trend slopes and s.e. as well as the status of the species are given below the graphs. Models for Slavonian grebe, red-throated diver, black-throated diver, common pochard, greater scaup, common scoter, Bewick's swan and Eurasian coot do not include temperature as a covariate. (Source: HELCOM 2023i, HELCOM 2023j).

Pelagic feeders
Wintering

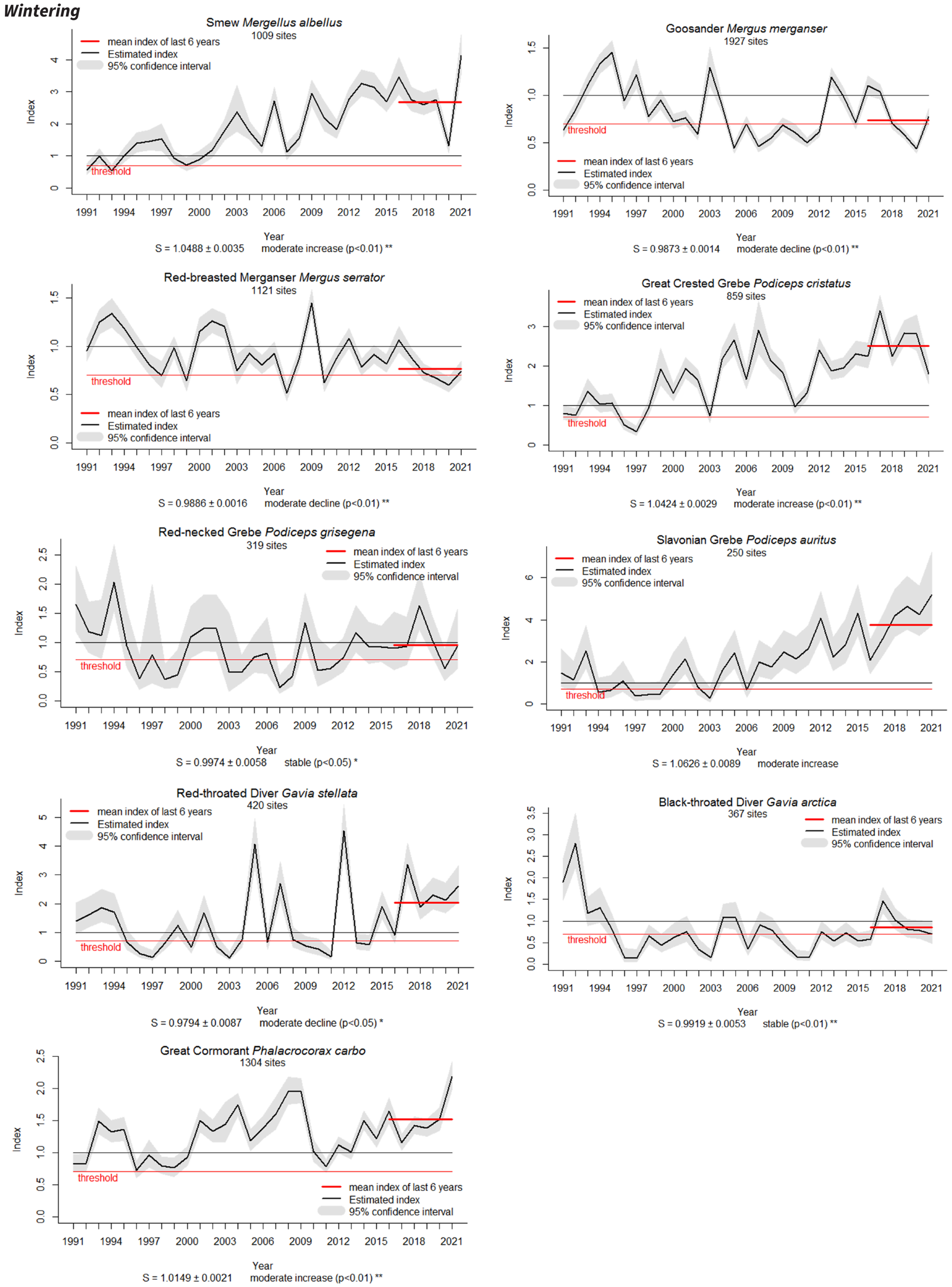


Figure 6.12. (Continued). Index graphs showing annual index values for breeding and wintering waterbirds in the entire Baltic (black line) and 95% confidence intervals (grey shading). The threshold value indicated in the graphs refers to the threshold value for the abundance indicators for breeding and wintering birds respectively. For breeding waterbirds the trends result from TRIM analyses after rescaling the annual indices to reference level where average of index values 1991–2000 is 1 (thin black line). Further, the threshold values for good status are shown (70% of baseline, 80% of baseline in species laying only one egg per year, thin red line) and the average index values 2016–2021 (geometric mean) used for the evaluation (red line). In addition, trend slopes and s.e. as well as the status of the species are given below the graphs. For wintering waterbirds the trends result from GAM analyses with reference level where average of index values 1991–2000 is 1 (thin black line). Further, the threshold values for good status are shown (70% of baseline, 80% of baseline in species laying only one egg per year, thin red line) and the average index values 2016–2021 (geometric mean) used for the evaluation (red line). In addition, trend slopes and s.e. as well as the status of the species are given below the graphs. Models for Slavonian grebe, red-throated diver, black-throated diver, common pochard, greater scaup, common scoter, Bewick's swan and Eurasian coot do not include temperature as a covariate. (Source: HELCOM 2023i, HELCOM 2023j).

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Biodiversity
6. Waterbirds

Benthic feeders
Breeding

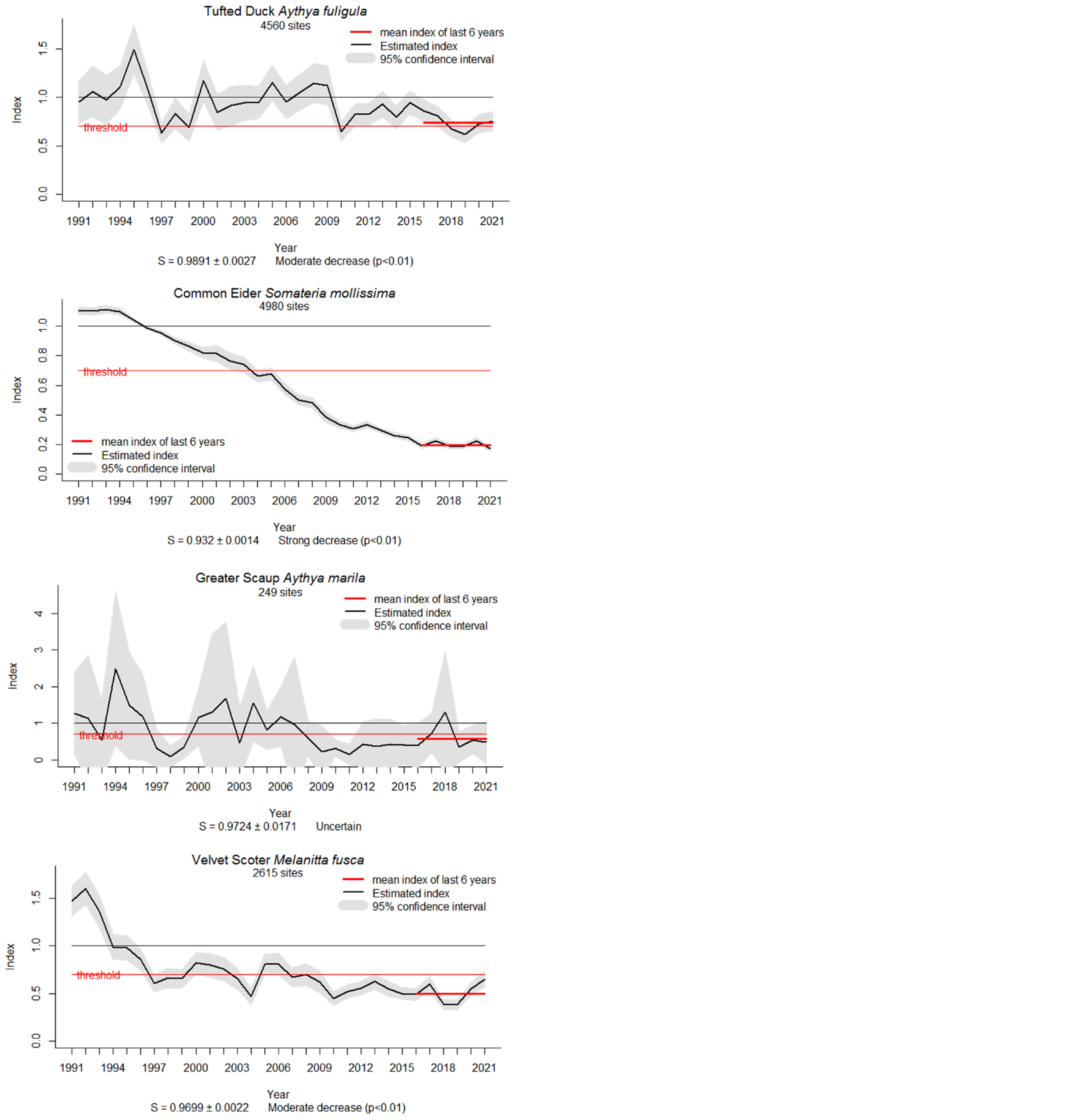


Figure 6.12. (Continued). Index graphs showing annual index values for breeding and wintering waterbirds in the entire Baltic (black line) and 95% confidence intervals (grey shading). The threshold value indicated in the graphs refers to the threshold value for the abundance indicators for breeding and wintering birds respectively. For breeding waterbirds the trends result from TRIM analyses after rescaling the annual indices to reference level where average of index values 1991–2000 is 1 (thin black line). Further, the threshold values for good status are shown (70% of baseline, 80% of baseline in species laying only one egg per year, thin red line) and the average index values 2016–2021 (geometric mean) used for the evaluation (red line). In addition, trend slopes and s.e. as well as the status of the species are given below the graphs. For wintering waterbirds the trends result from GAM analyses with reference level where average of index values 1991–2000 is 1 (thin black line). Further, the threshold values for good status are shown (70% of baseline, 80% of baseline in species laying only one egg per year, thin red line) and the average index values 2016–2021 (geometric mean) used for the evaluation (red line). In addition, trend slopes and s.e. as well as the status of the species are given below the graphs. Models for Slavonian grebe, red-throated diver, black-throated diver, common pochard, greater scaup, common scoter, Bewick's swan and Eurasian coot do not include temperature as a covariate. (Source: HELCOM 2023i, HELCOM 2023j).

Benthic feeders
Wintering

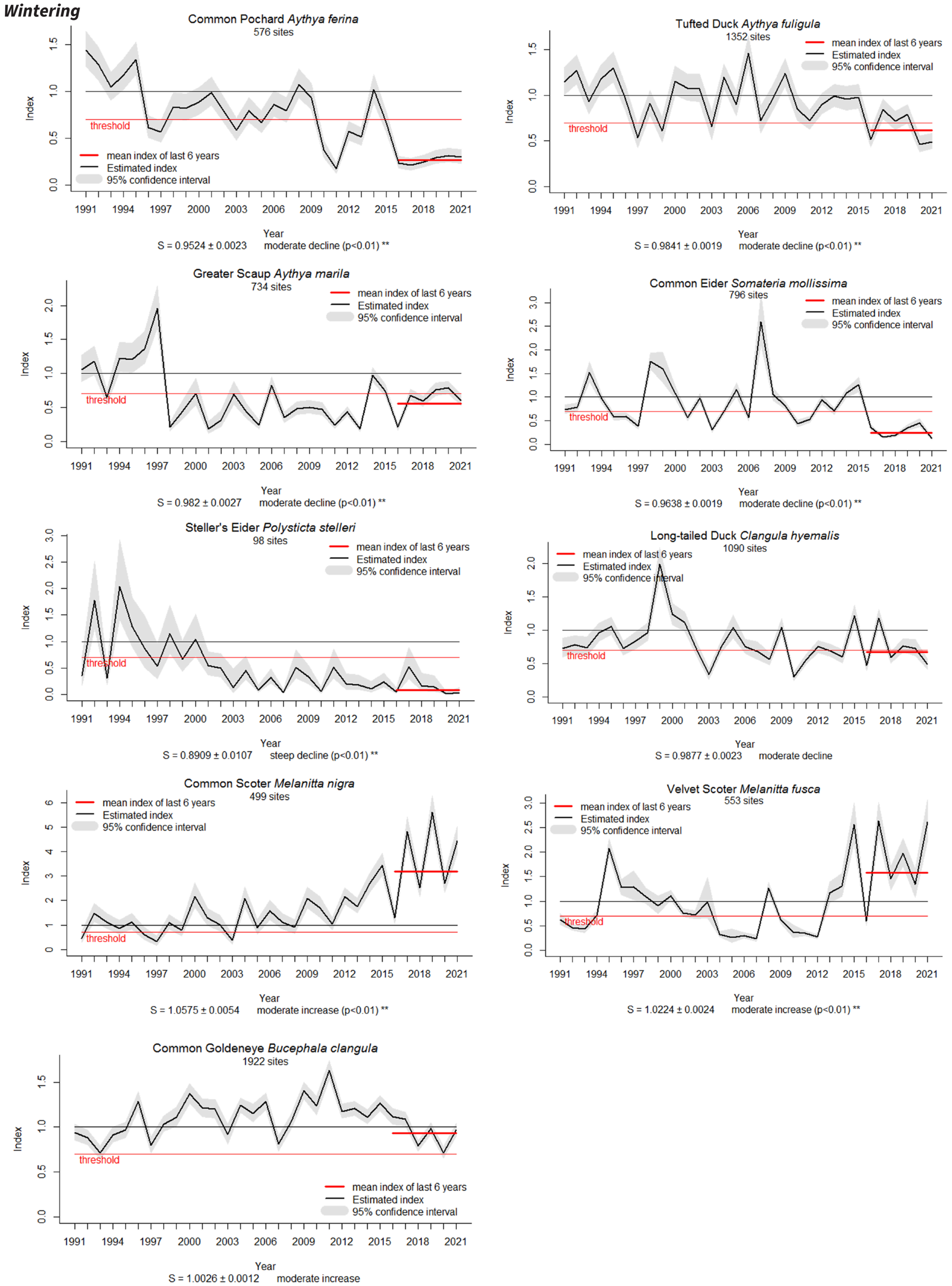
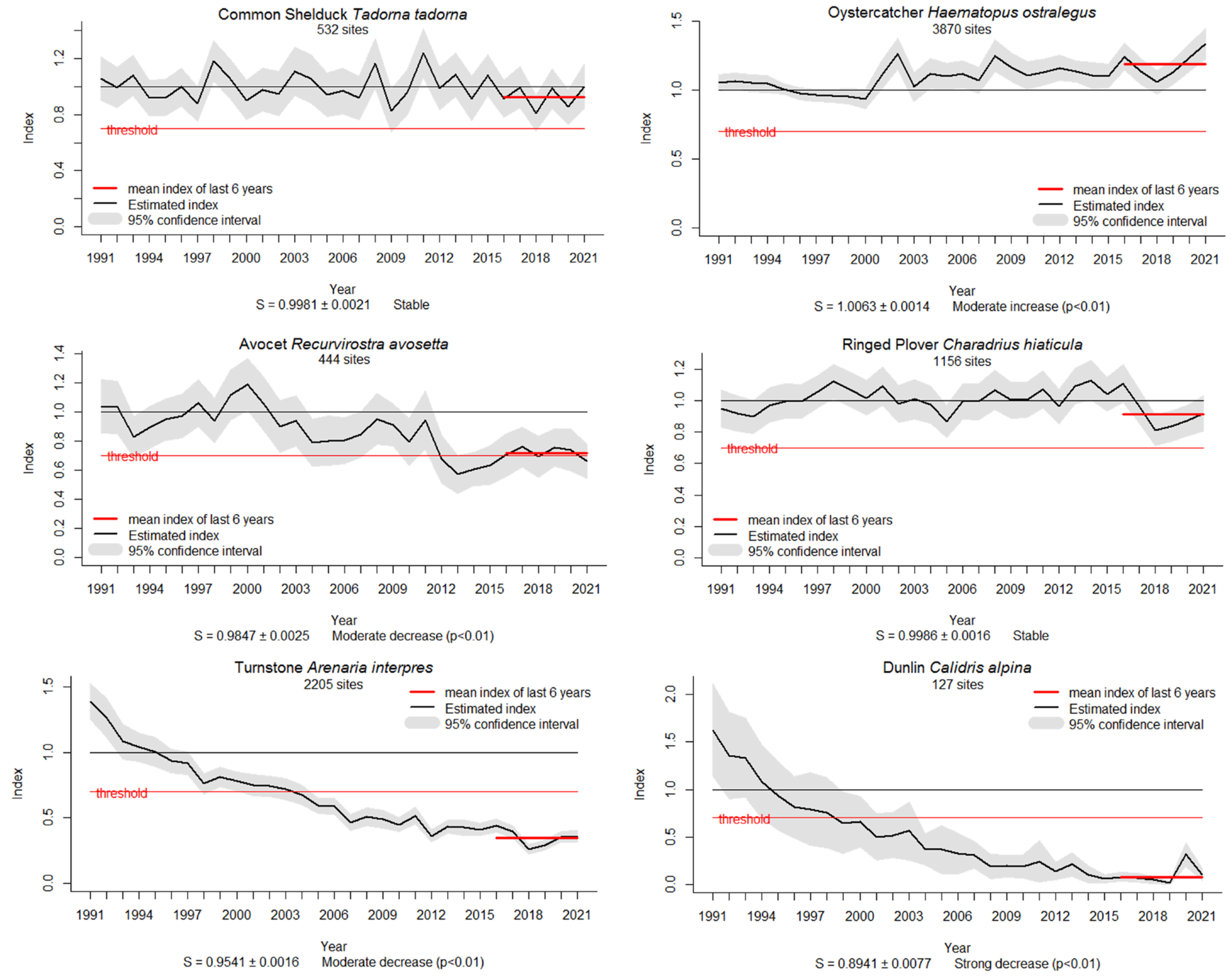


Figure 6.12. (Continued). Index graphs showing annual index values for breeding and wintering waterbirds in the entire Baltic (black line) and 95% confidence intervals (grey shading). The threshold value indicated in the graphs refers to the threshold value for the abundance indicators for breeding and wintering birds respectively. For breeding waterbirds the trends result from TRIM analyses after rescaling the annual indices to reference level where average of index values 1991–2000 is 1 (thin black line). Further, the threshold values for good status are shown (70% of baseline, 80% of baseline in species laying only one egg per year, thin red line) and the average index values 2016–2021 (geometric mean) used for the evaluation (red line). In addition, trend slopes and s.e. as well as the status of the species are given below the graphs. For wintering waterbirds the trends result from GAM analyses with reference level where average of index values 1991–2000 is 1 (thin black line). Further, the threshold values for good status are shown (70% of baseline, 80% of baseline in species laying only one egg per year, thin red line) and the average index values 2016–2021 (geometric mean) used for the evaluation (red line). In addition, trend slopes and s.e. as well as the status of the species are given below the graphs. Models for Slavonian grebe, red-throated diver, black-throated diver, common pochard, greater scaup, common scoter, Bewick's swan and Eurasian coot do not include temperature as a covariate. (Source: HELCOM 2023i, HELCOM 2023j).

Wading feeders
Breeding



Wintering

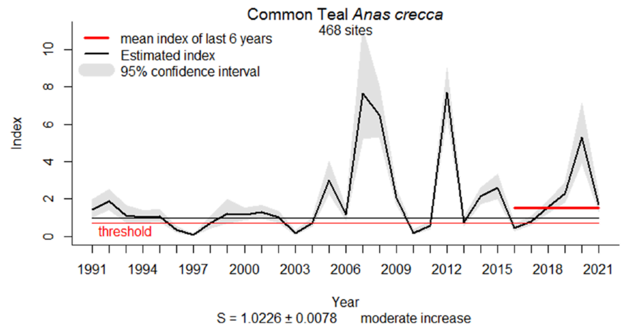


Figure 6.12. (Continued). Index graphs showing annual index values for breeding and wintering waterbirds in the entire Baltic (black line) and 95% confidence intervals (grey shading). The threshold value indicated in the graphs refers to the threshold value for the abundance indicators for breeding and wintering birds respectively. For breeding waterbirds the trends result from TRIM analyses after rescaling the annual indices to reference level where average of index values 1991–2000 is 1 (thin black line). Further, the threshold values for good status are shown (70% of baseline, 80% of baseline in species laying only one egg per year, thin red line) and the average index values 2016–2021 (geometric mean) used for the evaluation (red line). In addition, trend slopes and s.e. as well as the status of the species are given below the graphs. For wintering waterbirds the trends result from GAM analyses with reference level where average of index values 1991–2000 is 1 (thin black line). Further, the threshold values for good status are shown (70% of baseline, 80% of baseline in species laying only one egg per year, thin red line) and the average index values 2016–2021 (geometric mean) used for the evaluation (red line). In addition, trend slopes and s.e. as well as the status of the species are given below the graphs. Models for Slavonian grebe, red-throated diver, black-throated diver, common pochard, greater scaup, common scoter, Bewick's swan and Eurasian coot do not include temperature as a covariate. (Source: HELCOM 2023i, HELCOM 2023j).

Grazing feeders
Breeding

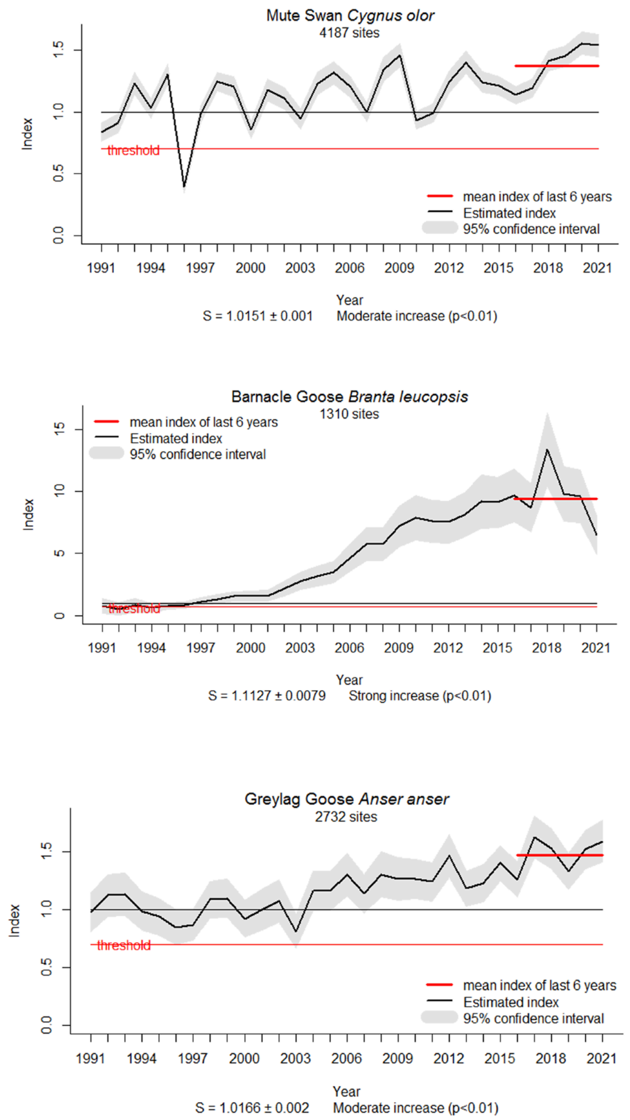
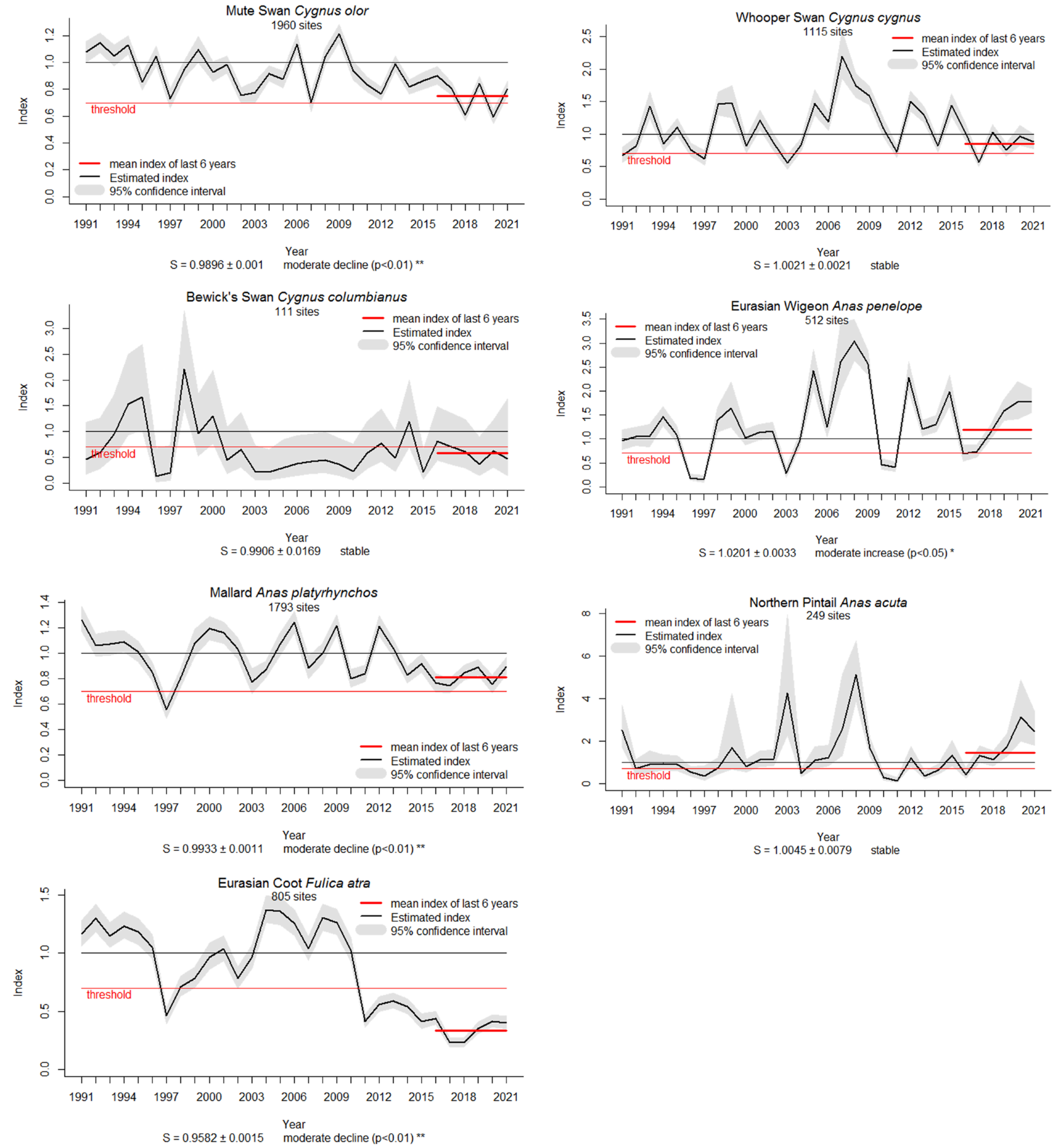


Figure 6.12. (Continued). Index graphs showing annual index values for breeding and wintering waterbirds in the entire Baltic (black line) and 95% confidence intervals (grey shading). The threshold value indicated in the graphs refers to the threshold value for the abundance indicators for breeding and wintering birds respectively. For breeding waterbirds the trends result from TRIM analyses after rescaling the annual indices to reference level where average of index values 1991–2000 is 1 (thin black line). Further, the threshold values for good status are shown (70% of baseline, 80% of baseline in species laying only one egg per year, thin red line) and the average index values 2016–2021 (geometric mean) used for the evaluation (red line). In addition, trend slopes and s.e. as well as the status of the species are given below the graphs. For wintering waterbirds the trends result from GAM analyses with reference level where average of index values 1991–2000 is 1 (thin black line). Further, the threshold values for good status are shown (70% of baseline, 80% of baseline in species laying only one egg per year, thin red line) and the average index values 2016–2021 (geometric mean) used for the evaluation (red line). In addition, trend slopes and s.e. as well as the status of the species are given below the graphs. Models for Slavonian grebe, red-throated diver, black-throated diver, common pochard, greater scaup, common scoter, Bewick's swan and Eurasian coot do not include temperature as a covariate. (Source: HELCOM 2023i, HELCOM 2023j).

Grazing feeders
Wintering



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6.4. Relationship of waterbirds to drivers and pressures

6.4.1 Human activities and associated pressures

The abundance of breeding waterbirds in the Baltic Sea is strongly influenced by a variety of human activities, both directly and indirectly. An overview of pressures on breeding waterbirds can be found in HELCOM (2013c) but can be summarized as relating to bycatch and habitat destruction and/or deterioration.

In relation to bycatch, while the estimates of the number of birds incidentally caught in fisheries are uncertain, studies have shown that set net (gillnet) fishery causes the death of up to 100,000-200,000 birds annually in the Baltic Sea and North Sea combined (Žydelis *et al.* 2009). The fine monofilament nets are nearly invisible to birds and thus they become entangled while diving for food and subsequently drown. The bycatch problem is of special relevance where gillnet fishery is practised in areas with high concentrations of resting, moulting or wintering seabirds. In the Baltic Sea, gillnet fisheries are mainly operated in shallow coastal areas or on shallow offshore grounds - areas that are also the most important habitats for birds. The overlap of gillnet fishing and high concentrations of birds usually occurs only during certain periods of the year (e.g. wintering, autumn and spring migration or moulting time (Zydelis *et al.* 2009, Sonntag *et al.* 2012). Studies show that both piscivorous birds (divers, grebes, mergansers, auks, cormorants) and benthophagic ducks are susceptible to entanglement and drowning in fishing gear (for more information on waterbirds and bycatch please see Chapter 9).

With regards to destruction of breeding habitats and resting or wintering sites which impact on bird populations, draining of coastal meadows, overgrowth of open areas, agricultural intensification and/or changes in arable land, as well as mining and quarrying/sediment extraction are all important contributors, which can also reduce the carrying capacity of certain wintering sites. Avoidance of offshore wind farms has been observed to affect the spatial distribution of divers and long-tailed ducks (Petersen *et al.* 2011; Dierschke *et al.* 2016) (see Figure 6.13 for an overview of current wind power installations in the Baltic Sea). These species, as well as other seaducks, also avoid shipping lanes (Bellebaum *et al.* 2006; Schwemmer *et al.* 2011, Fliessbach *et al.* 2019). For benthic feeders, additional habitat loss is caused by physical damage of the seafloor caused by both fisheries (see Figure 4.12 in chapter 4 for an overview of the spatial distribution and intensity of fishing with bottom touching gear in the Baltic Sea 2016-2021) and aggregate extraction (Cook & Burton 2010).

Figure 6.13. Operational windfarms in the Baltic Sea a of 2021. Information on planned wind farms has been provided only by Finland and is included in blue in the figure.

In the case of waterbirds, where the majority of species in the Baltic Sea are migratory, it is important to note that extra-regional threats can have a significant impact on the status of the populations. These are often associated with habitat deterioration as feeding and resting habitats during migration and wintering periods are of great importance for the status of the population. The food supply is influenced by manipulating fish communities by fishing and the input of nutrients. Losses of habitat quality and of feeding opportunities in some wintering areas and in the traditional staging areas are suggested as the reason for slow recovery for the affected species, e.g. the over-harvesting of mussels and cockles in the Dutch Wadden Sea has been shown to have a strong impact on the distribution of common eider (Piersma & Camphuysen 2001, Reneerkens *et al.* 2005) and may also lead to the degradation of feeding opportunities for other benthos-feeding ducks.

In general, waterbirds strongly respond to food availability. Therefore, human activities influencing the food supply of waterbirds are reflected in bird numbers. For fish-eating birds, direct human pressure is posed by the extraction of fish if birds and fishers target the same species and size classes (see Figure in Box 5.1 for an overview of intensity of extraction of herring (*Clupea harengus*), cod and sprat (*Sprattus sprattus*) during the assessment period 2016-2021). On the other hand, overfishing of large predatory fish species increases the abundance of smaller species and thereby improves the food supply for some birds. Indirect effects can also occur via human induced eutrophication affecting the foodweb structure and function. In the oligotrophic end of the eutrophication status, the bird populations are limited by the availability of food sources, whereas towards eutrophic conditions plant and zoobenthos biomass increases, which first benefits waterbird populations, but in the extreme end will cause a decrease in food availability.

In addition, high numbers of seaducks are hunted, with large bags in particular for common eider and goldeneye (*Bucephala clangula*) (Mooij 2005, Skov *et al.* 2011, Lehikoinen *et al.* 2022) as well as for common long tailed duck and common scooter (*Melanitta nigra*). See Figure 6.14 for an overview of intensity of hunting of seabirds in the Baltic Sea and tables 6.11 and 6.12 for more detailed information on hunting of waterbirds during the assessment period 2016-2021.

The number of oil spills has decreased, oil is still released into the Baltic environment (HELCOM 2023af), and such pollution can cause oiled plumage, hypothermia and finally death in waterbirds (Larsson & Tydén 2005; Žydelis *et al.* 2006). Negative impacts on body condition are also obtained year-round from the accumulation of contaminants ingested via the foodweb (Broman *et al.* 1990; Rubarth *et al.* 2011; Pilarczyk *et al.* 2012).

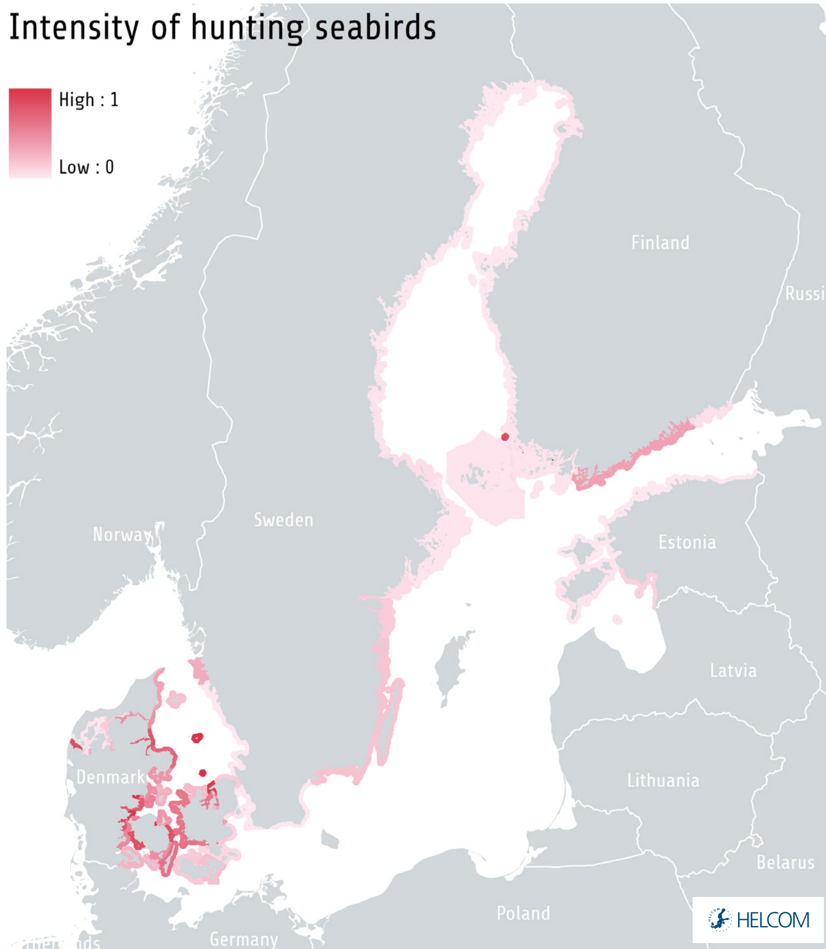

Figure 6.14. Spatial distribution and intensity of hunting of waterbirds in the Baltic Sea during the assessment period 2016–2021. Total numbers include both hunting for game and hunting for the purpouses of pest control.

Tabel 6.11. Hunting bags of eider, long tailed duck, common- and velvet scooter for the assessment period 2016–2021.

Country	Area	Eider						Long tailed duck						Common scooter						Velvet Scooter					
		2016	2017	2018	2019	2020	2021	2016	2017	2018	2019	2020	2021	2016	2017	2018	2019	2020	2021	2016	2017	2018	2019	2020	2021
Denmark	Struer	50	0	17	3	15	8	4	0	0	0	0	0	38	0	12	7	46	6	9	0	1	0	0	0
Denmark	Lemvig	376	515	489	425	751	599	90	49	26	23	0	0	149	213	213	202	288	77	37	58	53	44	0	0
Denmark	Syddjurs	766	589	640	722	750	582	3	2	2	0	0	0	172	214	157	180	228	68	201	325	165	264	0	0
Denmark	Randers	438	437	102	325	209	145	88	9	5	6	0	0	331	194	155	130	100	34	246	170	83	228	0	0
Denmark	Norddjurs	717	848	768	641	789	534	26	34	13	6	0	0	538	812	688	592	643	585	465	479	478	466	0	0
Denmark	Brøndby	1	0	0	2	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Denmark	Solrød	1	1	0	1	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Denmark	Roskilde	16	59	44	14	6	9	1	3	0	1	0	0	0	45	2	12	5	2	2	42	1	0	0	0
Denmark	Lejre	106	23	75	28	19	8	4	0	2	0	0	0	10	3	16	8	9	0	3	0	5	1	0	0
Denmark	Greve	6	31	6	0	0	0	6	0	0	0	0	0	0	13	0	0	0	0	0	0	0	0	0	0
Denmark	Gribskov	45	68	127	79	49	15	0	0	0	1	0	0	3	2	18	4	25	0	2	0	1	2	0	0
Denmark	Faxe	26	19	8	15	28	2	17	15	17	12	0	0	12	4	13	22	19	0	6	5	7	21	0	0
Denmark	Køge	59	30	23	43	67	29	42	31	2	14	0	0	3	12	2	6	1	0	6	0	0	1	0	0
Denmark	Hørsholm	0	0	0	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Denmark	Hillerød	30	3	24	44	8	0	9	0	0	0	0	0	10	0	1	21	3	0	10	0	5	24	0	0
Denmark	Egedal	3	2	2	0	1	0	0	0	0	0	0	0	4	3	0	0	1	0	3	4	0	0	0	0
Denmark	Kalundborg	1553	1072	1038	2061	1691	1427	26	31	64	52	0	0	640	796	815	536	585	460	204	588	667	370	0	0
Denmark	Holbæk	125	135	376	157	520	193	13	25	9	47	0	0	14	99	98	22	104	7	6	58	88	22	0	0
Denmark	Sønderborg	536	703	564	345	503	381	94	21	81	28	0	0	108	93	140	39	69	83	64	8	25	2	0	0
Denmark	Kolding	595	281	390	355	624	216	10	9	1	0	0	0	78	16	26	6	24	15	32	2	4	1	0	0
Denmark	Haderslev	561	414	564	300	522	929	25	18	7	2	0	0	90	71	34	5	20	12	7	15	3	5	0	0
Denmark	Stevns	44	38	4	21	19	2	69	70	57	55	0	0	8	5	9	10	12	0	7	0	9	8	0	0
Denmark	Guldborgsund	302	156	212	231	350	368	150	180	110	79	0	0	65	111	104	109	33	103	54	34	17	59	0	0
Denmark	Odder	688	414	560	323	447	505	9	1	6	1	0	0	91	53	53	42	63	85	23	23	39	68	0	0
Denmark	Hedensted	582	694	775	859	1165	963	15	7	5	8	0	0	99	108	241	229	418	102	50	62	108	219	0	0
Denmark	Vejle	162	113	128	172	246	49	4	3	3	7	0	0	63	63	68	47	78	6	24	8	16	71	0	0
Denmark	Horsens	660	429	377	479	581	473	9	48	6	26	0	0	117	75	28	129	74	7	24	54	4	46	0	0

Tabel 6.11. (continued) Hunting bags of eider, long tailed duck, common- and velvet scooter for the assessment period 2016–2021.

Country	Area	Eider						Long tailed duck						Common scooter						Velvet Scooter					
		2016	2017	2018	2019	2020	2021	2016	2017	2018	2019	2020	2021	2016	2017	2018	2019	2020	2021	2016	2017	2018	2019	2020	2021
Denmark	Frederikshavn	592	782	858	539	466	286	45	13	6	0	0	0	153	84	170	87	68	53	19	12	24	15	0	0
Denmark	Viborg	31	32	37	30	13	2	0	0	0	0	0	0	14	17	32	17	27	0	5	3	28	19	0	0
Denmark	Skive	8	19	9	16	59	0	1	3	0	0	0	0	9	22	11	23	23	1	2	1	0	18	0	0
Denmark	Morsø	39	9	22	16	8	0	5	2	0	0	0	0	23	8	1	4	2	1	0	2	0	0	0	0
Denmark	Odsherred	158	218	255	263	405	184	15	36	7	10	0	0	27	325	53	99	64	34	61	277	105	135	0	0
Denmark	Næstved	191	151	319	287	205	107	13	14	16	84	0	0	22	36	243	102	58	17	12	15	51	99	0	0
Denmark	Lolland	386	398	390	579	451	170	20	38	22	25	0	0	96	50	38	51	37	6	54	19	50	80	0	0
Denmark	Frederiksberg	0	0	0	0	2	0	0	0	0	0	0	0	0	3	0	0	0	0	0	1	0	0	0	0
Denmark	Mariagerfjord	301	296	298	271	189	168	24	9	5	2	0	0	782	506	396	362	185	123	509	210	182	251	0	0
Denmark	Tårnby	0	4	0	1	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
Denmark	Dragør	11	4	12	8	12	3	0	11	0	4	0	0	0	0	1	0	0	0	0	1	0	0	0	0
Denmark	Helsingør	33	67	79	80	68	53	0	0	0	0	0	0	1	0	6	2	1	1	0	0	0	2	0	0
Denmark	Aalborg	260	411	468	437	192	224	1	7	7	24	0	0	319	364	442	166	143	185	117	96	186	65	0	0
Denmark	Læsø	278	348	350	225	107	160	0	0	1	0	0	0	33	101	98	65	18	6	22	56	28	29	0	0
Denmark	Jammerbugt	22	0	7	27	8	2	1	0	0	0	0	0	18	4	4	9	2	0	0	0	1	0	0	0
Denmark	Assens	1320	1584	943	1301	1370	1061	89	62	29	63	0	0	307	452	511	212	366	99	71	119	39	86	0	0
Denmark	Vordingborg	86	183	113	140	141	96	32	138	43	31	0	0	15	47	47	43	12	21	10	57	28	18	0	0
Denmark	Hvidovre	15	14	1	8	0	0	0	9	2	3	0	0	0	0	0	0	0	0	0	2	0	0	0	0
Denmark	Frederikssund	405	411	428	365	508	503	16	4	2	7	0	0	44	90	66	42	61	92	55	21	27	45	0	0
Denmark	Vesthimmerland	40	98	27	24	41	0	4	10	0	0	0	0	61	61	114	35	70	0	24	89	25	33	0	0
Denmark	Holstebro	42	45	24	8	11	4	2	0	6	1	0	0	30	19	4	2	2	0	0	3	3	1	0	0
Denmark	Rebild	11	26	27	23	11	0	0	0	2	0	0	0	24	16	32	0	37	0	6	11	9	22	0	0
Denmark	Rødovre	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Denmark	Gladsaxe	0	0	0	1	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Denmark	Ærø	480	410	382	214	103	87	53	38	25	18	0	0	23	24	20	5	6	5	3	22	10	0	0	0
Denmark	Svendborg	664	483	757	583	783	453	25	8	33	9	0	0	98	51	64	32	29	32	29	57	37	26	0	0
Denmark	Odense	233	363	195	196	85	27	1	8	0	0	0	0	19	24	16	10	11	0	17	13	3	1	0	0

Tabel 6.11. (continued) Hunting bags of eider, long tailed duck, common– and velvet scooter for the assessment period 2016–2021.

Country	Area	Eider						Long tailed duck						Common scooter						Velvet Scooter					
		2016	2017	2018	2019	2020	2021	2016	2017	2018	2019	2020	2021	2016	2017	2018	2019	2020	2021	2016	2017	2018	2019	2020	2021
Denmark	Vallensbæk	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Denmark	Samsø	537	439	351	357	298	240	2	3	0	1	0	0	167	161	81	82	118	15	91	84	23	63	0	0
Denmark	Thisted	6	13	2	14	14	5	3	3	1	0	0	0	3	9	30	1	4	4	3	5	11	0	0	0
Denmark	Slagelse	994	1233	1567	758	1298	1823	103	56	47	38	0	0	350	348	497	360	296	1008	216	233	179	153	0	0
Denmark	Nyborg	1082	1021	872	722	1176	592	26	17	8	6	0	0	108	77	139	19	48	1	72	87	80	11	0	0
Denmark	Middelfart	607	435	568	579	666	514	9	3	16	25	0	0	50	54	82	68	81	10	8	27	22	43	0	0
Denmark	Langeland	2125	2235	1680	1537	2199	1595	126	107	52	56	0	0	174	183	293	110	63	92	17	65	23	20	0	0
Denmark	Kerteminde	414	314	404	601	682	603	1	0	0	2	0	0	117	81	97	125	285	137	28	25	17	46	0	0
Denmark	Fredericia	715	666	998	985	612	453	0	0	0	33	0	0	17	37	78	68	172	38	12	24	20	21	0	0
Denmark	Halsnæs	830	815	1095	791	696	489	11	10	11	7	0	0	66	226	411	139	192	69	45	170	169	101	0	0
Denmark	Fredensborg	24	0	0	0	3	0	0	0	0	0	0	0	9	0	0	0	2	0	3	0	0	0	0	0
Estonia	Saaremaa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0
Estonia	Pärnumaa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Estonia	Hiiumaa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Estonia	Läänemaa	0	0	0	0	0	0	0	75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Estonia	Ida-Virumaa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0	0	0	0	0
Estonia	Harjumaa	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Estonia	Lääne-Virumaa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Finland	Uusimaa	700	600	600	1700	201	212	14000	5700	2400	1100	568	411	0	0	0	0	0	0	0	0	0	0	0	0
Finland	Varsinais-Suomi	1000	400	700	1500	126	38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Finland	Keski-Pohjanmaa	0	0	0	0	0	0	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Finland	Lappi	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Finland	Pohjois-Pohjanmaa	0	0	0	0	0	0	0	1600	0	0	5	5	0	0	0	0	0	0	0	0	0	0	0	0
Finland	Pohjanmaa	0	0	0	0	0	0	0	100	0	0	11	0	0	0	0	0	0	0	0	0	0	0	0	0
Finland	Satakunta	0	0	0	0	0	6	300	100	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Finland	Kymenlaakso	0	300	0	0	0	1	0	0	100	700	11	7	0	0	0	0	0	0	0	0	0	0	0	0
Sweden	Västernorrland	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

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Tabel 6.11. (continued) Hunting bags of eider, long tailed duck, common– and velvet scooter for the assessment period 2016–2021.

Country	Area	Eider						Long tailed duck						Common scooter						Velvet Scooter					
		2016	2017	2018	2019	2020	2021	2016	2017	2018	2019	2020	2021	2016	2017	2018	2019	2020	2021	2016	2017	2018	2019	2020	2021
Sweden	Norrbottens län	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0
Sweden	Östergötlands län	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sweden	Västerbottens län	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sweden	Skåne	0	0	0	0	0	0	4	0	0	0	0	0	21	0	0	0	0	0	0	0	0	0	0	0
Sweden	Uppsala län	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sweden	Hallands län	21	16	26	13	15	0	0	0	0	0	0	0	0	0	0	4	5	0	0	0	0	0	0	0
Sweden	Blekinge	76	35	20	113	107	0	0	0	0	0	4	0	0	0	0	0	6	0	0	0	0	0	0	0
Sweden	Kalmar	34	16	13	15	12	0	10	3	2	4	4	0	0	0	0	0	0	0	0	0	0	0	0	0
Sweden	Västra Gotlands län	1675	848	767	864	792	0	4	4	0	0	0	0	0	0	17	0	6	0	0	0	0	0	0	0
Sweden	Gotlands län	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sweden	Stockholms län	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sweden	Gävleborgs län	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sweden	Södermanlands län	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total bag per species per year		**24907**	**22816**	**22977**	**23852**	**23506**	**17598**	**15661**	**8851**	**3261**	**2621**	**604**	**424**	**5846**	**6486**	**6987**	**4704**	**5363**	**3712**	**2996**	**3742**	**3159**	**3325**	**0**	**0**
Total bag per species for the assessment period 2016-2021							**135656**						**31422**						**33098**						**13222**

Tabel 6.12. Pest control hunting of cormorants in the Baltic Sea during the assessment period 2016–2021.

Country	Area	2016	2017	2018	2019	2020	2021
Estonia	Saaremaa	273	268	261	248	352	218
Estonia	Pärnumaa	560	460	588	264	274	154
Estonia	Hiiumaa	14	11	35	156	15	17
Estonia	Läänemaa	2	23	4	7	9	24
Estonia	Ida-Virumaa	0	2	0	1	1	7
Estonia	Harjumaa	12	8	11	7	6	27
Estonia	Lääne-Virumaa	2	5	9	1	8	10
Finland	Kustavi, Tiiraleto	0	0	0	53	0	0
Finland	Dragsfjärd	No data	0	0	0	0	0
Finland	Uusikaupunki	1	0	0	0	0	0
Finland	Taivassalo - Turku	0	0	6	No data	0	0
Finland	Uusikaupunki	0	0	0	0	0	0
Finland	Vaasa	0	2	0	0	0	0
Finland	Kustavi	0	0	0	0	16	7
Finland	Hailuoto	0	0	0	0	0	No data
Finland	Vaasa	0	0	0	0	0	30
Finland	Parainen	0	0	0	0	0	116
Finland	Kokkola	0	0	0	0	0	0
Finland	Åland	1006	841	938	1195	2420	1645
Sweden	Västernorrlands län	0	130	60	50	467	0
Sweden	Kronobergs län	0	0	0	0	1	0
Sweden	Örebro län	166	57	160	169	121	0
Sweden	Östergötlands län	638	678	23	468	1624	0
Sweden	Västerbottens län	99	110	40	72	50	0
Sweden	Skåne län	50	52	50	60	50	0
Sweden	Uppsala län	14	41	420	537	333	0
Sweden	Jönköpings län	18	15	19	34	44	0

Tabel 6.12. (continued) Pest control hunting of cormorants in the Baltic Sea during the assessment period 2016–2021.

Country	Area	2016	2017	2018	2019	2020	2021
Sweden	Hallands län	5	5	7	7	14	0
Sweden	Blekinge län	0	0	98	0	1568	0
Sweden	Kalmar län	771	985	1033	5280	3795	0
Sweden	Västra Götalands län	5	13	13	3	0	0
Sweden	Stockholms län	10	103	568	520	1849	0
Sweden	Västmanlands län	44	54	65	62	32	0
Sweden	Gävleborgs län	0	30	30	1	1159	0
Sweden	Södermanlands län	243	90	227	303	174	0
Sweden	Norrbottens län	0	0	0	0	0	0
Sweden	Jämtlands län	0	0	0	0	0	0
Sweden	Värmlands län	0	0	0	0	0	0
Sweden	Dalarnas län	0	0	0	0	0	0
Sweden	Gotlands län	0	0	0	0	0	0
Total bag per year		**3933**	**3983**	**4665**	**9498**	**14382**	**2255**
Total bag 2016-2021		**38716**					

Many of the pressures and activities outlined above, e.g. bird losses from drowning in fishing gear, hunting and plumage oiling as well as habitat loss from offshore wind farming, aggregate extraction and shipping are pressures mostly acting in the non-breeding season. However, for those species which both breed and spend the winter in the Baltic Sea, these anthropogenic pressures affect the numbers of breeding birds. This is done not only by the elimination of birds from the population, but also in terms of carry-over effects by reducing body condition with effects on survival and reproductive success. As their reproduction takes place on land, even waterbirds that live at sea during all other times are prone to predation by non-indigenous mammals such as American mink (*Neovison vison*) and raccoon dog (*Nyctereutes procyonoides)*, which have been introduced by humans and therefore have to be treated as a human pressure. While many breeding colonies are well protected nowadays, some breeding sites are still under pressure from direct human disturbance, for example from tourism and recreational boating. Such activities can also contribute with indirect impacts – they may increase nest and egg predation when waterbirds are on alert in the air or even leave the breeding site temporarily. Habitat loss due to changes in land use and agriculture may also lower breeding success.

6.4.2 Climate change

Global warming has many effects also in the Baltic region (HELCOM/Baltic Earth 2021, Meier *et al.* 2022). In the Baltic Sea, effects on waterbirds are mainly seen in wintering birds, of which many are also part of the breeding populations along the coasts of the Baltic. Part of the population of some species (mainly diving ducks) that formerly wintered further to the southwest now remain in the Baltic (Skov *et al.* 2011, Nilsson & Haas 2016, Pavón-Jordán *et al.* 2019). Consequently, the distance of migration is shorter and therefore less energy demanding (Lehikoinen *et al.* 2006, Gunnarsson *et al.* 2012). Climate change scenarios predict a strong temperature increase in the Arctic and sub-Arctic regions, which will likely increase the northward extension of species ranges, including colonization by new breeding and wintering species, as well as local species decline following redistribution of the population into northern ice-free waters (Pavón-Jordán *et al.* 2019; Fox *et al.* 2019).

Mainly owing to milder spring temperatures and related effects on vegetation and prey, many waterbirds migrate earlier in spring (Rainio *et al.* 2006), and hence arrive earlier in the breeding area (Vähätalo *et al.* 2004), and some also start breeding earlier (van der Jeugd *et al.* 2009). Earlier loss of sea ice was found to improve pre-breeding body condition of female common eiders, leading to increasing fledging success in offspring (Lehikoinen *et al.* 2006). On the other hand, algal blooms promoted by higher seawater temperature has in some cases caused low quality in bivalve prey for common eiders, leading more birds to skip breeding (Larsson *et al.* 2014). Warmer seawater in winter also increases the energy expenditure of mussels, thus directly reducing their quality as prey for eiders (Waldeck & Larsson 2013).

Most Baltic breeding waterbird species are migratory and affected by climate change also outside the Baltic region when wintering in southern Europe and western Africa (Fox *et al.* 2015). This is important, given that climate warming is above average also in southern Europe and northern Africa (Allen *et al.* 2018).

Climate change also affects the prey of Baltic waterbirds. Future scenarios for the Baltic Sea (summarised by Meier *et al.* 2022) include decreasing salinity. Invertebrate species serving as prey for waterbirds (e.g. blue mussels (*Mytilus* spp.) for common eiders) would change distribution, body size and quality, with consequences for the distribution, reproduction and survival of the respective predatory waterbirds (Fox *et al.* 2015).

The consequences for piscivorous seabirds are complex, because effects of climate change are not uniform among Baltic Sea fish species. For example, expected increase of recruitment and abundance in an important prey species (sprat; (MacKenzie *et al.* 2012; Lindegren *et al.* 2012) as well as declining numbers of large predatory fish (cod) may provide support for fish-eating birds, although management efforts to improve cod stocks may counteract the expected increase in sprat and lead to population declines of their main bird predator, the common guillemot (Kadin *et al.* 2019). On the other hand, from the bird's perspective another important prey species (herring) is negatively affected by decreasing salinity (declining energy content; Rajasilta *et al.* 2018).

A rising sea level would reduce the area of saltmarshes available for waders and other waterbirds for breeding and for geese for foraging (Clausen *et al.*, 2013), particularly in the southern Baltic Sea. Other coastal habitats would be affected likewise (Clausen and Clausen, 2014). Coastal breeding habitats may also experience physical loss due to erosion. In combination with storms, sea level rise would also affect the breeding success of coastal waterbirds due to flooding of their breeding sites.

Climate change induced changes in the pattern of occurrence of diseases and parasites can be expected to affect waterbirds in the Baltic (Fox *et al.* 2015).

It is important to note that all the above-mentioned human activities, and their subsequent pressures, have a cumulative impact on waterbird populations, which is not limited to either the breeding or wintering season, but carries over, affecting overall status. The cumulative impact on waterbirds has been reviewed by the example of red-throated diver and black-throated diver (Dierschke *et al.* 2012) and was addressed in the frame of the proposed indicator which assesses waterbird habitat quality with regard to disturbance from activities (Mercker *et al.* 2021).

6.5. Assessment methodological details

6.5.1 Data collection and monitoring

In many European countries, breeding populations of birds have been studied and monitored for a long time. For species breeding in the Baltic Sea region, there are several recent, comprehensive publications of population numbers and trend data that have been used for the assessment. Studying birds at sea is much more challenging. While nearshore areas are covered by the land-based International Midwinter Waterbird Census (IWC), information from the offshore areas is scarce. Only the implementation of ship-based and aerial surveys in the last decades have enabled scientists to describe the distribution and number of birds wintering at sea. However, there are no comprehensive monitoring programmes for birds wintering in the Baltic Sea.

Monitoring of breeding waterbirds

The indicator on breeding waterbirds is primarily based on counts of breeding pairs or nests along the shorelines of the Baltic Sea, i.e. is restricted to coastal landscape (including islands). Many species only breed in nature reserves or other protected sites, which have been monitored using constant methods for decades. In many sites, breeding birds are counted annually, and gaps can be filled by a TRIM analysis.

Monitoring of breeding waterbirds in the Contracting Parties of HELCOM is described on a general level in the HELCOM Monitoring Manual in the sub-programme Marine breeding birds abundance and distribution.

There are some differing characteristics in the countries' monitoring programmes, e.g. the species covered and the temporal scaling. Surveys are in most cases conducted annually, but every three or six years (as an adaptation to Natura 2000 reporting cycles, see European Commission 1992, 2010) or even every ten years (e.g. common eider in Denmark) in some cases.

Monitoring of wintering waterbirds

The data available for the assessment is primarily based on midwinter counts of waterbirds along the shoreline, carried out as national monitoring, i.e. the indicator is mostly restricted to coastal staging areas. Additionally, data from boat surveys in Polish offshore and Finnish Archipelago are included.

Monitoring of wintering waterbirds in the Contracting Parties of HELCOM is described on a general level in the HELCOM Monitoring Manual in the sub-programme Marine wintering birds abundance and distribution.

Guidelines for monitoring methods were originally developed by the HELCOM BALSAM project (HELCOM 2015). They have since been further elaborated and specified for waterbird monitoring at sea. For coastal areas census methods are standardized by Wetlands International for the International Waterbird Census (Wetlands International 2010), and currently used monitoring methods for offshore censuses are described by Camphuysen *et al.* (2004).

Monitoring of wintering waterbirds is running in all countries bordering the Baltic Sea and specifications are provided in the monitoring concepts table in the HELCOM Monitoring Manual. Monitoring of coastal wintering waterbirds (i.e. the IWC) is organized by Wetlands International and has been carried out annually in mid-January for more than 50 years, with high coverage of the Baltic Sea since 1991.

Currently, offshore monitoring has only been implemented in a few parts of the Baltic Sea, and these efforts are not regionally coordinated. However, the Joint OSPAR/HELCOM/ICES Working Group on Marine Birds has outlined a strategy for offshore monitoring in northern Europe including the whole HELCOM area and addressing questions of coordination, periods of surveys and methods applied (ICES 2017). This is brought forward in the guidelines for waterbird monitoring at sea. Monitoring of offshore areas requires the use of ships and/or aircrafts as observation platforms for manned transect counts or the use of digital imagery. In the future, digital aerial surveys are expected to add to offshore surveys by observers based on ships and aircrafts. National programmes for offshore monitoring are implemented in several countries and efforts have commenced to coordinate surveys on a regional level (ICES 2020). All past and ongoing offshore surveys are included in a metadatabase developed in the BALSAM project (HELCOM 2014). The aim is to expand the assessment by including waterbirds wintering in offshore areas of the Baltic Sea by adding more data collected in Baltic offshore (ICES 2017), and the possible application is demonstrated using the example of one species (the long-tailed duck) in the Bornholm Group subdivision.

Monitoring of breeding success

Monitoring of breeding success can be conducted in breeding colonies or in areas where a sufficient number of breeding pairs can be observed. The standard method is to record the number of breeding pairs and the number of fledged offspring, either by observation of individual nests or by recording the total number of fledged offspring per colony or area. Currently, monitoring of breeding success is very rare in the HELCOM area. There are no HELCOM Monitoring and Assessment Guidelines in place yet, but a detailed description of methods was compiled by Walsh *et al.* (1995).

The assessment does not need long time series of breeding success (though such data additionally provided context and the possibility to evaluate the topic more clearly). Demographic data required for the population modelling can be taken from literature or from ongoing projects such as bird ringing.

6.5.2 Assessment scales

The assessment provides results across the entire Baltic Sea but was conducted at the spatial scale of seven subdivisions of the Baltic Sea, which were defined as aggregations of up to four of the 17 sub-basins (HELCOM assessment unit scale 2, See Section 2.3) following recommendation by JWGBIRD (ICES 2017, 2018) (Figure 6.15). Several waterbird species (terns in particular) are known to switch between breeding colonies from year to year, possibly even at distances involving switches between sub-basins, leading to the estimate that HELCOM assessment unit scale 2 is not an appropriate scale. Further, the use of the seven subdivisions makes it easier to localize problems and to implement necessary regional or local measures to improve status. These smaller scale evaluations are better suited to reflect the conditions of a given part of the Baltic Sea rather than downscaling the results from the entire Baltic Sea to everywhere. In addition, subdivision evaluations better serve the national reporting according to Article 8 of MSFD, because there is much less influence from other parts of the Baltic on the national evaluations. The seven subdivisions are defined as follows:

- A: Kattegat (Kattegat),
- B: Belt Group (Great Belt, The Sound),
- C: Bornholm Group (Kiel Bay, Bay of Mecklenburg, Arkona Basin, Bornholm Basin),
- D: Gotland Group (Gdansk Basin, Eastern Gotland Basin, Western Gotland Basin, Gulf of Riga),
- E: Åland Group (Northern Baltic Proper, Åland Sea),
- F: Gulf of Finland (Gulf of Finland),
- G: Bothnian Group (Bothnian Sea, The Quark, Bothnian Bay).

6.5.3 Methodology for the integrated assessment of waterbirds

The assessment methodology for waterbirds is presented in Annex 1, section on waterbirds.

6.6. Follow up and needs for the future with regards to seabirds

6.6.1 HELCOM actions

The assessment of waterbirds addresses the Baltic Sea Action Plan (BSAP) biodiversity segment's ecological objectives 'Viable populations of all native species', 'Natural distribution, occurrence and quality of habitats and associated communities', 'Functional, healthy and resilient foodwebs ' as well as the eutrophication segment's ecological objective 'Natural distribution and occurrence of plants and animals'. It is of direct relevance for the 2021 BSAP Actions:

Code	Action
B11	Maintain an updated map of the sensitivity of birds to threats such as wind energy facilities, wave energy installations, shipping and fisheries. Complete, as a first step, the mapping of migration routes, staging, moulting and breeding areas based on existing data by 2022. By 2025 further develop these maps by incorporating new data, post-production investigation information and addressing the subject of cumulative effects from these activities in space and time.
B12	By 2023 and onwards with new findings use the maps on sensitivity of migratory birds to threats in environmental impact assessment (EIA) procedures with the aim to protect migratory birds against potential threats arising from new offshore wind farms and other installations with barrier effect.
B13	By the next update cycle of the maritime spatial plans seek to incorporate the maps on sensitivity of migratory birds to threats in the work concerning maritime spatial planning to avoid that maritime activities impair birds and their habitats.
B14	By 2027 assess the effectiveness of conservation efforts to protect waterbirds against threats and pressures.
B33	By 2024 develop a roadmap to fill gaps to enable a holistic assessment for all relevant ecosystem components and pressures and, by 2030 at the latest, develop and fully operationalise a set of indicators fulfilling HELCOM's needs, including the need to provide a regional platform for the Marine Strategy Framework Directive (MSFD).

The assessment is also directly relevant to the following action of the 2013 HELCOM Ministerial Declaration and 2018 HELCOM Ministerial Declaration, respectively:

— 4 (B). WE DECIDE to protect seabirds in the Baltic Sea, taking into consideration migratory species and need for co-operation with other regions through conventions and institutions such as the Agreement on Conservation of African Eurasian Migratory Waterbirds (AEWA) under the Convention on Migratory Species (CMS), and particularly in the North Sea (OSPAR) and Arctic (Arctic Council) areas.
— 43. WE COMMIT to increasing the protection and restoration of biodiversity, to intensifying regional, subregional and cross-sectoral cooperation, and to preserving and promoting the ecological balance of the Baltic Sea area with strengthened resilience, also as streamlined response to adaptation needs stemming from human-induced climate change;
— 59. WE AGREE to strengthen the fruitful cooperation with OSPAR on transboundary issues and common challenges to gain efficiency and effectiveness in the implementation of SDGs such as ballast water management and introduction of invasive alien species, the issue of underwater noise, micro-plastic, migratory birds, MPA network and management, and threatened and endangered species

In order to protect migrating birds in the Baltic Sea region, HELCOM has adopted the Recommendation 34/E-1 'Safeguarding important bird habitats and migration routes in the Baltic Sea from negative effects of wind and wave energy production at sea'. Since some species included in the assessment are vulnerable to habitat loss caused by wind farms and access to feeding areas of breeding birds may be blocked by wind farms, while others are prone to collisions (e.g., Masden *et al.* 2010, Furness *et al.* 2013, Bradbury *et al.* 2014), the assessment is linked to the intentions of the recommendation.

6.6.2 Other international commitments

The assessment also addresses the following qualitative descriptors and criteria of the MSFD for determining good environmental status (European Commission 2008, European Commission 2017):

Descriptor 1: 'Biological diversity is maintained. The quality and occurrence of habitats and the distribution and abundance of species are in line with prevailing physiographic, geographic and climatic conditions';
— Criterion D1C2 (population abundance)
— Criterion D1C3 (population demographic characteristics)
— Criterion D1C4 (species distribution)
— Criterion D1C5 (habitat for the species)

Descriptor 4: 'All elements of the marine foodwebs, to the extent that they are known, occur at normal abundance and diversity and levels capable of ensuring the long-term abundance of the species and the retention of their full reproductive capacity'.
— Criterion D4C1 (diversity of trophic guild)
— Criterion D4C2 (balance of total abundance between trophic guilds)
— Criterion D4C4 (productivity of trophic guild)

The EU Birds Directive covers all migratory bird species, and requires that Member States report on these. In addition the Directive lists barnacle goose, pied avocet, dunlin (Baltic subspecies *Calidris alpina schinzii*), Caspian tern, sandwich tern, common tern, Arctic tern and little tern as subject of special conservation measures on its Annex 1 (European Commission 2010). Thus, all species included in the concept of the indicator are also covered by the EU Birds Directive, which requires conservation of habitats in a way that allows birds to breed, moult, stage during migration and spend the winter.

Furthermore, the Baltic Sea is located in the agreement area of the Agreement on the Conservation of African-Eurasian Migratory Waterbirds (AEWA). Contracting Parties (all HELCOM member countries except Poland and Russia) are obliged to undertake measures warranting the conservation of migratory waterbirds and their habitats.

The goals of the BSAP, EU MSFD, AEWA and EU Birds Directive are largely overlapping and the data needed for the assessment are roughly the same as needed for reporting within the framework of the EU Birds Directive.

The assessment also supports the work towards attaining the UN Sustainable Development Goal 14: Conserve and sustainably use the oceans, sea and marine resources for sustainable development.

6.6.3 Needs for future assessment

While the assessment of waterbirds is well developed it, like most assessments, would still benefit from further improvement towards future assessments. In order to ensure an improved assessment in the future the following challenges would need to be addressed.

Establishment of baselines

The evaluation of population sizes would gain from the establishment of species-specific reference periods, which would allow to compare recent population sizes with relevant baseline populations.

Gaps in monitoring
Breeding waterbirds

For abundance of breeding birds, the currently operational national monitoring schemes are only partly sufficient to supply the necessary data for the indicator. There are still gaps regarding spatial coverage (lack of monitoring schemes in Russia and Latvia) and coverage of species (not all monitoring schemes include all the species dealt with in the indicator), and an optimal monitoring would have to close these gaps. The monitoring methods applied could benefit from international standardization, however, need to take into consideration the varying environmental conditions and species composition of the different regions of the Baltic Sea. As not all species can be monitored in every country, depending on the spatial assessment unit applied, it would be wise to coordinate national monitoring schemes in a way that allows for coverage of as many species as possible. For rare species, and those showing higher degrees of inter-annual relocation, coordinated Baltic-wide surveys should be aspired to, in order to minimize the effects of data gaps and low site fidelity.

Wintering waterbirds

The coverage of offshore area monitoring for wintering birds is far from complete, and intervals of monitoring as well as methods and platforms differ between programmes. For the abundance of wintering birds it would be desirable to include offshore parts of the Baltic in the indicator evaluation, and subsequent assessment. Important components of the avian community concentrate in marine areas not covered by land-based surveys, i.e. divers, grebes, seaducks, gulls and alcids. Improved international coordination for offshore wintering bird monitoring is necessary in order to integrate national monitoring schemes into Baltic-wide surveys.

Where reasonable, special programmes such as the visual observation of waterbird migration at exposed sites (Hario *et al.* 2009, Ellermaa & Lindén 2015) would add valuable information to support the explanatory power of the monitoring results. It has to be noted that so far only two data points for total numbers of waterbirds wintering in the Baltic are available (Durinck *et al.* 1994, Skov *et al.* 2011), with another one (based on a coordinated survey in early 2016) awaiting finalisation of analysis. Depending on weather conditions and other (e.g. dietary) reasons, the distribution of some species show variability between years, creating a need for simultaneous surveys in all parts of the Baltic Sea. Simultaneous surveys are possible and already carried out in the land-based IWC. Owing to high costs, there is no capacity for full-coverage surveys in the offshore parts of the Baltic Sea on a yearly basis. Instead, monitoring programmes should aim at carrying out these surveys at a lower frequency, e.g. once or twice within a six-year reporting cycle of the EU MSFD or Birds Directive. It is recommended to conduct coordinated surveys for wintering birds in the entire Baltic Sea at least every three years with additional surveys of sub-areas at a higher frequency to increase accuracy of the assessment results. It is further proposed that digital methods for aerial surveys are further developed (ICES 2017). It is desirable that all Contracting Parties that collect offshore data make it available for assessment purposes.

In this assessment, the short time available for processing made it impossible to try out the methods for assessing birds offshore in more than one species in the German part of the Baltic Sea. Especially the elaboration of baseline values based on relatively old data was a challenge. Further work is needed to solve the problems encountered (especially the very wide confidence intervals in the baseline period).

For wintering birds future IWC surveys need to take into account that the importance of Bothnian Bay and eastern Gulf of Finland may increase due to the predicted milder winters as a consequence of climate change.

Breeding success

It is further highly recommended to establish or expand monitoring for the breeding success of waterbirds in the HELCOM region. Better monitoring and data from HELCOM Contracting Parties (more species, and temporal and spatial data) would accordingly increase the scope (e.g. include representative species covering other functional groups), quality and effectiveness of the assessment in order to use the potential of such assessments for further species and further subdivisions of the Baltic Sea. Thus, implementation of suitable monitoring and the potential to expand this indicator to other species and areas are considered a viable option towards future assessments.

7. Results for the marine mammals assessment

Assessment results in short

— Overall marine mammals are not in good status in the Baltic Sea.
— Several seal populations are markedly lower in abundance and with reduced distribution compared to pristine environmental conditions. Grey seals and some harbour seal poplations show increasing population sizes, but population growth rates are evaluated as too low.
— Both reproductive and nutritional status of seals are below the threshold values for good status.
— For grey seal and the Kattegat harbour seal population, there is some uncertainty whether populations are close to the carrying capacity of the environment.
— As a results of a warming climate the ice conditions have changed and the seals use the new ice conditions in a different manner. This has implications for the data quality for abundance of ringed seals in the Bothnian Bay which in turn introduces some uncertainty in the results for these populations.
— The status of both populations of harbour porpoise is not good with regard to both abundance and distribution. Part of the assessment of harbour porpoise is qualitative.

7.1. Introduction to marine mammals in the Baltic Sea

Five marine mammal species are resident in the Baltic Sea: the grey seal (*Halichoerus grypus*), harbour seal (*Phoca vitulina*), ringed seal (*Pusa hispida*), the harbour porpoise (*Phocoena phocoena*) and the Eurasian otter (*Lutra lutra*).

The Baltic Sea grey seals range widely and no distinct subpopulations occur (Figure 7.1). Grey seals are gregarious and gather together for breeding, moulting and hauling out at exposed areas such as skerries in the outer archipelago, sandbanks and rocky coasts. The main breeding season in the Baltic Sea is from February to March. Pupping in the Baltic Sea takes place mostly on drift ice although in some areas seals also give birth on land. The pup is nursed for about 15–18 days. Grey seals moult on ice and haul-out sites from April-June. In the Baltic, they grow to an average length of 1.65–2.1 meters and a mass of 100–180 kg for females and more than 300 kg for males. They can reach an age of 25 (males) – 35 (females) years. Females become sexually mature between 3 and 5 years. The pup is born with a creamy-white woolly lanugo coat, which it will moult after 2–4 weeks for a shorter adult-like coat. Grey seals are sexually dimorphic, e.g. distinct larger sized males with a more convex muzzle, although grey seals in the Baltic do not exhibit the degree of sexual dimorphism generally ascribed to this species (Karlsson 2003). They feed on a wide variety of fish. The diet varies with location, season and prey availability (Stenman & Pöyhönen 2005, Lundström *et al.* 2007). Fasting occurs during the breeding and moulting seasons. Juveniles in particular are known to travel over long distances (Sjöberg *et al.* 1999).

Ringed seals in the Baltic Sea exist as two populations which are geographically isolated from each other (Figure 7.2). They grow to an average length of 1.5–1.75 meters and a mass of less than 120 kilograms, and can reach a maximum age of 48 years. Females become sexually mature between 3 and 6 years after which they normally generate one pup every year. The moulting season is from mid-April to early May. Ringed seals feed on a wide variety of small fish and invertebrates.

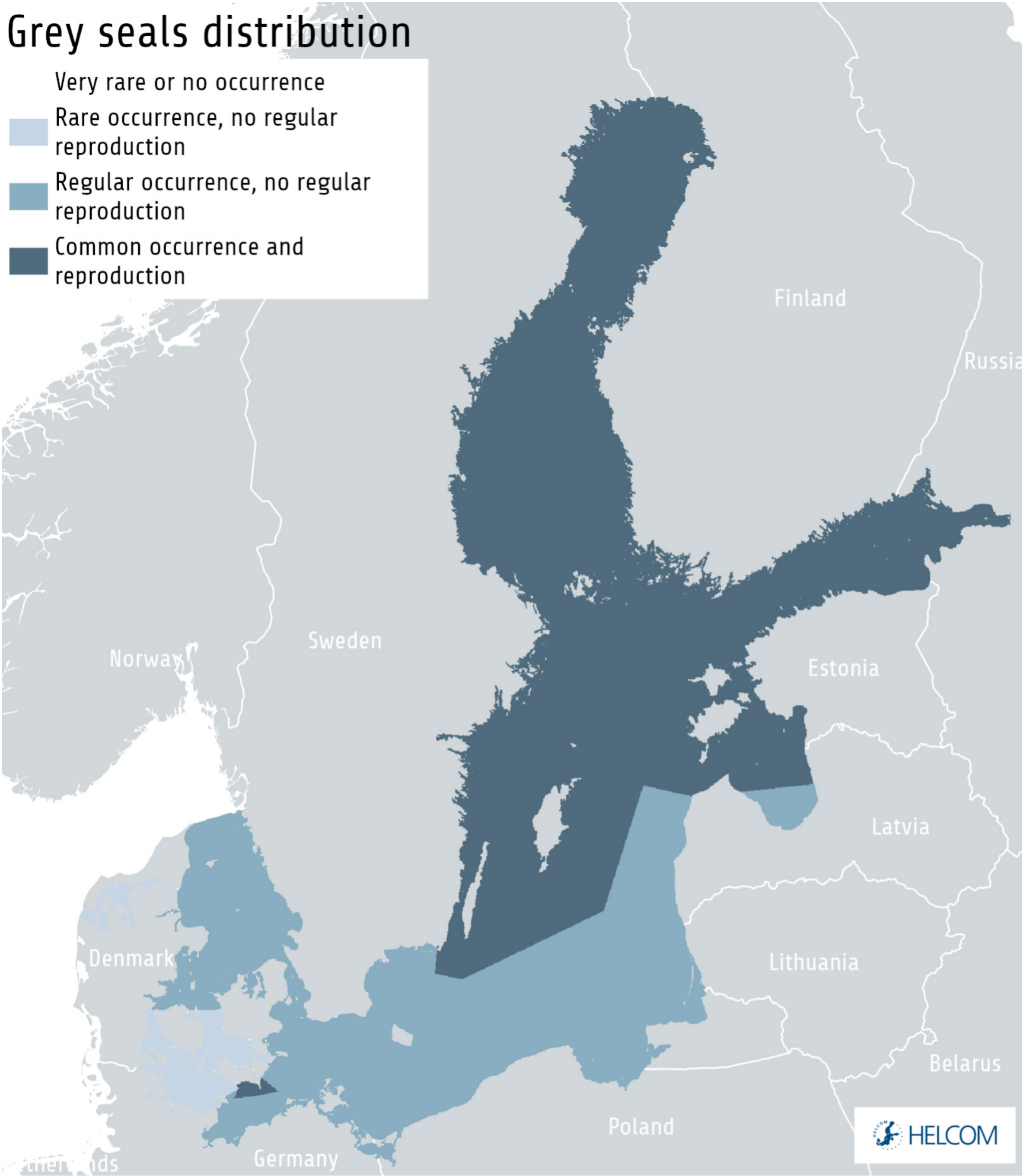


Figure 7.1. Distribution of grey seal in the Baltic Sea, produced for the spatial pressures and impacts assessment (HELCOM 2023a), based on expert input.

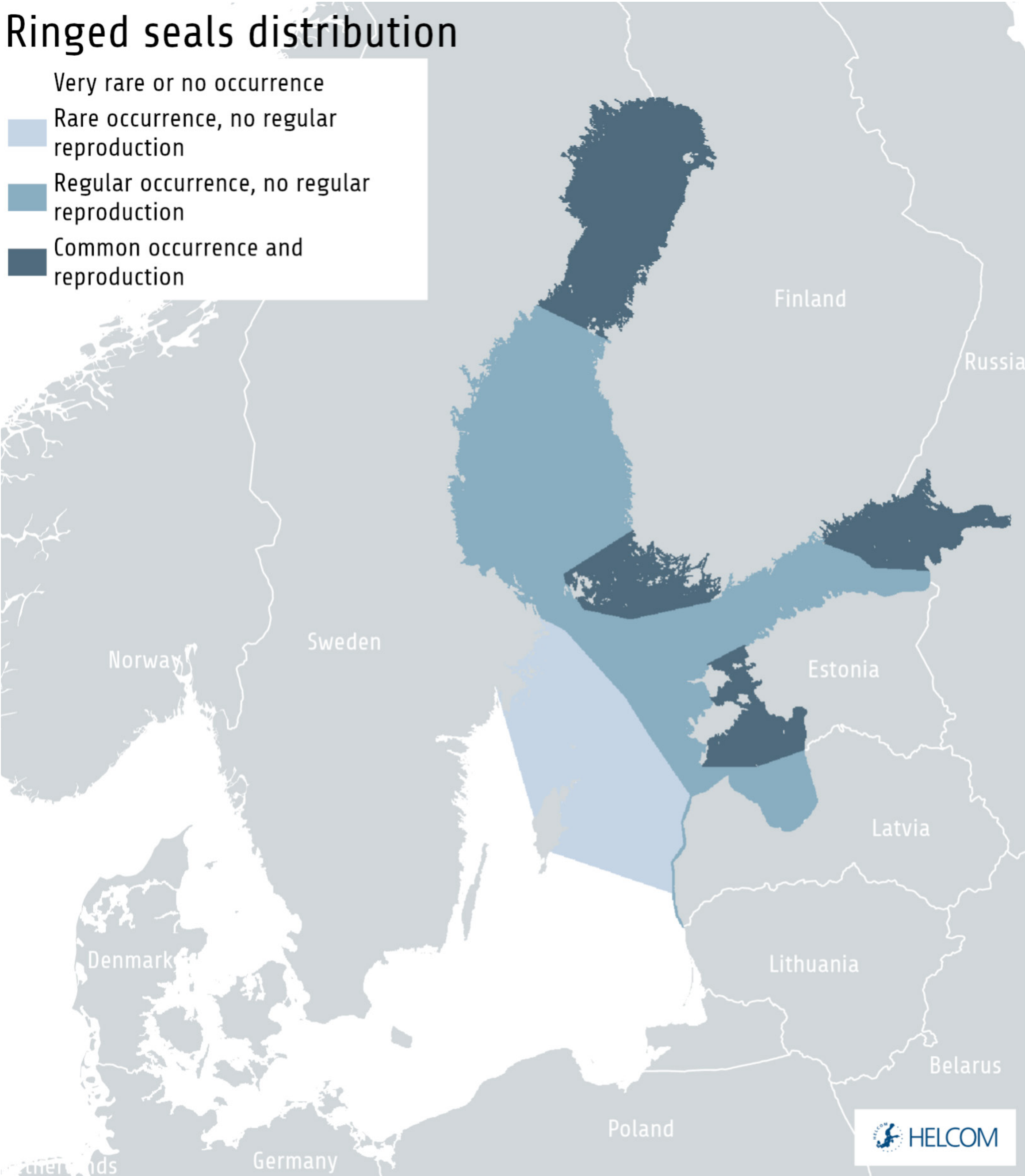


Figure 7.2. Distribution of ringed seal in the Baltic Sea, produced for the spatial pressures and impacts assessment (HELCOM 2023a), based on expert input.

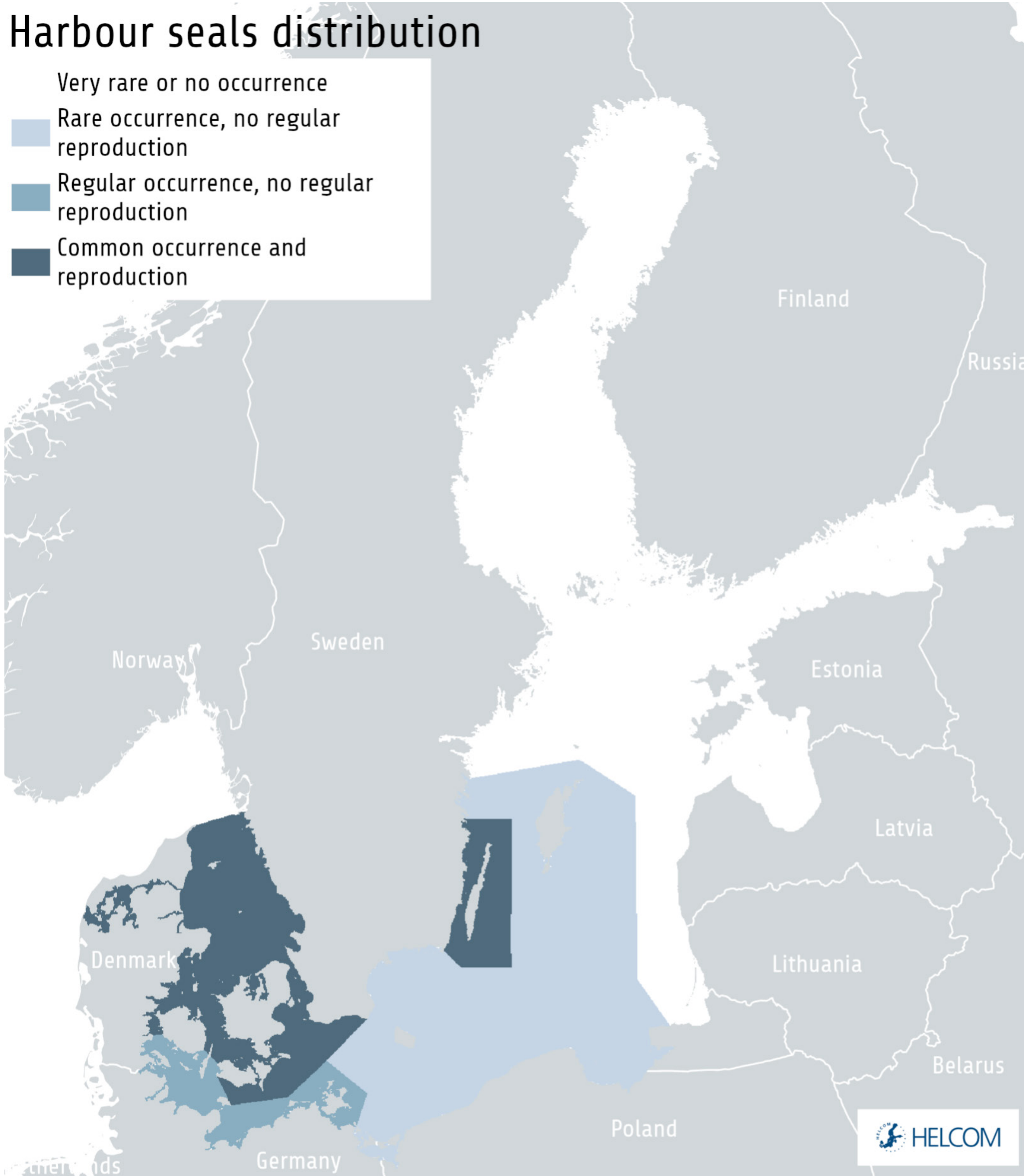


Figure 7.3. Distribution of harbour seal in the Baltic Sea, produced for the spatial pressures and impacts assessment (HELCOM 2023a), based on expert input.

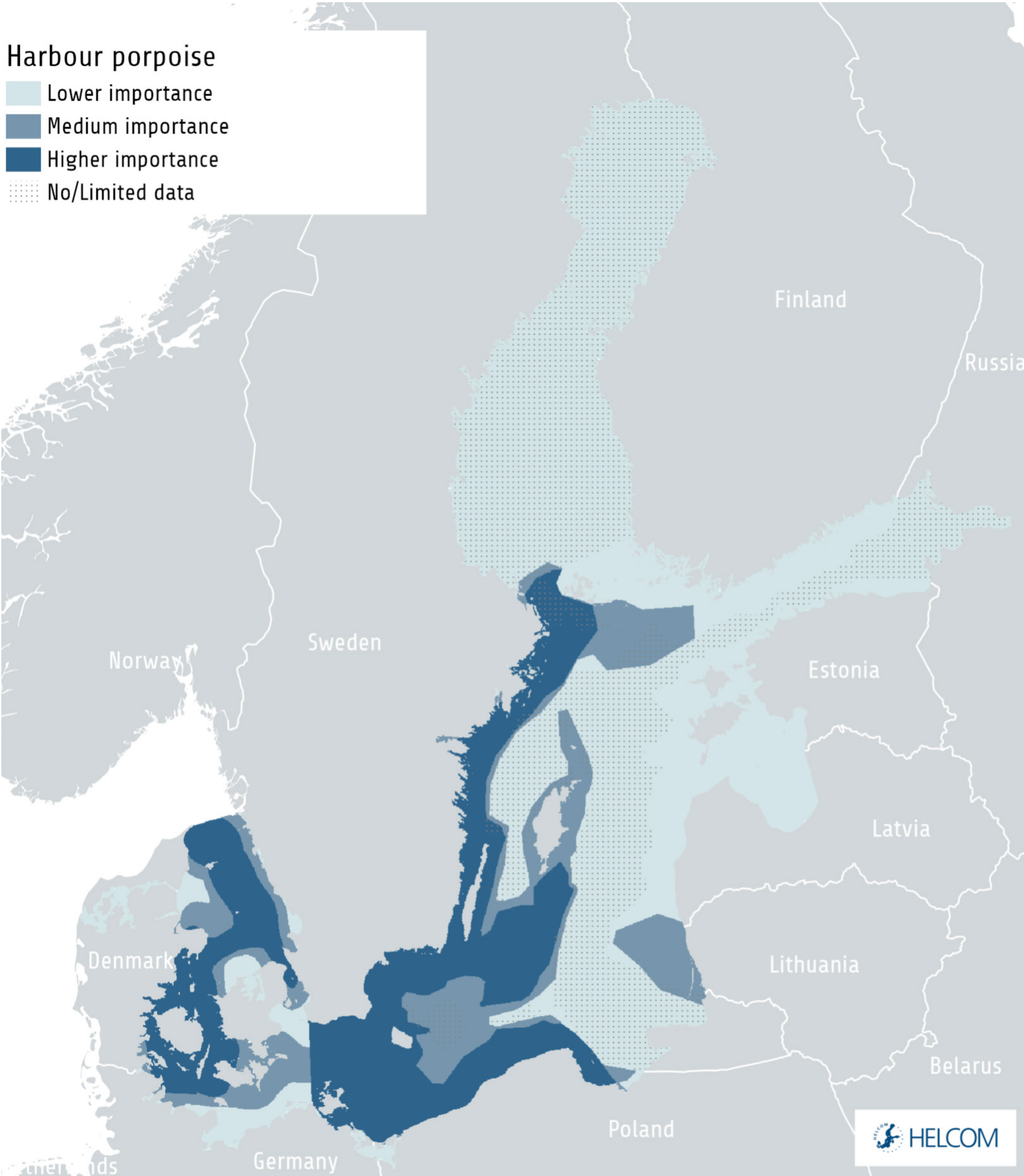


Figure 7.4. Map of areas in the Baltic Sea of importance for the two harbour porpoise populations in the Baltic Sea, produced for HOLAS 3, (https://dce2.au.dk/pub/TR240.pdf), based on data from harbour porpoise tracking data, national monitoring data and the SAMBAH project. Due to the significant difference in the abundance of the two Baltic Sea harbour porpoise populations, the harbour porpoise map in HOLAS 3 focuses on areas of importance for harbour porpoise as opposed to relative density of porpoises. This enables removing bias against the critically endangered Baltic Proper due to its low abundance. Areas are categoriezed as "higher" importance, "medium" importance, "lower" importance and "no/limited data". These categories were chosen due to concern about the implications of the lowest category for the Baltic Proper population, and to underline that the categories are relative and not absolute. The low abundance of the Baltic Proper population is of such high concern, that each individual must be considered of high importance and since individual porpoise detections/incidental sightings do occur in basically all of the Baltic Sea (east of the Belt Sea population management unit), it could be argued that all of the Baltic Sea (the Baltic Proper, the Gulf of Finland and the Gulf of Bothnia) is of importance. For more information please see Svegaard *et al.* 2022. (Source: HELCOM 2023a).

In the Baltic Sea harbour seals are abundant in the Kattegat and the Belt Sea area, as well as in the Limfjord whereas further east they are restricted to only three small breeding colonies with the Kalmarsund as their easternmost breeding area (Figure 7.3). They grow to an average length of 1.4–1.7 metres and a mass of up to 100 kilograms, and they can reach a maximum age of 36 years (Härkönen & Heide-Jörgensen 1990). Generally the species is gregarious, hauling out in small to large scattered groups to breed, moult and rest. Some colonies in protected bays and estuaries can number over 1 000 individuals. Females become sexually mature between 3 and 6 years and they then normally generate one pup every year. The pups are usually born on sheltered beaches, rocks or littoral sandbanks, from where they can follow the mother into the water immediately after birth. Harbour seals feed on a great number of fish species (Härkönen 1987 a, b, 1988). They tend to stay within 25 km from shore but individuals are occasionally found 100 km or more offshore.

There are two populations of harbour porpoises in the Baltic Sea area, one in the western Baltic Sea encompassing the Kattegat, the Belt Sea, the Sound and the German Baltic and a second one in the proper Baltic Sea (Figure 7.4). The harbour porpoise is one of the smallest cetacean species in the world. In the Baltic Sea, adult males reach average lengths of 1.45 meters, while females average 1.60 meters. Age at sexual maturity is 3–4 years, after which females can potentially produce a calf each year (Lockyer 2003). Maximum recorded longevity is 24 years, but few porpoises live beyond 12 years (Lockyer 2003). Harbour porpoises primarily feed on fish, in the Baltic Sea mainly on cod (*Gadus morhua*), herring (*Clupea harengus*), sprat (*Sprattus sprattus*), gobies and eelpout (*Zoarces viviparus*) (Aarefjord and Bjørge 1993, Santos and Pierce 2003, Malinga *et al.* 1996).

7.1.1 Importance of marine mammals for the ecosystem

Marine mammals play an important role in the functioning of the Baltic Sea ecosystem. The presence of top predators allows for natural control of the distribution, abundance, diversity, and health of their prey species, with harbour porpoises likely previously playing an important role in maintaining natural balance in the Baltic Sea ecosystem. Being a highly mobile species both horizontally over space and vertically over depth, harbour porpoises also likely played an important role in nutrient transfer across the Baltic Sea region.

Out of the four species of marine mammals in the Baltic Sea, grey seal occurs in the whole region, whereas harbour seal is restricted to the southwestern parts of the Baltic Sea and the Kattegat, and ringed seal to the eastern and northern Baltic Sea. The harbour porpoise occurs mainly in the Kattegat, the Belt Sea, the Sound and the southern parts of the Baltic Sea, and in far lower numbers in the Baltic Proper.

7.1.2 Importance of marine mammals for Baltic Sea environmental management

As mobile top-predators with a varied diet marine mammals are good indicators for variety of changes in the ecosystem. These species are sensitive to pressures in all their areas of distribution, as well as to changes in the foodweb. Their exposure to accumulated pressures make marine mammals important indicators of the health of the ecosystem, as they are sensitive to changes at lower trophic levels in the ecosystem as well as human induced pressures. Their abundance, distribution and health would be expected to respond to changes, both natural and anthropogenic, in the marine environment or at their haul out sites. Such changes can include disease outbreaks, competition with other species, shifts in resources, disturbance, and fisheries interactions as well as other pressures caused by human activities. The Baltic Sea has a relatively large catchment area and only limited exchange of water with the larger North Sea and is especially vulnerable to e.g. environmental contaminants and many other human impacts. One of the strongest threats to marine mammals is the risk of being incidentally bycaught in fishing gear, which results in direct mortality of individuals. Climate change, through its implications on sea ice conditions also has a direct impact on ice breeding seal species. Survival and fecundity can also be reduced by exposure to contaminants. Additionally, both impulsive and continuous underwater noise have negative influences, especially on porpoises, ranging from behavioural disturbance that reduces the efficiency of foraging and communication, through to permanent injury and death. Harbour porpoises also have high-energy requirements and must feed almost continuously to meet energy demands. This makes the species particularly susceptible to negative impacts from resource depletion and disturbance from human presence.

Seals in the Baltic Sea are managed based on defined and agreed management units for the Baltic Sea seal populations as laid down in HELCOM Recommendation 27/28. The current management units are divided as follows:

1. Harbour seals in the Kalmarsund region (Sweden);
2. Southwestern Baltic and Kattegat harbour seals (Denmark, Germany, Poland, Sweden);
3. Gulf of Bothnia ringed seals (Finland, Sweden);
4. Southwestern Archipelago Sea, Gulf of Finland and Gulf of Riga ringed seals (Finland, Estonia, Latvia, Russia);
5. Baltic Sea grey seals (all Contracting Parties to the Helsinki Convention).

The management units spatially deliniate the developement and implementation of National Management Plans for the seal species, which are the main management instruments to ensure that the favourable conservation status of the species is attained or maintained. For more information on the approach to management units for the assessment of seals please see section 7.5.3.

7.2. Assessment results for marine mammals

7.2.1 Integrated assessment results for marine mammals

The overall status of marine mammal species is assessed as not good (Figures 7.5, 7.6 and 7.7). Several of the populations are still markedly lower in abundance and with reduced distribution compared to pristine environment. Grey seals and some harbour seal populations show increasing population sizes but the population growth rates remain under the threshold values. The reduced growth rates could be partly explained by hunting in some species/populations, but for others the reasons are unknown. Southern subpopulations of ringed seals are in a reduced or a critical state with low numbers in their fragmented remains of once continuous distribution. Currently only around 100 ringed seals live in the Gulf of Finland, 200-300 in the Archipelago Sea and 1000 in the Western Estonia - Gulf of Riga area. No signs of increase have been observed in any of these subpopulations. Distribution areas of most marine mammal populations are still not reaching the pristine levels. Indicator evaluations for reproductive and nutritional status are available for the grey seal population and both pregnancy rate and blubber thickness are below the threshold values for good status. The pregnancy rate in the ringed seal population in the Bothnian Bay is also below the threshold, and in addition, the lesions historically associated with environmental contaminants are still occasionally observed in old ringed seal females.

Confidence in the integrated marine mammal assessment is considered high. Data coverage is rather good for most of the parameters, though data to some indicators are not available for all the populations. Poor data-coverage in some populations is connected with low abundance, which makes the evaluation still rather straightforward in these cases.

For the grey seal and Kattegat harbour seal populations it is difficult to interpret whether or not they are close to carrying capacity of the environment. That makes a difference into the selection of the threshold for Population trends and abundance –indicator and decreases the certainty.

Data quality for abundance of ringed seals in the Bothnian Bay has decreased due to behavioural change, which is assumedly linked to climate warming. This makes trend calculation for the Bothnian Bay ringed seal impossible, however there is no indication of improving trend in the population and growth rate is below threshold value (HELCOM 2023w).

The assessment presented in this chapter should be considered together with other relevant biodiversity assessments in order to achieve an overall overview of the status of biodiversity. More information on the assessment methodology and approach can be found in Chapter 2 (BEAT methodology) and in Annex 1 (Methodology manuals).

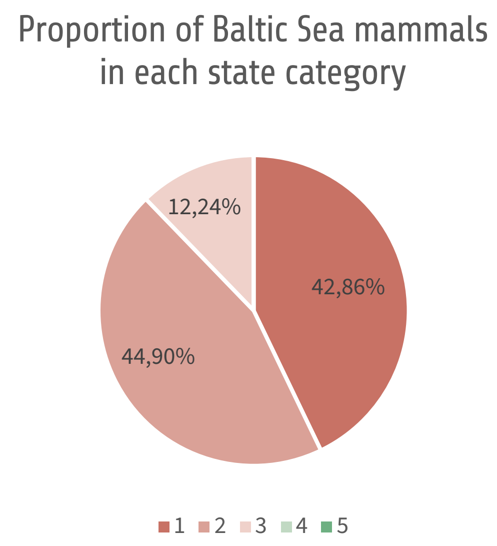


Figure 7.5. Proportion of Baltic Sea mammals found in each of the five status categories used for integrated status assessment (three categories representing poor status and two categories representing good status).

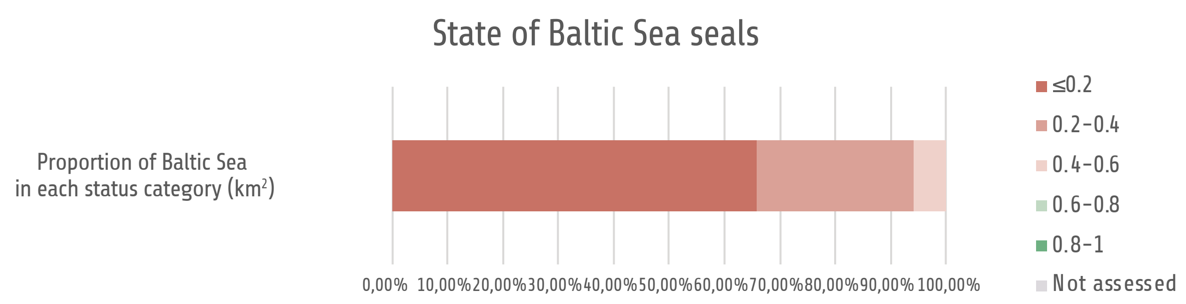
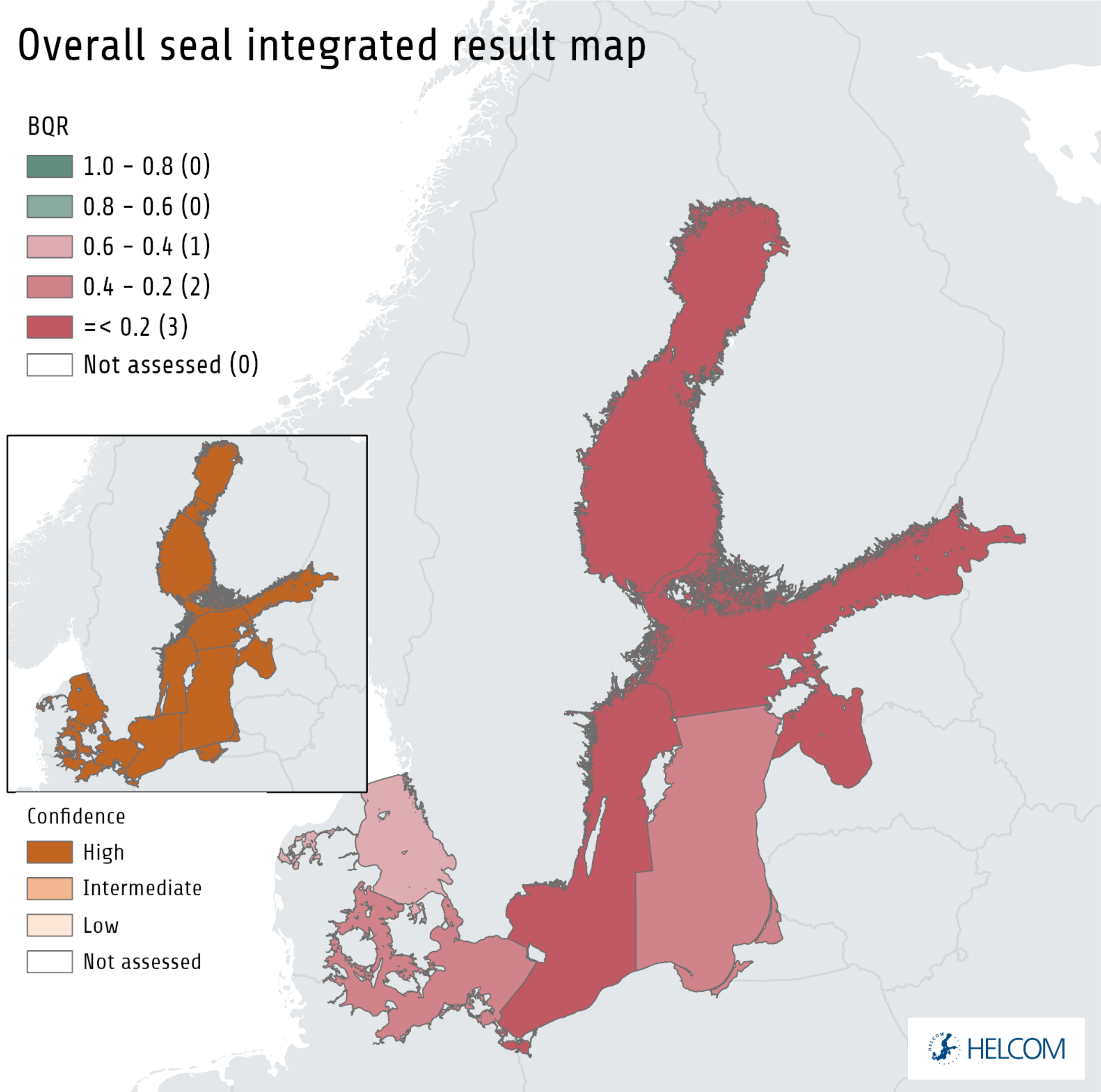


Figure 7.6. Proportion of Baltic Sea in each of the five status categories used for integrated status assessment (three categories representing poor status and two categories representing good status).



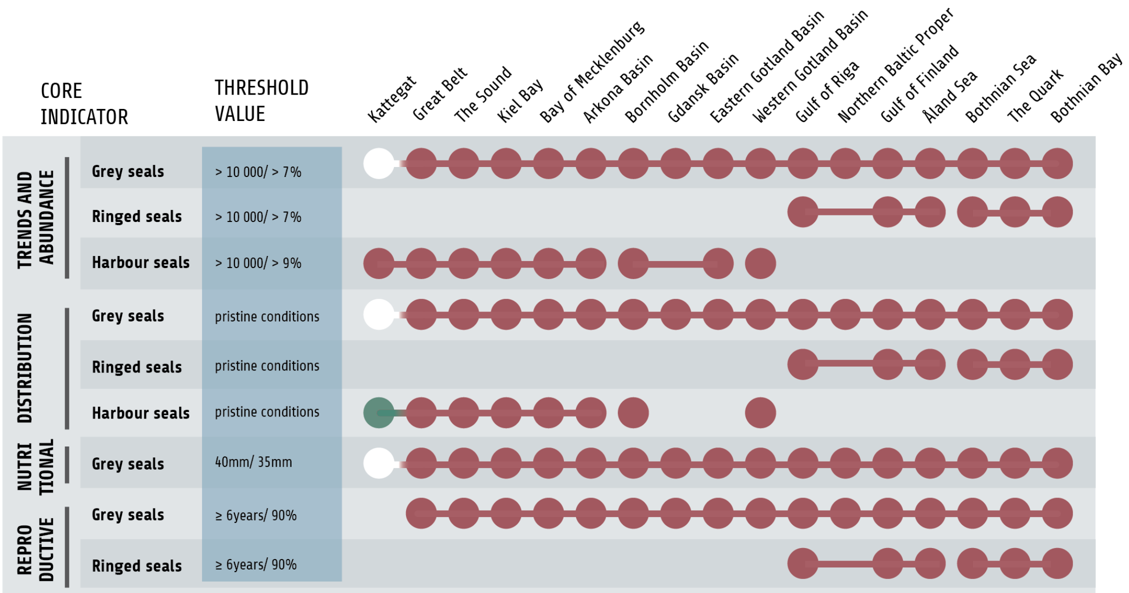


Figure 7.7. Integrated biodiversity status assessment results for seals, as generated by the BEAT tool, based on the indicator evaluations for population trends and abundance (grey seal, ringed seal and harbour seal), distribution (grey seal, ringed seal and harbour seal), nutritional status (grey seal), and reproductive status (grey seal, ringed seal) (HELCOM 2023v,2023w, 2023x, 2023y, 2023z, 2023aa,2023ab,2023m). As the figure present integrated results over three species the overall status for a sub-basin is affected by the status of the individual species occurring in the sub-basin, across the indicators listed above. Values >0.6 represent good status. Confidence is presented in the map insert. Corresponding indicator evaluation results for indicators included in the integrated assessment are presented in the bottom of the figure.

Table 7.1. BEAT output from the integrated assessment of seals. The column "Sub-divsion" referes to the agreed name of each individual assessment area. "Spatial assessment unit level" indicates at what spatial resolution the assessment was conducted (see Section 2.3.2 or the HELCOM Monitoring and Assessment Strategy for more information on the assessment units used for HELCOM assessments). "Biological Quality Ratio" represents the quantitative results of the integrated assessment for the topic, with results >0.6 constituting Good Status (see Section 2.1.1 for more information on the BEAT tool). The column "Status" indicates whether the quantitative assessment results achieve of fail the threshold for good status. The columns "Confidence" and "Confidence Class", respectivey, provides a quantified value for confidence in the assessment and translates this value into a discreet confidence class, in line with the methodology outlined in Section 2.1.1.

Sub-division	Spatial assessment unit level	Biological quality ratio	Status	Confidence	Confidence Class
Kattegat	2	0.6	not good	1.00	High
South-Western Baltic (Arkona basin, Kiel Bay, Bay of Mecklenburg, The Sound and Belt Sea)	2	0.3	not good	0.93	High
Remaining areas (Eastern Gotland Basin and Gdansk Basin)	2	0.3	not good	0.96	High
Kalmarsund area (Western Gotland Basin + Bornholm Basin)	2	0.2	not good	0.88	High
South-Western Archipelago sea (Northern Baltic Proper, Åland Sea, Gulf of Finland and Gulf of Riga)	2	0.1	not good	0.88	High
Gulf of Bothnia (Bothnian Bay, Bothnian Sea and The Quark)	2	0.2	not good	0.92	High

Integrated assessment results for grey seal

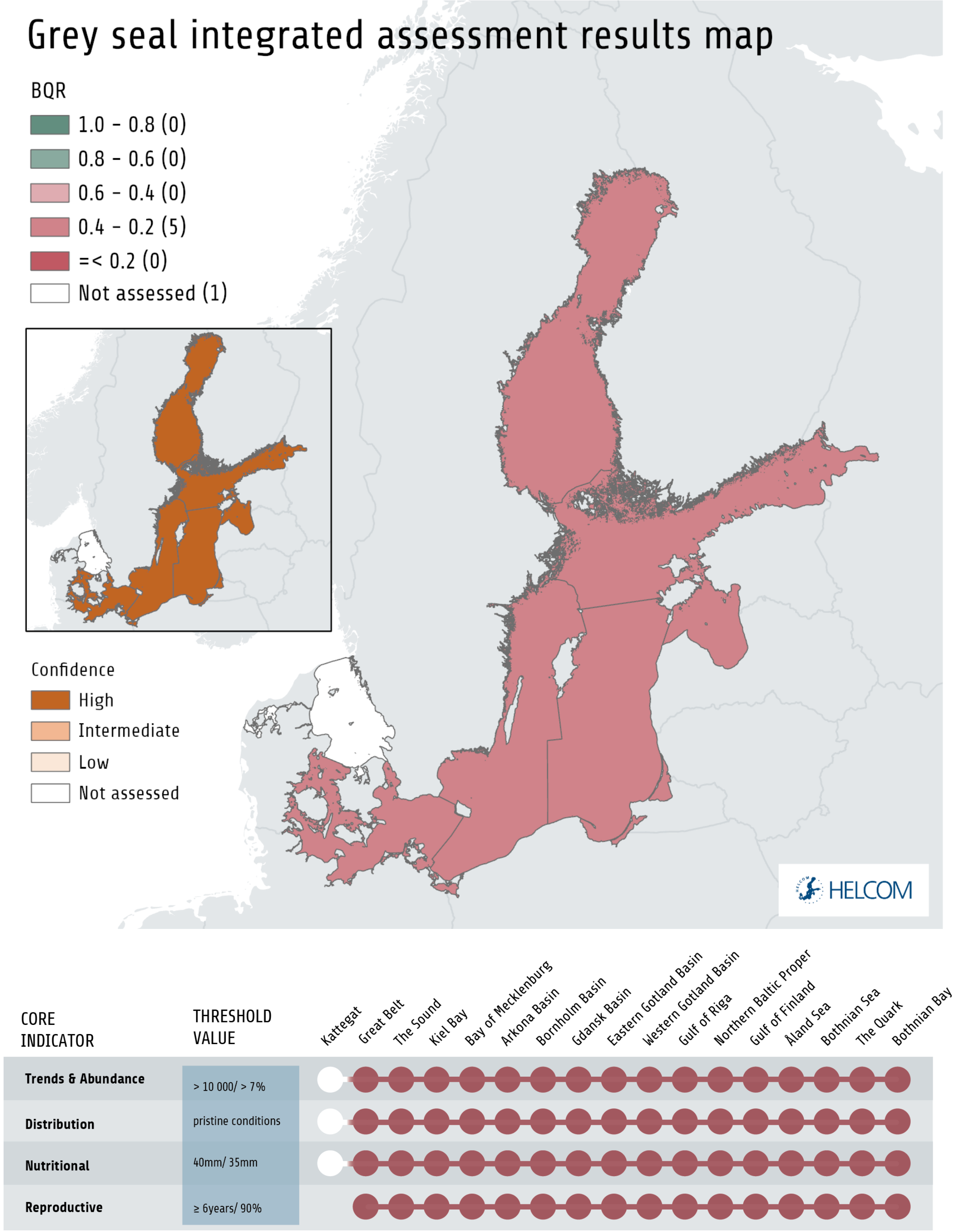


Figure 7.8. Integrated biodiversity status assessment results for grey seals, as generated by the BEAT tool, based on the indicator evaluations for population trends and abundance, distribution, nutritional status and reproductive status (HELCOM 2023v, 2023y, 2023ab, 2023m). Values >0.6 represent good status. Confidence is presented in the map insert. Corresponding indicator evaluation results are presented in the bottom of the figure.

The grey seal is assessed as one management unit in the Baltic Sea. The overall status for grey seal is not good (Figures 7.8).

The number of grey seals counted in the whole Baltic Sea region in 2021 is approximately 42,000 individuals. Assuming a haulout-fraction of 70%, the total population estimate would be around 60 000 animals. The indicator on population trends and abundance for grey seal uses a limit reference level of 10,000 individuals, and the population trend is thus assessed as achieving the threshold value. However, population growth rate is below the threshold for good status. For the grey seal population, there is some uncertainty whether population are close to the carrying capacity of the environment, i.e. the maximum population size of a biological species that can be sustained by that specific environment. This may be causing a decreased growth rate. However, at the moment the population doesn not yet fully show the signs of having reach carrying capacity, and thus it is estimated in not good condition. Distribution is slowly expanding, but has not yet reached the pristine level in the southwest Baltic. Grey seal blubber thickness and pregnancy rate are both below their threshold values for good status (see Table 7.2). Pregnancy rates are significantly increasing. Blubber thickness, however, shows no trend during the last 15 years and remains lower than the threshold.

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 areas. The number of grey seals in their core area of moulting distribution (covering the Bothnian Sea, Archipelago Sea, Gulf of Finland and Western Estonian waters), is counted to just below 34,000 in 2021. Around 1,200 grey seals are estimated for the other parts of the Gulf of Bothnia and just below 7,000 for the southern Baltic Sea. 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.

Table 7.2. BEAT output from the integrated assessment for grey seal. The column "Sub-division" referes to the agreed name of each individual assessment area. "Spatial assessment unit level" indicates at what spatial resolution the assessment was conducted (see Section 2.3.2 or the HELCOM Monitoring and Assessment Strategy for more information on the assessment units used for HELCOM assessments). "Biological Quality Ratio" represents the quantitative results of the integrated assessment for the topic, with results >0.6 constituting Good Status (see Section 2.1.1 for more information on the BEAT tool). The column "Status" indicates whether the quantitative assessment results achieve of fail the threshold for good status. The columns "Confidence" and "Confidence Class", respectivey, provides a quantified value for confidence in the assessment and translates this value into a discreet confidence class, in line with the methodology outlined in Section 2.1.1.

Sub-divsion	Spatial assessment unit level	Biological quality ratio	Status	Confidence	Confidence Class
South-Western Baltic (Arkona basin, Kiel Bay, Bay of Mecklenburg, The Sound and Belt Sea)	2	0.3	not good	0.96	High
Remaining areas (Eastern Gotland Basin and Gdansk Basin)	2	0.3	not good	0.96	High
Kalmarsund area (Western Gotland Basin + Bornholm Basin)	2	0.3	not good	0.96	High
South-Western Archipelago sea (Northern Baltic Proper, Åland Sea, Gulf of Finland and Gulf of Riga)	2	0.3	not good	0.96	High
Gulf of Bothnia (Bothnian Bay, Bothnian Sea and The Quark)	2	0.3	not good	0.96	High

Integrated assessment results for ringed seal

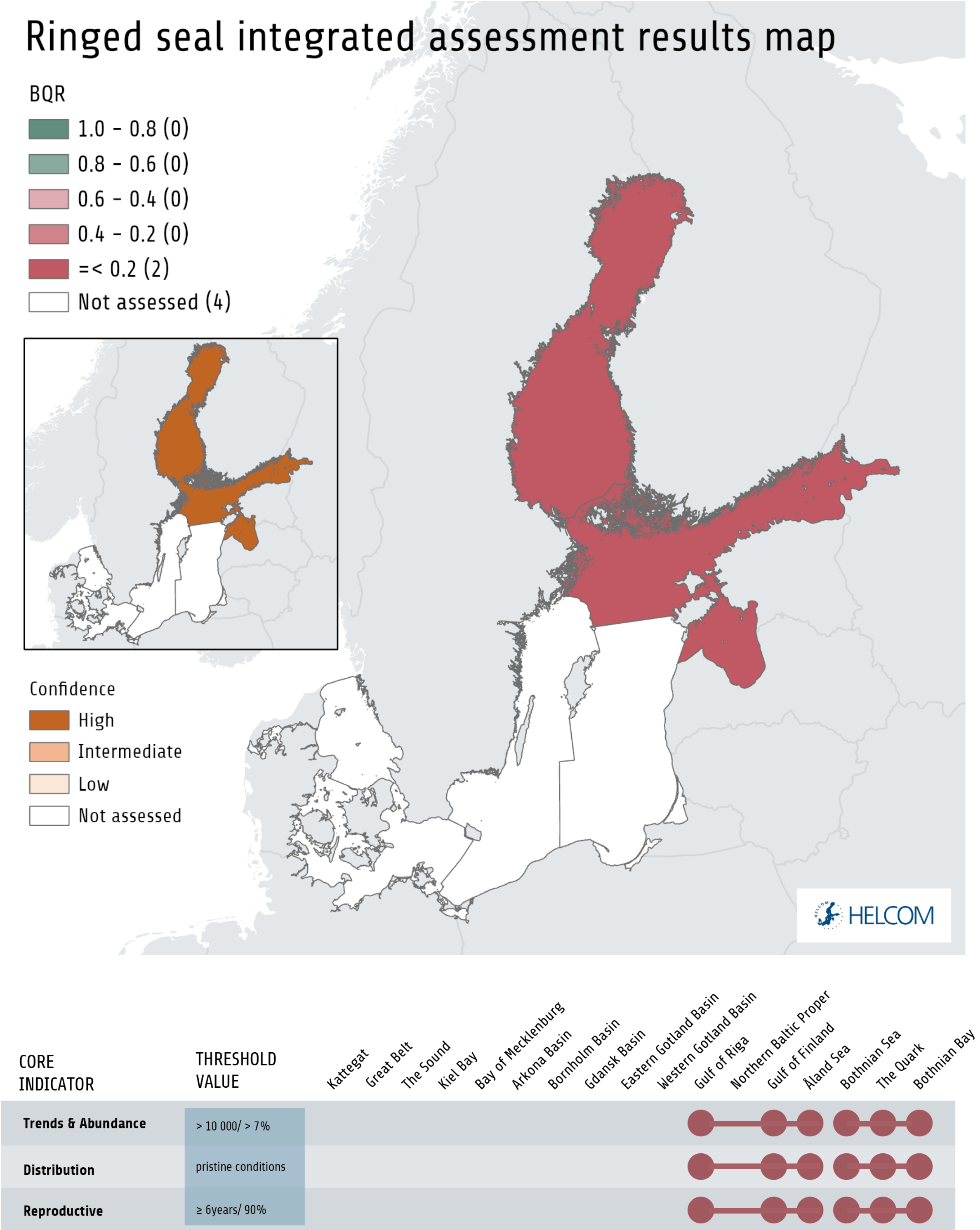


Figure 7.9. Integrated biodiversity status assessment results for ringed seals, as generated by the BEAT tool, based on the indicator evaluations for population trends and abundance, distribution, and reproductive status (HELCOM 2023w, 2023z, 2023m). Values >0.6 represent good status. Confidence is presented in the map insert. Corresponding indicator evaluation results are presented in the bottom of the figure.

Ringed seals are assessed separately for northern (Bothnian Bay) and southern (the Archipelago Sea, Gulf of Finland and western Estonia – Gulf of Riga sub-populations) management units. The status of ringed seals is not good in any of the two management units (see Figure 7.9).

In the Bothnian Bay, abundance of ringed seals exceeds the Limit Reference Level (LRL), but growth rate of the population cannot be calculated for the assessment period due to exceptional monitoring results in most years during the last decade. Before the assessment period the growth rate was below the threshold for good status and there is no indication of improvement with increased hunting pressure and deteriorated breeding conditions. Although the pregnancy rate trend has been slowly increasing since the all-time low pregnancy rates in the 1970s and continues to increase, the proportion of pregnant adult ringed seal females are below the threshold for good status.

In the southern management unit, abundances in all three sub-populations are very low and no indication of growth in them has been observed. Distribution is fragmented and breeding and moulting distribution on ice are strongly restricted by poor availability of ice in most years. Blubber thickness or pregnancy rate data are not available for the southern ringed seals.

Table 7.3. BEAT output from the integrated assessment for ringed seal. The column "Sub-division" referes to the agreed name of each individual assessment area. "Spatial assessment unit level" indicates at what spatial resolution the assessment was conducted (see Section 2.3.2 or the HELCOM Monitoring and Assessment Strategy for more information on the assessment units used for HELCOM assessments). "Biological Quality Ratio" represents the quantitative results of the integrated assessment for the topic, with results >0.6 constituting Good Status (see Section 2.1.1 for more information on the BEAT tool). The column "Status" indicates whether the quantitative assessment results achieve of fail the threshold for good status. The columns "Confidence" and "Confidence Class", respectivey, provides a quantified value for confidence in the assessment and translates this value into a discreet confidence class, in line with the methodology outlined in Section 2.1.1.

Sub-division	Spatial assessment unit level	Biological quality ratio	Status	Confidence	Confidence Class
Western Archipelago sea (Northern Baltic Proper, Åland Sea, Gulf of Finland and Gulf of Riga)	2	0.1	not good	0.80	High
Gulf of Bothnia (Bothnian Bay, Bothnian Sea and The Quark)	2	0.2	not good	0.88	High

Integrated assessment results for harbour seal

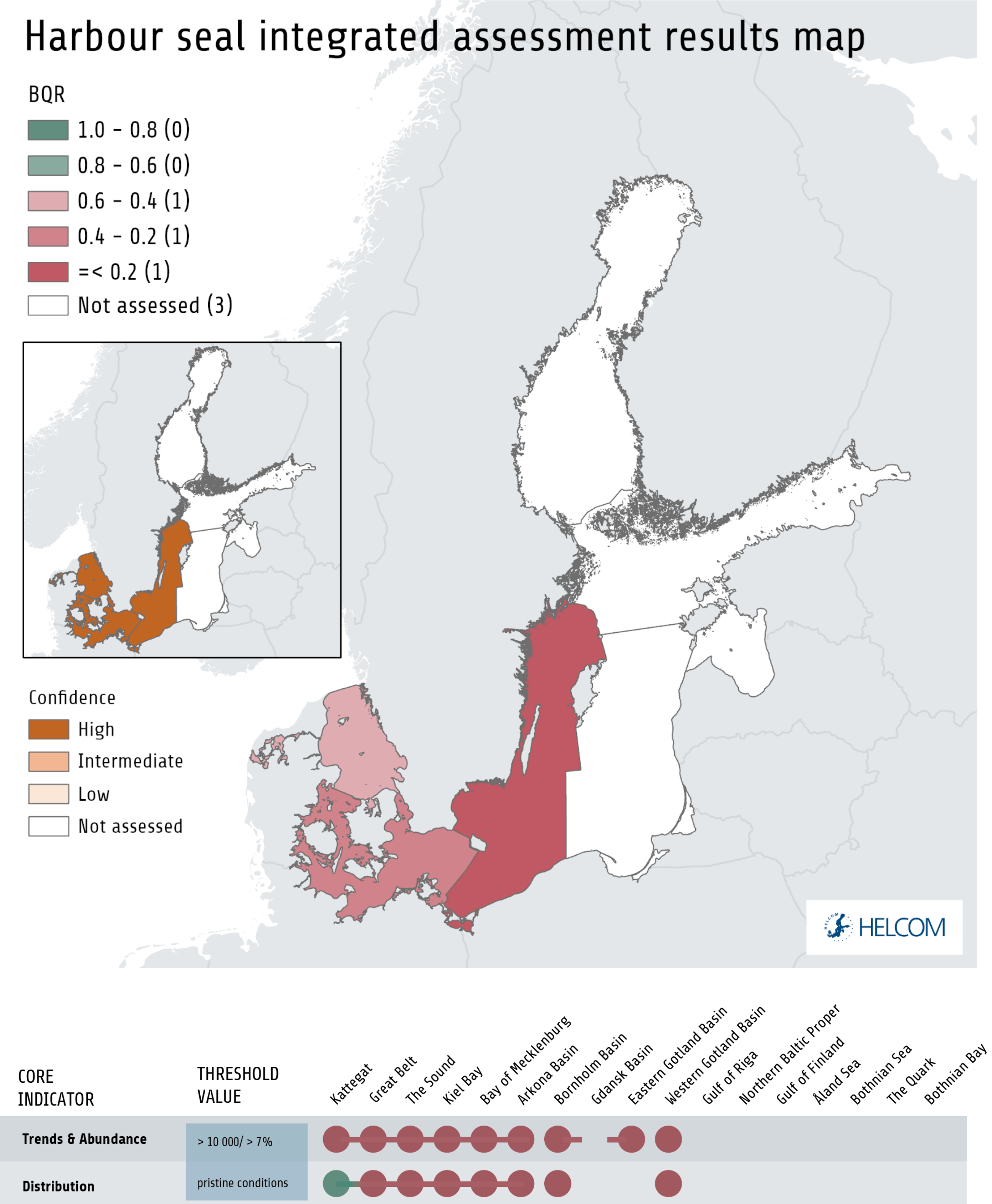


Figure 7.10. Integrated biodiversity status assessment results for harbour seals, as generated by the BEAT tool, based on the indicator evaluations for population trends and abundance and distribution (HELCOM 2023x, 2023aa). Values >0.6 represent good status. Confidence is presented in the map insert. Corresponding indicator evaluation results for indicator included in the integrated assessment are presented in the bottom of the figure.

Harbour seals appear in four different sub-populations in the HELCOM area, namely Kalmarsund, SW Baltic, Kattegat and Limfjord. However, according to the Recommendation 27-28/2 the agreed management units are the Kalmarsund and SW Baltic together with Kattegat. Following the HOLAS II, harbour seal abundance is evaluated for SW Baltic and Kattegat combined while the trend is evaluated separately for them, Kalmarsund is evaluated as an independent unit. Assessment for Limfjord is unofficial since it is not mentioned in the Recommendation 27-28/2. Harbour seals do not have good status in any of the assessment units (Figure 7.10).

Growth rate of harbour seals in Kalmarsund is close to the threshold value, but abundance is well below. In the southwest Baltic, the trend is increasing with a rate below the threshold for good status and the southwest Baltic population, when considered alone, is below LRL. Abundance of harbour seals in Kattegat alone exceeds the threshold of 10,000 individuals. In Kattegat, the trend was still increasing until 2019 followed by a marked decrease in the survey results. It is unclear to what extent the decrease is due to increased disturbance and weather factors which affect the proportion of the animals seen in the surveys, and to what extent it indicates true population change and, in that case, if the growth rate is limited due to the population reaching carrying capacity of the environment. Therefore, it is difficult to interpret if the trend should be evaluated against the threshold for growth rate for populations below or at Target Reference Level (TRL). If evaluated as a population below TRL, the growth rate indicates not good status. If evaluated as a population at TRL, the marked decrease after 2019 is larger than 10%, but during the period of last 10 years the trend is first increasing and the decreasing, not exceeding the threshold of 10% in the end when evaluated over the whole period. In Limfjord, abundance is well below the threshold and growth has been levelling off. The unofficial assessment for the sub-population is also challenging since TRL seems to be below LRL in the area. If the population is encountering density dependence, the level of abundance indicates reduced carrying capacity and potentially deteriorated habitat as the counts were significantly higher before the 2002 PDV epidemic.

Distribution of harbour seals is considered to reach the threshold of pristine level in Kattegat and Limfjord, but not in the southwestern Baltic nor in Kalmarsund. Adequate data for blubber thickness and pregnancy rate are not available for these management units.

Table 7.4. BEAT output from the integrated assessment for harbour seal. The column "Sub-division" referes to the agreed name of each individual assessment area. "Spatial assessment unit level" indicates at what spatial resolution the assessment was conducted (see Section 2.3.2 or the HELCOM Monitoring and Assessment Strategy for more information on the assessment units used for HELCOM assessments). "Biological Quality Ratio" represents the quantitative results of the integrated assessment for the topic, with results >0.6 constituting Good Status (see Section 2.1.1 for more information on the BEAT tool). The column "Status" indicates whether the quantitative assessment results achieve of fail the threshold for good status. The columns "Confidence" and "Confidence Class", respectivey, provides a quantified value for confidence in the assessment and translates this value into a discreet confidence class, in line with the methodology outlined in Section 2.1.1.

Sub-division	Spatial assessment unit level	Biological quality ratio	Status	Confidence	Confidence Class
Kattegat	2	0.6	not good	1	High
South-Western Baltic (Arkona basin, Kiel Bay, Bay of Mecklenburg, The Sound and Belt Sea)	2	0.3	not good	0.9	High
Kalmarsund area (Western Gotland Basin + Bornholm Basin)	2	0.2	not good	0.8	High

Integrated assessment results for harbour porpoise

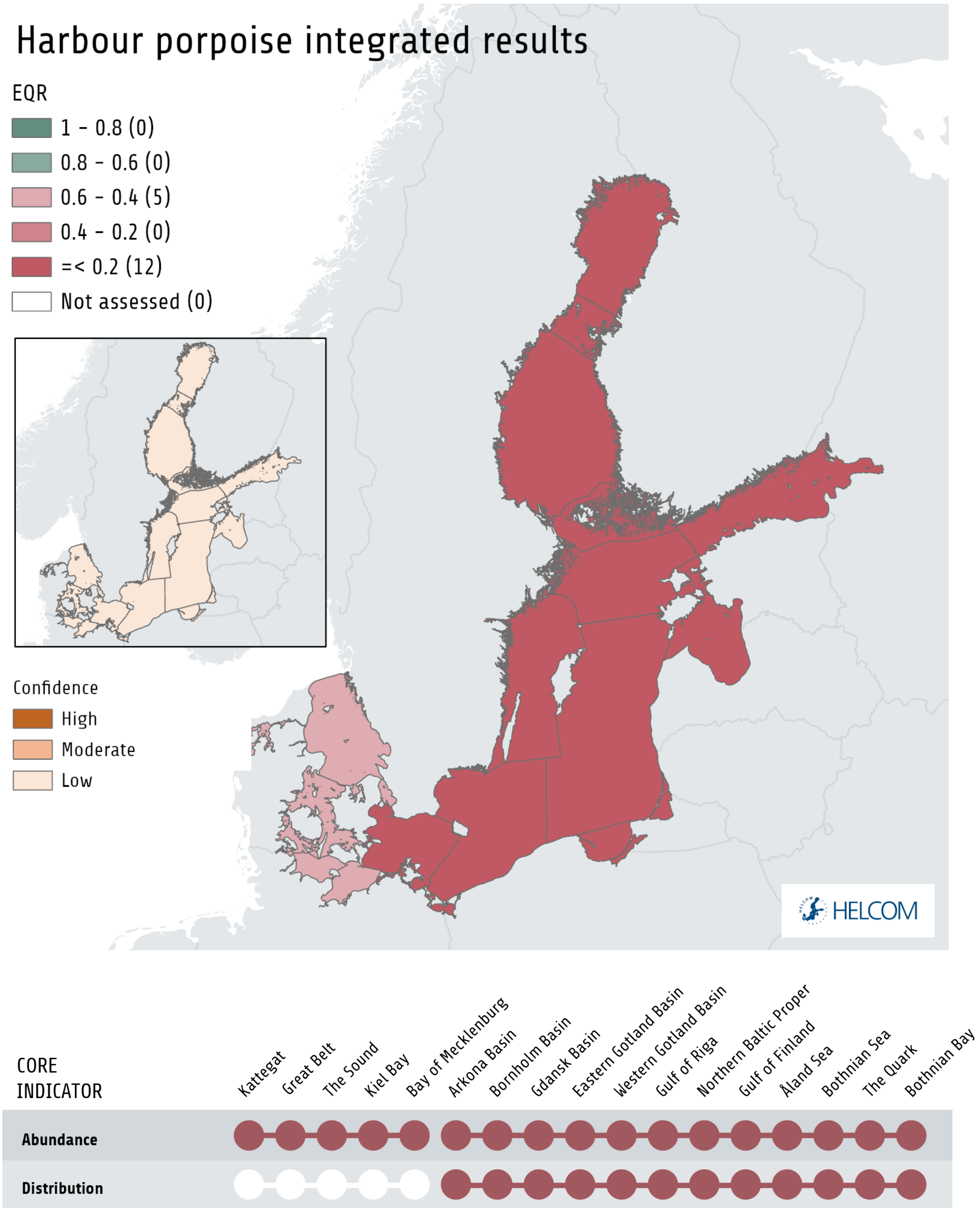


Figure 7.11. Integrated biodiversity status assessment results for harbour porpoise, as generated by the BEAT tool, based on the qualitative evaluations for population trends and abundance and distribution(HELCOM 2023k, HELCOM 2023l). Values >0.6 represent good status. Confidence is presented in the map insert. Corresponding qualitative evaluation results for the indicators included in the integrated assessment are presented in the bottom of the figure.

The status of harbour porpoise is not good in the Baltic Sea (Figure 7.11).

Both assessed populations fail to achieve the threshold value in any of the included indicators and thus the integrated status is not assessed as good. Of particular concern are the local population of harbour porpoise in the Baltic Proper, with a population size estimated at around 500 animals in 2011-2013. The indicators on harbour porpoise abundance and distribution were evaluated using a qualitative approach and the overall confidence of the assessment is low. Bycatch pressure exceeds threshold values for both popultions.

7.2.2 Indicator evaluation results for marine mammals

The status assessment of marine mammals presented in section 7.3.1 is underpinned by indicators, and subsequent indicator evaluation results, as presented in Annex 2, section Marine mammals. These indicator evaluations provide more detailed information on the status of marine mammals in the Baltic Sea, and are then integrated to achieve a status assessment for marine mammals by species and group. Annex 2 provides a comprehensive overview of the coverage, results and status provided through the relevant indicator evaluations for the assessment period 2016-2021. For overview maps showing the status, as well as brief summaries, please see the section for the indicator in question further down in this chapter.

Table 7.5. BEAT output from the integrated assessment for harbour porpoise. The column "Sub-basin" referes to the agreed name of each individual assessment area. "Spatial assessment unit level" indicates at what spatial resolution the assessment was conducted (see Section 2.3.2 or the HELCOM Monitoring and Assessment Strategy for more information on the assessment units used for HELCOM assessments). "Biological Quality Ratio" represents the quantitative results of the integrated assessment for the topic, with results >0.6 constituting Good Status (see Section 2.1.1 for more information on the BEAT tool). The column "Status" indicates whether the quantitative assessment results achieve of fail the threshold for good status. The columns "Confidence" and "Confidence Class", respectivey, provides a quantified value for confidence in the assessment and translates this value into a discreet confidence class, in line with the methodology outlined in Section 2.1.1.

Sub-basin	Spatial assessment unit level	Biological quality ratio	Status	Confidence	Confidence Class
Kattegat	2	0.4	not good	0.44	Low
Great Belt	2	0.4	not good	0.44	Low
The Sound	2	0.4	not good	0.44	Low
Kiel Bay	2	0.4	not good	0.44	Low
Bay of Mecklenburg	2	0.4	not good	0.44	Low
Arkona Basin	2	0.2	not good	0.33	Low
Bornholm Basin	2	0.2	not good	0.25	Low
Gdansk Basin	2	0.2	not good	0.25	Low
Eastern Gotland Basin	2	0.2	not good	0.25	Low
Western Gotland Basin	2	0.2	not good	0.25	Low
Gulf of Riga	2	0.2	not good	0.25	Low
Northern Baltic Proper	2	0.2	not good	0.25	Low
Gulf of Finland	2	0.2	not good	0.25	Low
Åland Sea	2	0.2	not good	0.25	Low
Bothnian Sea	2	0.2	not good	0.25	Low
The Quark	2	0.2	not good	0.25	Low
Bothnian Bay	2	0.2	not good	0.25	Low

Grey seal

Evaluation of population trends and abundance for grey seal

The core indicator 'Population trends and abundance for grey seal' evaluates the status of the marine environment based on population trends and abundance of the grey seal in the Baltic Sea. Good status is achieved when i) the abundance of seals in each management unit has attained a Limit Reference Level (LRL) of at least 10,000 individuals to ensure long-term viability and ii) the population trend, evaluated by species-specific growth rate, for a population either under or at Target Reference Level (TRL) is achieved indicating that growth-rates are not affected by severe anthropogenic pressures.

As a highly mobile species the grey seal population of the Baltic Sea is evaluated as a single management unit covering the whole HELCOM area. The evaluations for population trends are based on data from 2003-2021. For reliable trend calculations this longer time-series is needed, however the most recent data from the assessment period 2016-2021 is used to assess population abundance.

The abundance of grey seals (around 60,000 animals) is above the threshold of Limit Reference Level (LRL) of 10,000. The population is still growing, and was, as such, evaluated as being below Target reference Level (TRL) and evaluated against the threshold of 7% annual increase during exponential growth. The annual estimated growth rate during the period 2003-2021 was 5.1% and a Bayesian analysis showed 80% support for growth rate of ≥4.7%, which is under the threshold of 7% (Figure 7.12). Grey seals reach good status with regard to abundance, but they do not achieve good status with regard to population trend when evaluated as under TRL. With one-out-all-out –approach, the grey seals fail to achieve good status. For more information on the evaluation, please see the relevant indicator report (HELCOM 2023v)

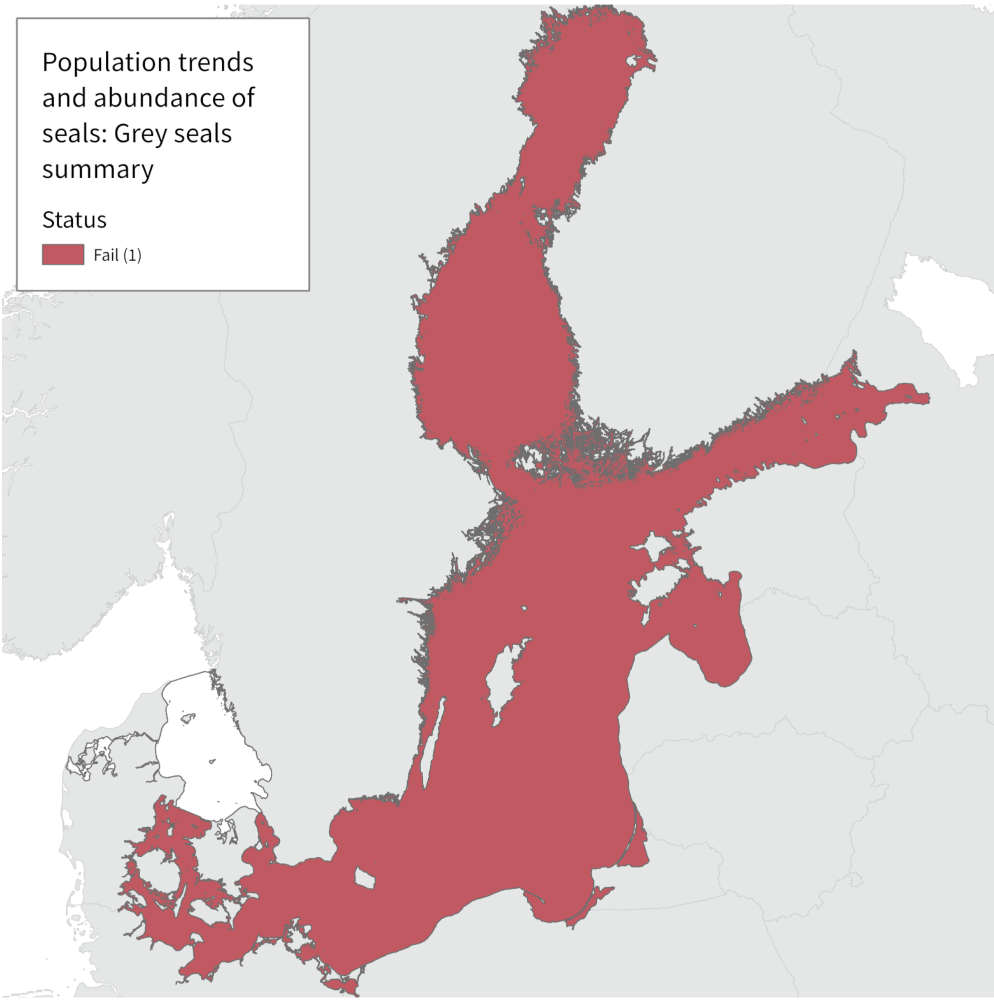


Figure 7.12. The overall status evaluation results based on evaluation of the indicator 'population trends and abundance of seals' –Grey seals. The evaluation is carried out using Scale 2 HELCOM assessment units (using the one-out-all-out approach). Thus, if a seal management unit, in not good status, has a given HELCOM assessment unit as part of its range, the assessment unit is marked red. (Source: HELCOM 2023v).

Evaluation of distribution of grey seals

This core indicator evaluates the state of the marine environment based on the distribution of grey seal in the Baltic Sea. The core indicator has three components: Breeding distribution, Moulting distribution and Area of occupancy (i.e. at-sea distribution). Good status is achieved when the distribution of grey seals is close to pristine conditions (e.g. 100 years ago), or where appropriate when currently available haul-out sites are occupied (modern baseline), and when no decrease in area of occupation occurs. The current evaluation covers the assessment period 2016-2021.

The component area of occupancy for grey seals achieves the threshold value for good status, since grey seals forage in the entire Baltic Sea. For the evaluation of land haul-outs, "modern baseline" is used since some haul-outs in the southern Baltic have vanished due to human exploitation of sand. Grey seals achieve the threshold in most areas of the Baltic except a few HELCOM assessment units in the southwestern areas. Arkona basin, Bay of Mecklenburg, Kiel Bay, Great Belt, the Sound and Kattegat fail for both breeding and moulting distribution and, in addition, Bornholm and Gdansk basins fail for breeding distribution. Considering the one-out-all-out approach, the Baltic grey seal thus fails to achieve good status for the distribution (Figure 7.13). For more information on the evaluation please see the relevant indicator report (HELCOM 2023y).

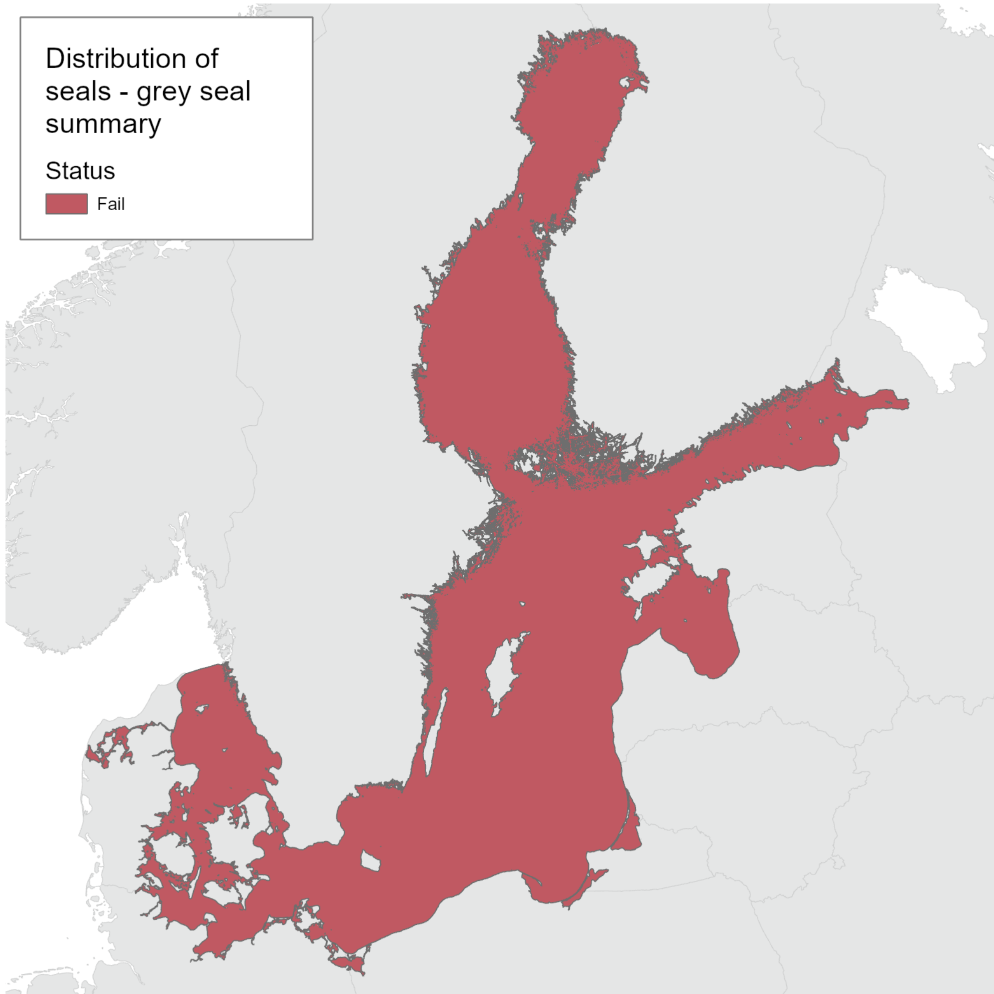


Figure 7.13. Status evaluation results based on evaluation of the indicator 'distribution of Baltic Seals' – Grey seal . The evaluation is carried out using grouping of scale 2 HELCOM assessment units to match with the range of the seal management unit. (Source: HELCOM 2023y).

Evaluation of nutritional status of grey seals

This core indicator evaluates the status of the marine environment in terms of the nutritional status of seals, measured as average blubber thickness of seal populations based on data collected on hunted grey seals. This signals both long-term and short-term changes in food supply and many other stressors. Good status is achieved when the subcutaneous blubber thickness is above the defined threshold value, which reflects good conditions. In the current evaluation (2016-2021) the grey seal failed to achieve the threshold value for both hunted and bycaught seals (Figure 7.14) and the population is thus in not good status for the whole Baltic Sea. For more information on the evaluation please see the relevant indicator report (HELCOM 2023ab).

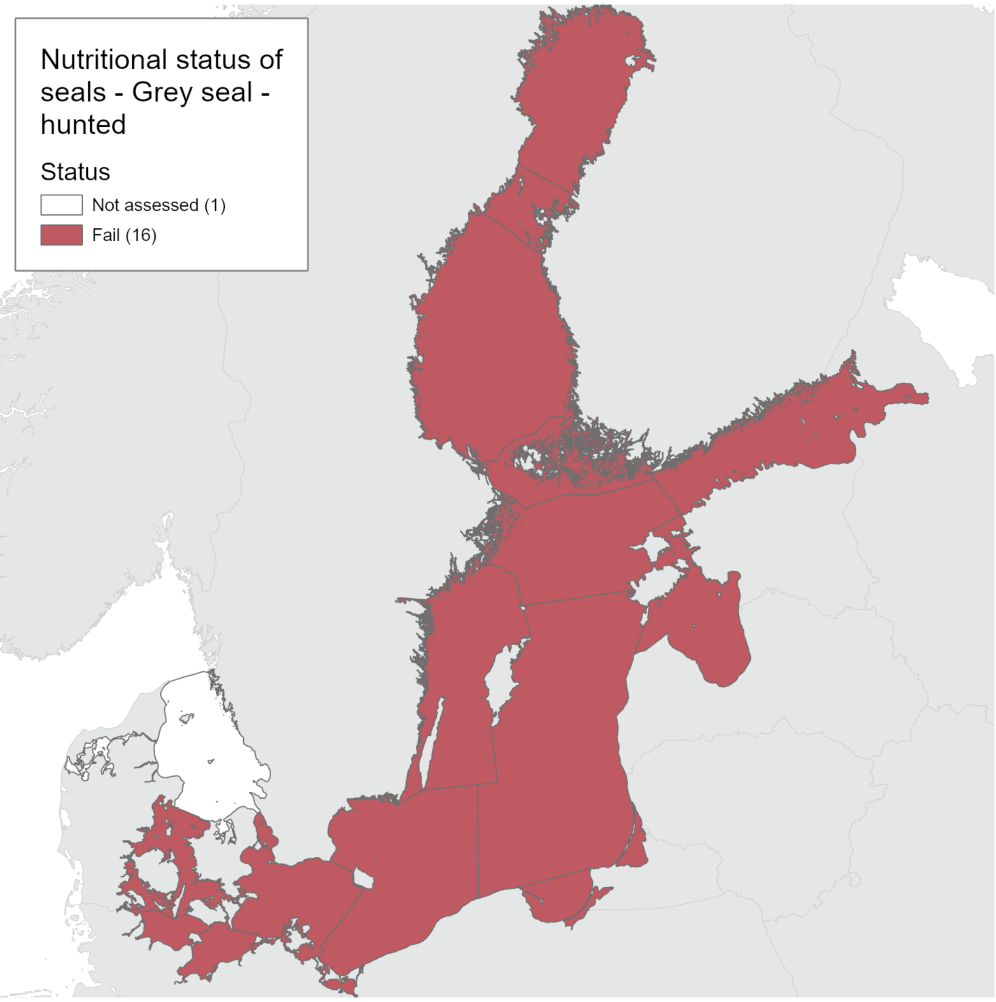


Figure 7.14. Status evaluation results based on evaluation of the indicator 'nutritional status of seals' 2016–2021. The evaluation is carried out using aggregated Scale 2 HELCOM assessment units – whole Baltic Sea excluding the Kattegat and Limfjord. Status evaluation is carried out based on standardized samples of blubber thickness observations in hunted grey seals and a threshold of 40 mm is used (left). Status evaluation is carried out based on standardized samples of blubber thickness observations in bycaught grey seals and a threshold of 35 mm is used (right). The indicator is applicable in the waters of all the countries bordering the Baltic Sea since the indicator targets a marine mammal species that occur in all HELCOM assessment units. In the 2023 indicator evaluation, presented here, only the grey seal nutritional status is directly assessed and the status evaluation for the entire Baltic Sea region is extrapolated from data gathered from Finland and Sweden (including the southern parts of Sweden). (Source: HELCOM 2023ab).

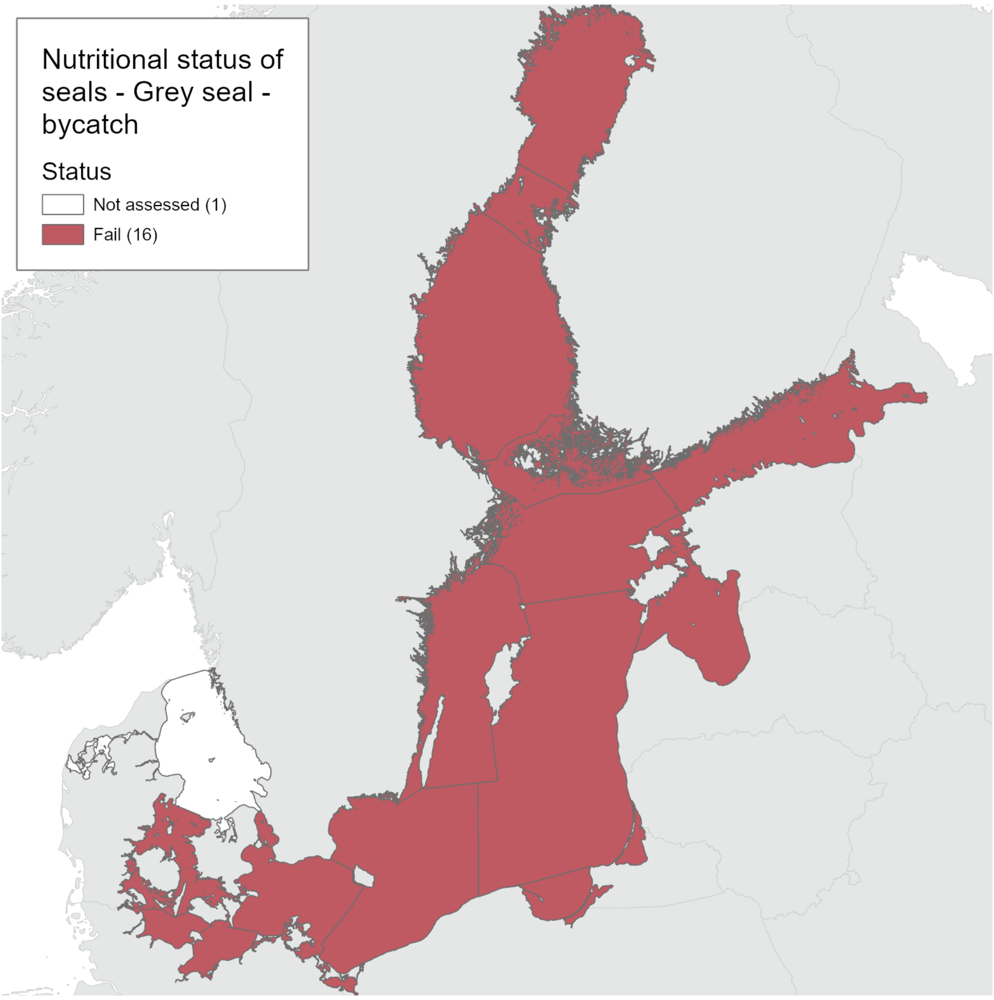


Figure 7.14. (Continued). Status evaluation results based on evaluation of the indicator 'nutritional status of seals' 2016–2021. The evaluation is carried out using aggregated Scale 2 HELCOM assessment units – whole Baltic Sea excluding the Kattegat and Limfjord. Status evaluation is carried out based on standardized samples of blubber thickness observations in hunted grey seals and a threshold of 40 mm is used (left). Status evaluation is carried out based on standardized samples of blubber thickness observations in bycaught grey seals and a threshold of 35 mm is used (right). The indicator is applicable in the waters of all the countries bordering the Baltic Sea since the indicator targets a marine mammal species that occur in all HELCOM assessment units. In the 2023 indicator evaluation, presented here, only the grey seal nutritional status is directly assessed and the status evaluation for the entire Baltic Sea region is extrapolated from data gathered from Finland and Sweden (including the southern parts of Sweden). (Source: HELCOM 2023ab).

Evaluation of reproductive status of grey seal

This core indicator evaluates the status of the marine environment based on the reproductive status of seals in the Baltic Sea, more specifically for grey. Good status is achieved when the annual pregnancy rate is at least 90%. The overall status assessment is evaluated based on the combined gestation rate (visible foetus during the gestation period) and the postpartum pregnancy rate (*corpus albicans* and a placental scar during the postpartum period). The aggregated pregnancy rate is calculated for each reproductive period during the assessment period 2016-2021. Grey seal females aged between 6-24 years for the gestation rate and 7-25 years for the postpartum pregnancy signs rate are included in the assessment. Grey seal reproduction is not in good status with regards to reproductive rate in the entire Baltic when evaluated as one single population. The pregnancy rate (aggregated ratio) reached the threshold value in 2017 and in 2018, but on average across the current assessment period a rate of 87% was reached, thus the threshold value of 90% was not achieved (Figure 7.15). For more information on the evaluation please see the relevant indicator report (HELCOM 2023m).

Currently, a full status evaluation has been carried out based on Finish and Swedish data only.

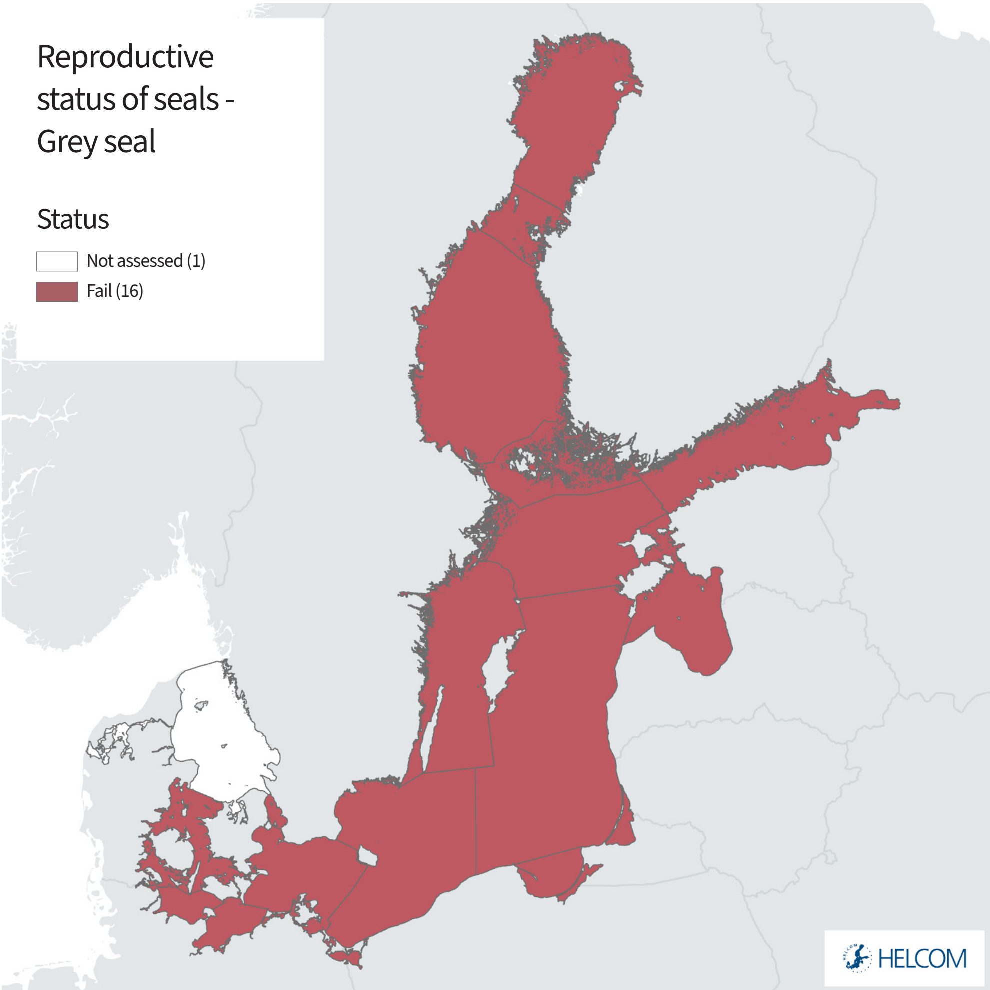


Figure 7.15. Status assessment results based on evaluation of the indicator. The assessment is carried out using HELCOM assessment unit scale 2. (Source: HELCOM 2023m).

Ringed seal

Evaluation of population trends and abundance of ringed seal

This core indicator report evaluates the status of the marine environment based on population trends and abundance of the Baltic Sea ringed seals. Good status is achieved for each species when i) the abundance of seals in each management unit has attained a Limit Reference Level (LRL) of at least 10,000 individuals to ensure long-term viability and ii) the population trend, assessed by species-specific growth rate, for a population either under or at Target Reference Level (TRL) is achieved, indicating that growth-rates are not affected by severe anthropogenic pressures.

The ringed seal is evaluated in two management units: the Bothnian Bay and the southern management unit, which consists of sub-populations in the Archipelago Sea, the Gulf of Finland and western Estonia.

For the ringed seal population in Bothnian Bay the Bayesian analyses showed 80% support for growth rate of ≥ 5.0% for 2003-2012. This is below the threshold of 7%. Trend calculation for data collected after 2012 was not possible. The inventory results from these years have been anomalously high with extreme inter-annual variation, the results do not fit with the previous trend-lines and show “increases” that are not biologically possible. The ice-conditions are changing in Bothnia Bay and it is hypothesised that the inconsistent survey results are a result of an increased fraction of the total population being observed hauled-out on the ice during the survey period, likely due to lower ice-coverage and earlier ice-breakup. There have, however, been no indication of a major decrease in the population. The highest estimate of hauled out ringed seals during the assessment period (i.e. 2016-2021) was 14,602 (2021), which is over the abundance threshold of Limit Reference Level (LRL) 10,000. With one-out-all-out –approach, the Bothnian Bay ringed seal fail to achieve good status (Figure 7.16).

In the Gulf of Finland, Archipelago Sea and western Estonia, the numbers of counted ringed seals only sums up to a small fraction of the threshold for abundance and none of the areas are showing signs of increase. The southern ringed seal management unit does not achieve good status (Figure 7.16). For more information on the evaluation please see the relevant indicator report (HELCOM 2023w).

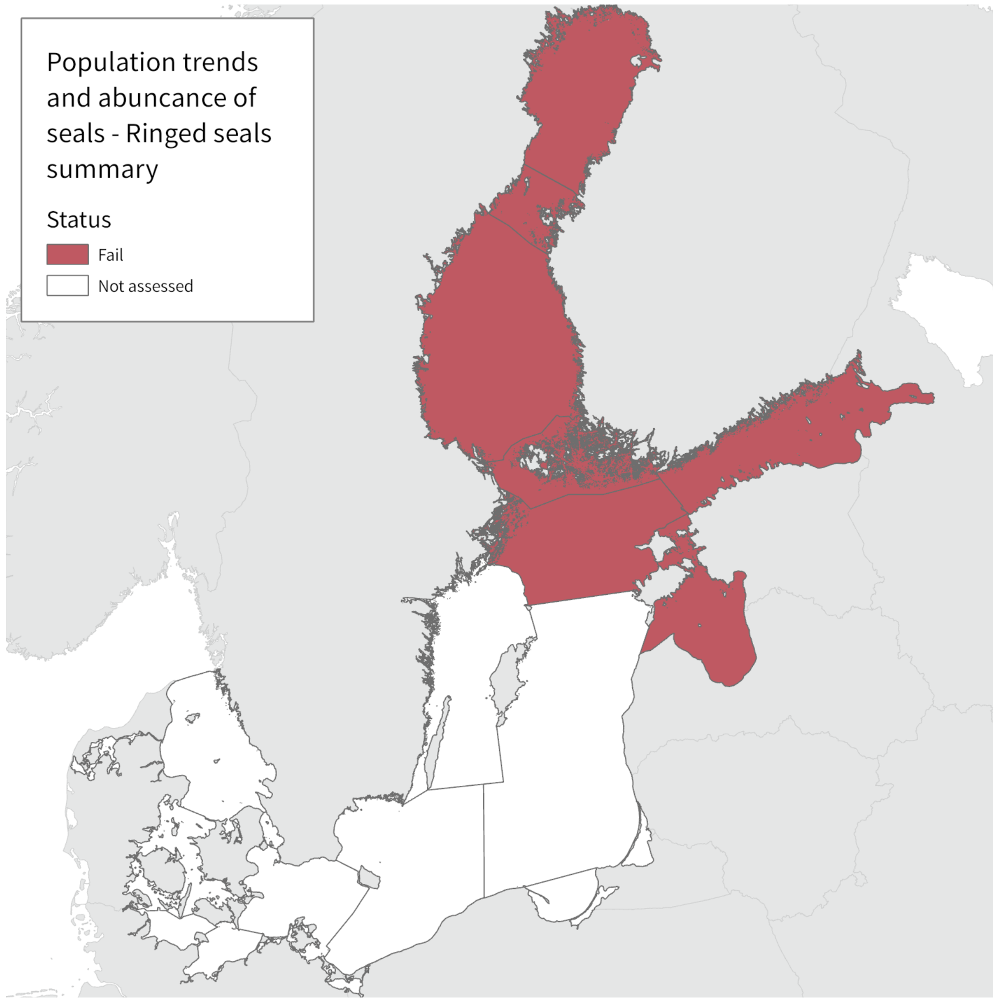


Figure 7.16. The overall status assessment results based on evaluation of the indicator ‘population trends and abundance of seals’ – Ringed seals. The assessment is carried out using Scale 2 HELCOM assessment units, using the one-out-all-out approach. Thus, if a seal management unit, in not good status, has a given assessment unit as part of its range, the assessment unit is marked red. (Source: HELCOM 2023w).

Evaluation of distribution of ringed seal

This core indicator report evaluates the state of the marine environment based on the distribution of the ringed seal in the Baltic Sea. The core indicator has three components: Breeding distribution, Moulting distribution and Area of occupancy. Good status is achieved when the distribution of seals is close to pristine conditions (e.g. 100 years ago), or where appropriate, when currently available haul-out sites are occupied (modern baseline), and when no decrease in area of occupation occurs. The current evaluation covers the assessment period 2016-2021. The ringed seal is evaluated in two management units: the Bothnian Bay and the southern management unit. The latter consists of sub-populations in the Archipelago Sea, the Gulf of Finland and western Estonia.

While the at sea area of occupancy of ringed seals is not limited, breeding and moulting distribution is currently significantly reduced compared to pristine conditions in all subpopulations (Figure 7.17). Therefore the ringed seals do not achieve good status for the Distribution indicator. For more information on the evaluation please see the relevant indicator report (HELCOM 2023z).

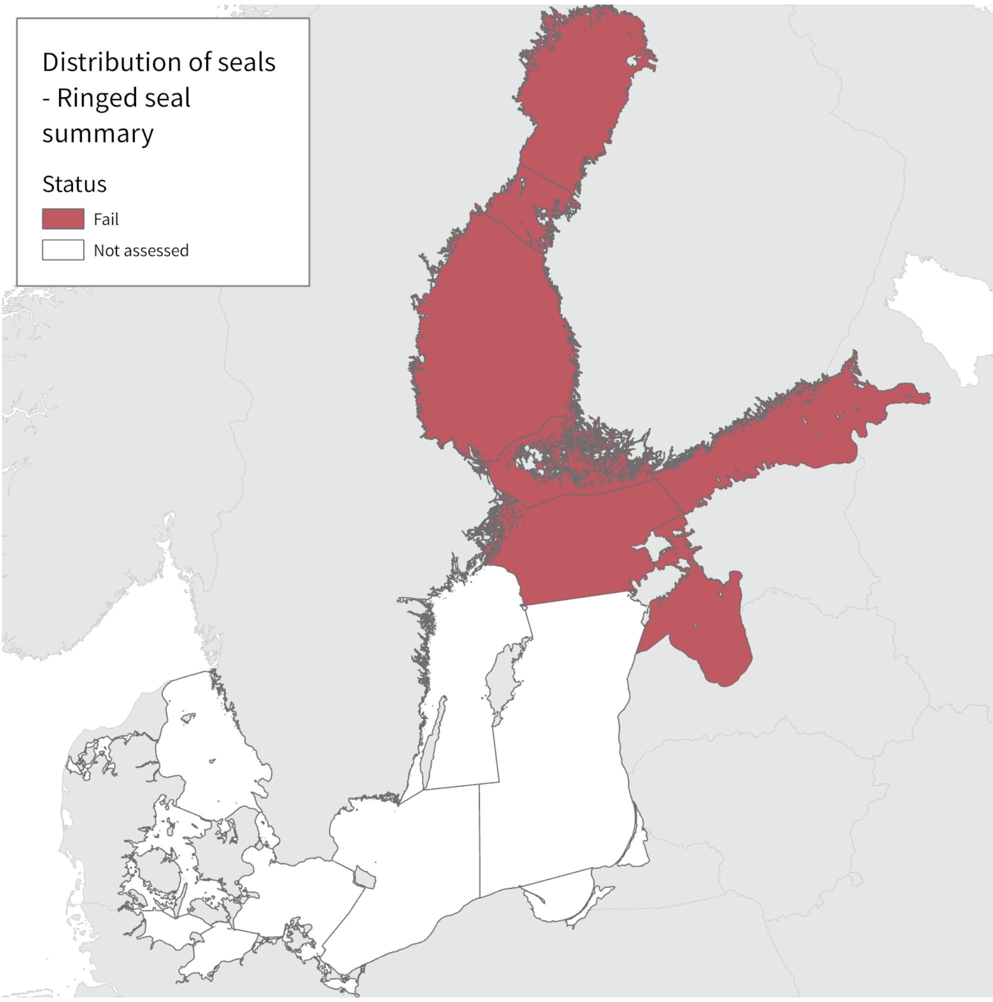


Figure 7.17. Status assessment results based on evaluation of the indicator 'distribution of Baltic Seals – Ringed seals'. The assessment is carried out using grouping of scale 2 HELCOM assessment units. (Source: HELCOM 2023z).

Evaluation of reproductive status of ringed seal

This core indicator evaluates the status of the marine environment based on the reproductive status of seals in the Baltic Sea, more specifically for ringed seals. Good status is achieved when the annual pregnancy rate is at least 90%. The overall status assessment is evaluated based on the combined gestation rate (visible foetus during the gestation period) and the postpartum pregnancy rate (*corpus albicans* and a placental scar during the postpartum period). The aggregated pregnancy rate is calculated for each reproductive period during the assessment period 2016-2021. Ringed seal females aged between 6-24 years for the gestation rate and 7-25 years for the postpartum pregnancy signs rate are included in the assessment. Currently, a full status evaluation has been carried out for the grey seal and the ringed seal based on Finish and Swedish data only and data for ringed seal was only present for the Bothnian Bay management unit, in which the reproductive rate falls below the threshold during the assessment period (Figure 7.18). For more information on the evaluation please see the relevant indicator report (HELCOM 2023m).

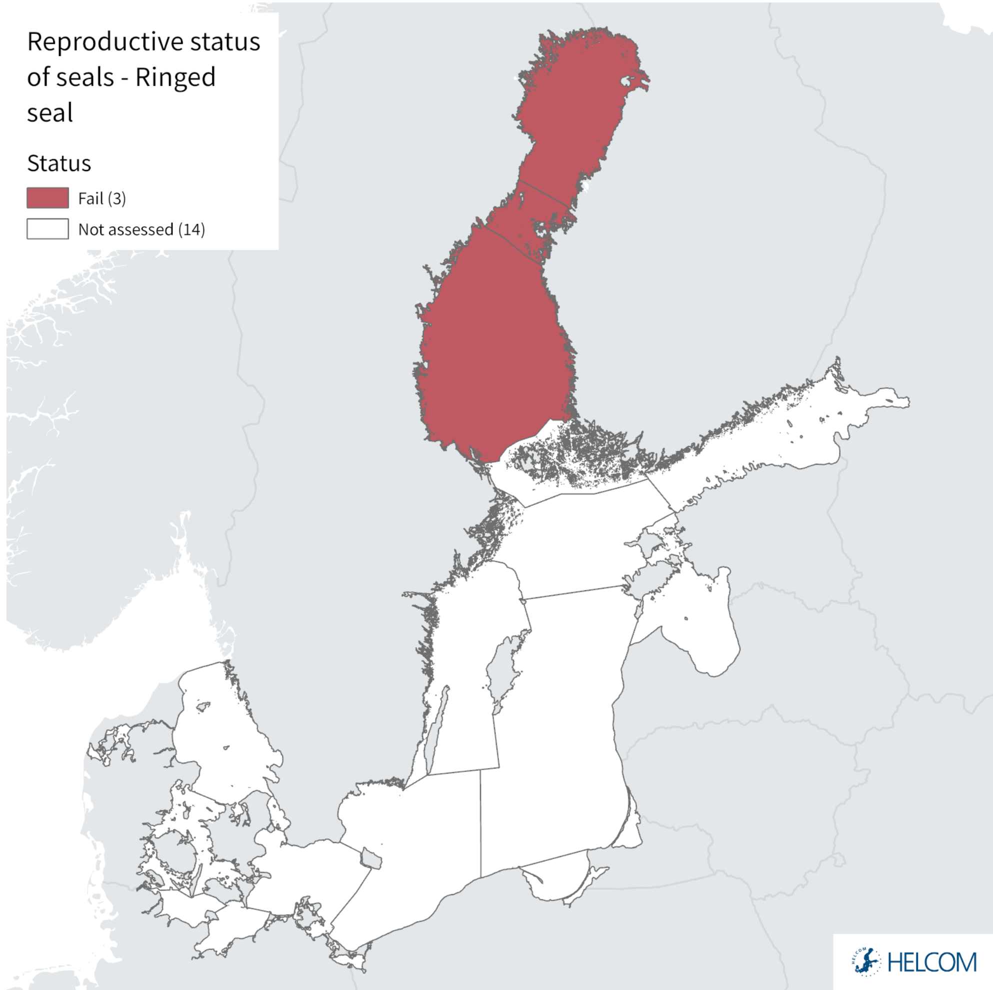


Figure 7.18. Status assessment results based on evaluation of the indicator 'reproductive status of seals' for ringed seals. The assessment is carried out using HELCOM assessment unit scale 2. (Source: HELCOM 2023m).

Harbour seal

Evaluation of population trends and abundance of harbour seal

This core indicator evaluates the status of the marine environment based on population trends and abundance of the Baltic Sea harbour seal. Good status is achieved when i) the abundance of seals in each management unit has attained a Limit Reference Level (LRL) of at least 10,000 individuals to ensure long-term viability and ii) the population trend, assessed by species-specific growth rate, for a population either under or at Target Reference Level (TRL), is achieved, indicating that growth-rates are not affected by severe anthropogenic pressures.

The harbour seal populations in the HELCOM area are currently recognized as two official management units consisting of: (i) Kalmarsund, (ii) southwestern (SW) Baltic Sea and the Kattegat. In addition, a third unofficial unit, (iii) the Limfjord, is also assessed.

Multiple lines of evidence suggest that Kattegat and SW Baltic harbour seals are demographically independent, but currently they are officially recognised as one unit (on the basis of HELCOM RECOMMENDATION 27-28/21). They have been evaluated in line with the approach used for HOLAS II: abundance has been evaluated using the combined abundance of the two areas, whereas trends have been evaluated for each area independently. Finally, harbour seals in the Limfjord are not related to other units in the HELCOM area however this area is not recognised as a separate unit under HELCOM. A separate unofficial evaluation was prepared for this area.

The evaluation for population trends is based on data from 2003-2021, since long-term time-series are needed to detect changes in population growth rates. Data from the assessment period 2016-2021 is used to assess population abundance.

All assessed harbour seal management units fail to achieve good status because they fail the threshold values for both the population abundance and population trend evaluation (Figure 7.19).

Kalmarsund harbour seals have increased with a rate very close to the threshold for good status, but their abundance is still well below the Limit Reference Level and thus, status for the subpopulation is not good. However, it is uncertain if the LRL established for this population is achievable as the threshold value might be above the carrying capacity.

The SW Baltic population alone is below Limit Reference Level, but when assessed together with Kattegat, the combined abundance exceeds Limit Reference Level. The growth rate in SW Baltic however is still below the threshold value, indicating not good status. Abundance in Kattegat exceeds LRL, but growth rate is below the threshold when assessed as below Target Reference Level and the unit does not achieve good status. However, it is uncertain if the Kattegat unit is at or below Target Reference Level or undergoing a decline. Both abundance and growth rate of harbour seals in Limfjord are low and they do not achieve good status. For more information on the evaluation please see the relevant indicator report (HELCOM 2023x).

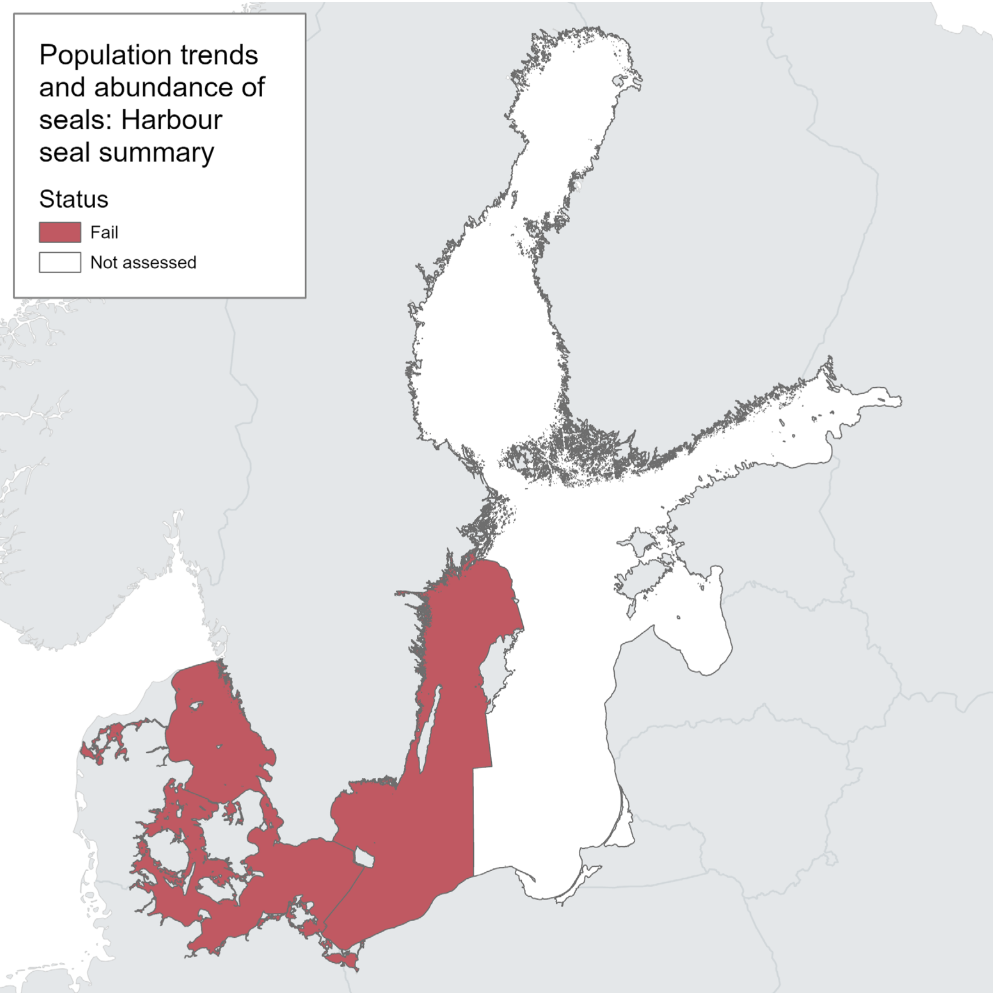


Figure 7.19. The overall status evaluation results based on the indicator 'population trends and abundance of seals' – Harbour seals. The evaluation is carried out using Scale 2 HELCOM assessment units, using the one-out-all-out approach. Thus, if a seal management unit, in not good status, has a given HELCOM assessment unit as part of its range, the assessment unit is marked red. (Source: HELCOM 2023x).

Evaluation of distribution of harbour seal

This core indicator evaluates the state of the marine environment based on the distribution of harbour seals that occur in the Baltic Sea. The core indicator has three components: Breeding distribution, Moulting distribution and Area of occupancy (i.e. at-sea distribution). Good status is achieved when the distribution of seals is close to pristine conditions (i.e. 100 years ago), or where appropriate when currently available haul-out sites are occupied (modern baseline), and when no decrease in area of occupation occurs. The current evaluation covers the assessment period 2016-2021. For the distribution indicator, the subpopulations Kalmarsund, and the group consisting of the SW Baltic, Kattegat and Limfjord are assessed independently.

The state of distribution of harbour seals achieves the threshold value for good status in the Kattegat and Limfjord where the breeding and moulting distribution as well as area of occupancy are at pristine levels. However, good status is not achieved for the SW Baltic, therefore when combined as one management area (HELCOM Recommendation 27/28-2) overall good status is not achieved. The Kalmarsund sub-population fails to achieve good status, since although the area of occupancy (i.e. at-sea distribution) is at pristine levels, not all suitable land sites are used (Figure 7.20). For more information on the evaluation please see the relevant indicator report (HELCOM 2023aa).

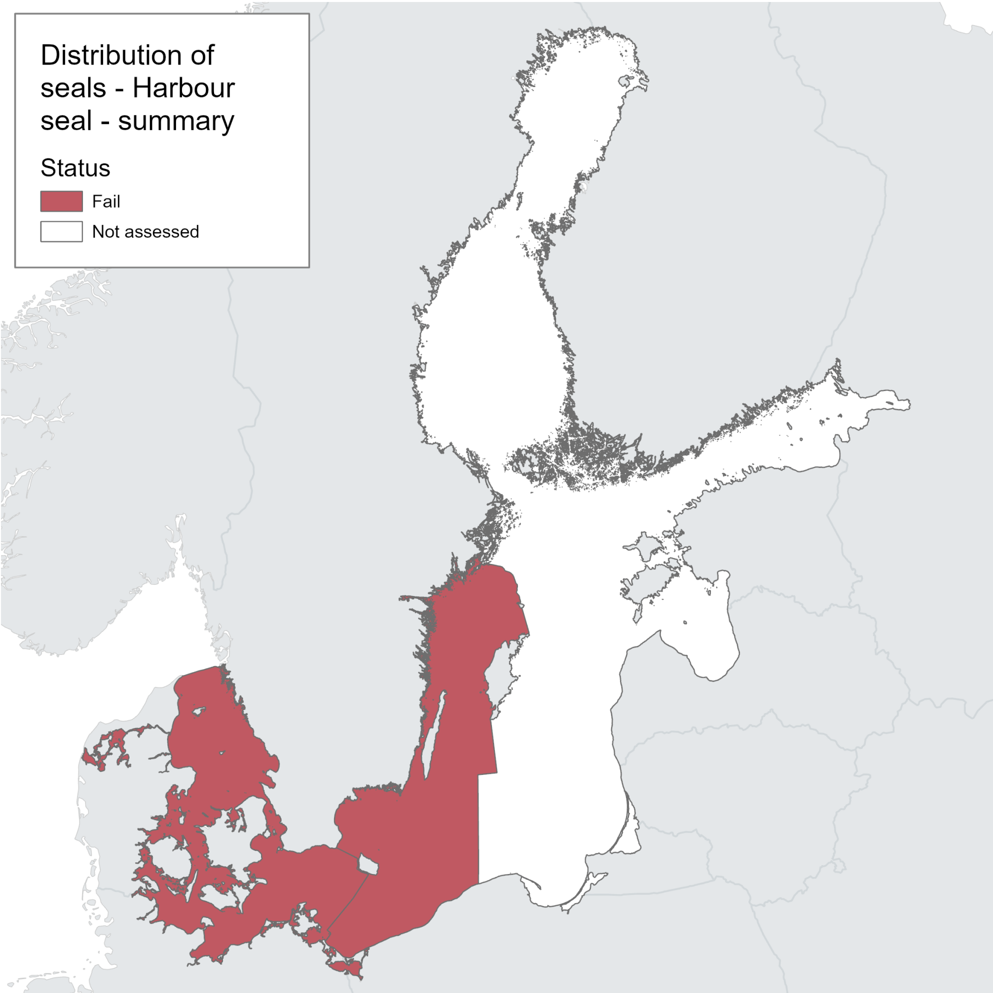


Figure 7.20. Status assessment results based on evaluation of the indicator 'distribution of Baltic Seals' –Harbour seal . The assessment is carried out using grouping of scale 2 HELCOM assessment units, aggregated to relevant agreed management areas. (Source: HELCOM 2023aa).

Harbour porpoise

Pre-core evaluation of abundance and population trends of harbour porpoises. This pre-core indicator evaluates whether the absolute abundance and the trend in abundance of harbour porpoises in the Baltic Sea is adversely affected due to anthropogenic pressures, and whether its long-term viability is ensured. In an optimal situation, good status for abundance is achieved when a population's abundance exceeds the population-specific Limit Reference Level (LRL) with a steady increasing trend towards the population-specific Target Reference Level (TRL). Since regionally agreed threshold values are not yet vailable, quantitative assessment of status was not applicable and a qualitative, expert-based assessment was conducted instead.

The HELCOM area is inhabited by two separate harbour porpoise populations: (i) the Belt Sea population in southern Kattegat, the Belt Sea, the Sound, and southwestern Baltic, and the (ii) the Baltic Proper population in the waters east thereof (summer distribution range, winter distribution range uncertain for the Baltic Proper population) (Carlén *et al.* 2018, Sveegaard *et al.* 2015). The assessments are carried out separately for the two populations, and presented on the level of scale 2 HELCOM assessment units aggregated to relevant population scales. The assessment of absolute abundance and trends are always completed on the population level (assessed using population-level surveys, e.g. SCANS, MiniSCANS or SAMBAH).

Based on the very small current abundance estimate in combination with a drastic reduction in occurrence inferred from the historical records, the abundance of the Baltic Proper harbour porpoise is assessed as not good. To date, only one population-wide abundance survey has been carried out in 2011-2013, yielding an abundance of 491 animals (95% CI: 71-1105) (Amundin *et al.* 2022), and the small population size clearly indicates that the status of the population is not good. Due to the lack of appropriate data for a quantitative assessment of trend, a qualitative assessment was carried out, based on an evaluation of the absolute abundance estimate from SAMBAH in combination with historical records on harbour porpoise occurrence within the May-October management range of the Baltic Proper population. The qualitative assessment shows that the abundance of the Baltic Proper harbour porpoise has declined over the last century and does not achieve good status (Figure 7.21).

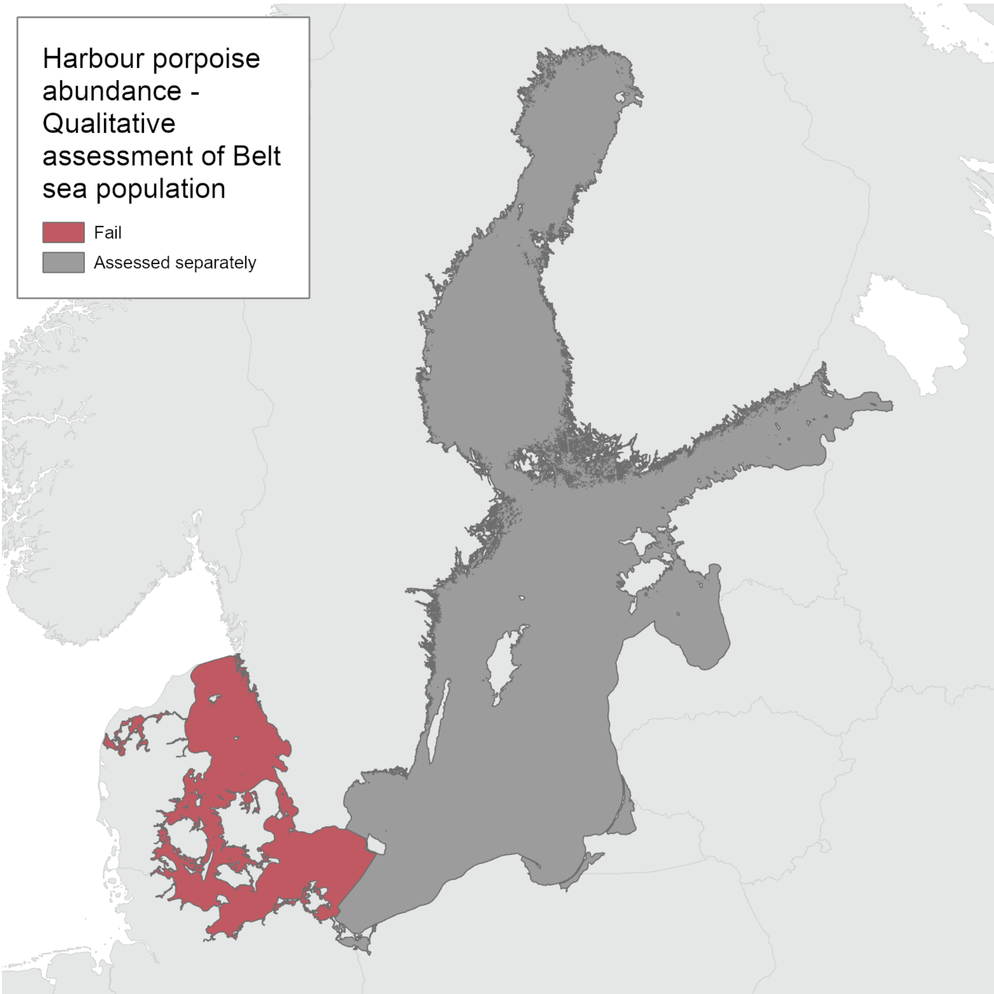


Figure 7.21. Status qualitative assessment results based on an evaluation of the trend in abundance and absolute abundance of the Belt Sea harbour porpoise population (left), and of the absolute abundance and historical occurrence of the Baltic Proper harbour porpoise population (right). The qualitative assessments are carried out using Scale 2 HELCOM assessment units. (Source: HELCOM 2023k).

Similarly, a qualitative assessment was carried out for the Belt Sea population, due to a lack of sufficient data and absence of threshold values for good status. The qualitative assessment integrated the aspects of absolute abundance and the trend in abundance. For the absolute abundance, the latest abundance estimate of 17,301 harbour porpoises (CV: 0.20) from 2020 was evaluated (Unger *et al.,* 2021) against an indicative target threshold of 10,000 mature individuals, as suggested as the limit for a population to be 'Vulnerable' in the IUCN Red List of Threatened Species, (IUCN, 2012). In advice to OSPAR, ICES (2014) recommended to consider IUCN quantitative criteria when implementing the Marine Strategy Framework Directive (MSFD) for marine mammals and this has been adopted by OSPAR (2021). It is considered that the number of mature animals in the Belt Sea population is below 10,000 individuals, as the majority of animals in the population are unlikely to have reached sexual maturity (Kesselring *et al.*, 2017). Thus, the absolute abundance was evaluated as not being in good status.

Two different trend-based approached were utilised to evaluate trends in abundance for the Belt Sea population (Gilles *et al.* 2022). Considering the available data for the Belt Sea population, for both approaches a trend could only be assessed over a relatively short period of 15 years (2005-2020) since the survey area of the first abundance estimate (SCANS 1994) did not completely cover the distributional range of the population and missed out a large part (30%) of the area in the east. Both analytical approaches showed no statistically significant trend in abundance for the Belt Sea population of harbour porpoises indicating good status. Hence, the absolute abundance failed the threshold value for good status but good status was achieved according to the indicator trend in abundance. However, when integrating the two assessments, the one-out-all-out rule applies, and thus the overall qualitative assessment of the Belt Sea harbour porpoise population indicates that it does not achieve good status (Figure 7.21). For more information on the evaluation please see the relevant indicator report (HELCOM 2023k).

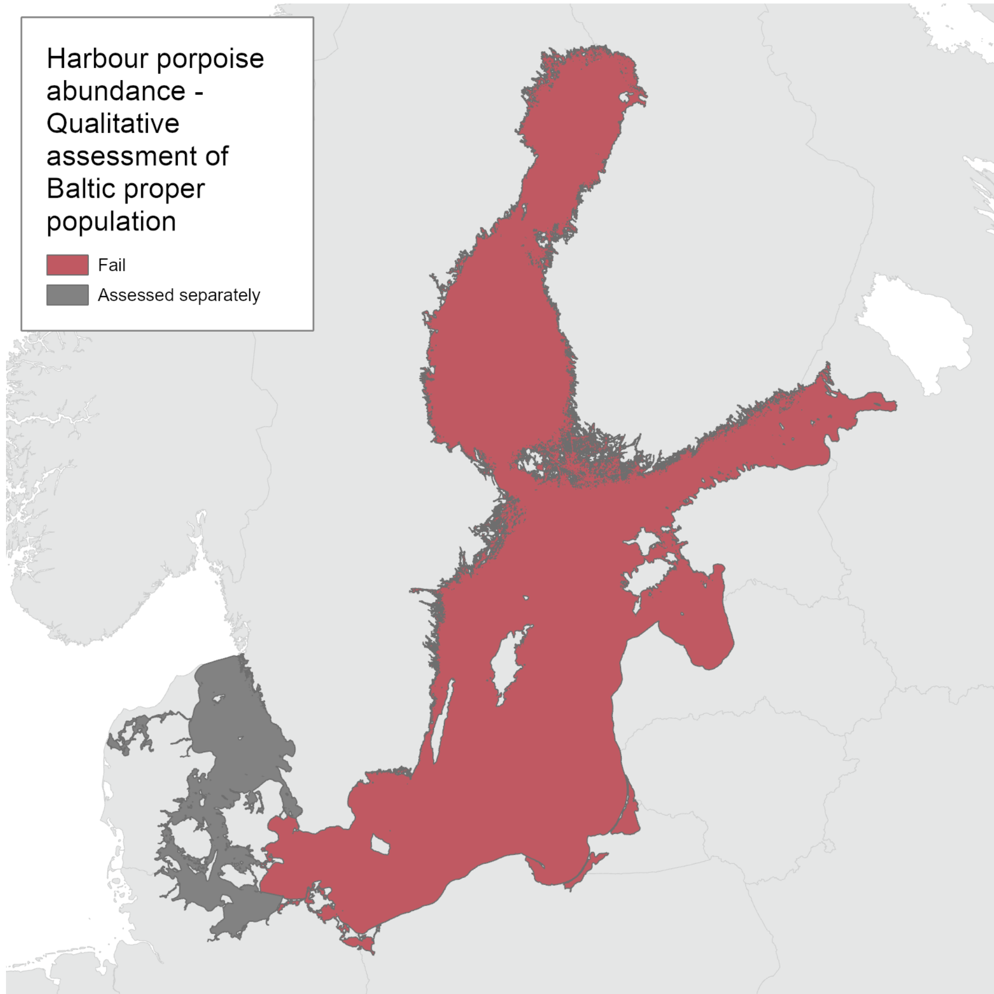


Figure 7.21. (Continued). Status qualitative assessment results based on an evaluation of the trend in abundance and absolute abundance of the Belt Sea harbour porpoise population (left), and of the absolute abundance and historical occurrence of the Baltic Proper harbour porpoise population (right). The qualitative assessments are carried out using Scale 2 HELCOM assessment units. (Source: HELCOM 2023k).

Pre-core evaluation of distribution of harbour porpoise

This pre-core indicator evaluates whether the distribution of harbour porpoises in the Baltic Sea is adversely affected due to anthropogenic pressures, and thus, if its distributional range and pattern is in line with prevailing physiographic, geographic and climatic conditions.

For this expert-based evaluation (currently addresses only one population), good status for distribution is achieved when the distributional range, and the frequency of harbour porpoise records, in the Baltic Sea is the same as that indicated by historical records (starting from late 17th century), taking confounding factors into account. The threshold is not achieved by the Baltic Proper population.

The HELCOM area is currently inhabited by two separate harbour porpoise populations: (i) the Belt Sea population in southern Kattegat, the Belt Sea, the Sound, and southwestern Baltic, and the (ii) the Baltic Proper population in the waters east thereof (Carlén *et al.* 2018, Sveegaard *et al.* 2015). While there are reasonable estimates for distribution to support management (particularly in relation to summer distribution) there remain some uncertainties, especially with regard to the Baltic Proper population. The evaluation of population distribution is always completed on the population level (based on the results of population level surveys, e.g. SCANS, MiniSCANS and SAMBAH), together with the population level abundance evaluation. This is done to determine whether any observed change in distribution is likely to be a positive or negative factor as it can be challenging to evaluate whether an increase or decrease in distributional range is positive or negative without additional information on population status, or ideally, habitat quality over the current range (Owen *et al.* 2022).

The evaluation of the Baltic Proper population is based on data from one passive acoustic monitoring (PAM) survey (SAMBAH) in 2011-2013 (Carlén *et al.* 2018, Amundin *et al.* 2022). Due to the very low density of the Baltic Proper population, only dedicated acoustic methods should be applied. The SAMBAH survey identified a summer core area for the Baltic Proper population around the offshore banks, Hoburg's Bank, and the Northern and Southern Mid-Sea Banks (Carlén *et al.*, 2018). Due to the lack of appropriate data for a quantitative distribution assessment, a qualitative evaluation was carried out based on historical information on harbour porpoise occurrence within the May-October management range of the Baltic Proper population (HELCOM 2022b). The qualitative evaluation show that the distribution of the Baltic Proper harbour porpoise does not achieve good status (Figure 7.22).

The method for assessing changes in distribution for harbour porpoises in the Belt Sea is curently under developement, and it is thus not possible to make an evaluation of distribution for the Belt Sea population. Consequently this population is not included. For more information on the evaluation please see the relevant indicator report (HELCOM 2023l).

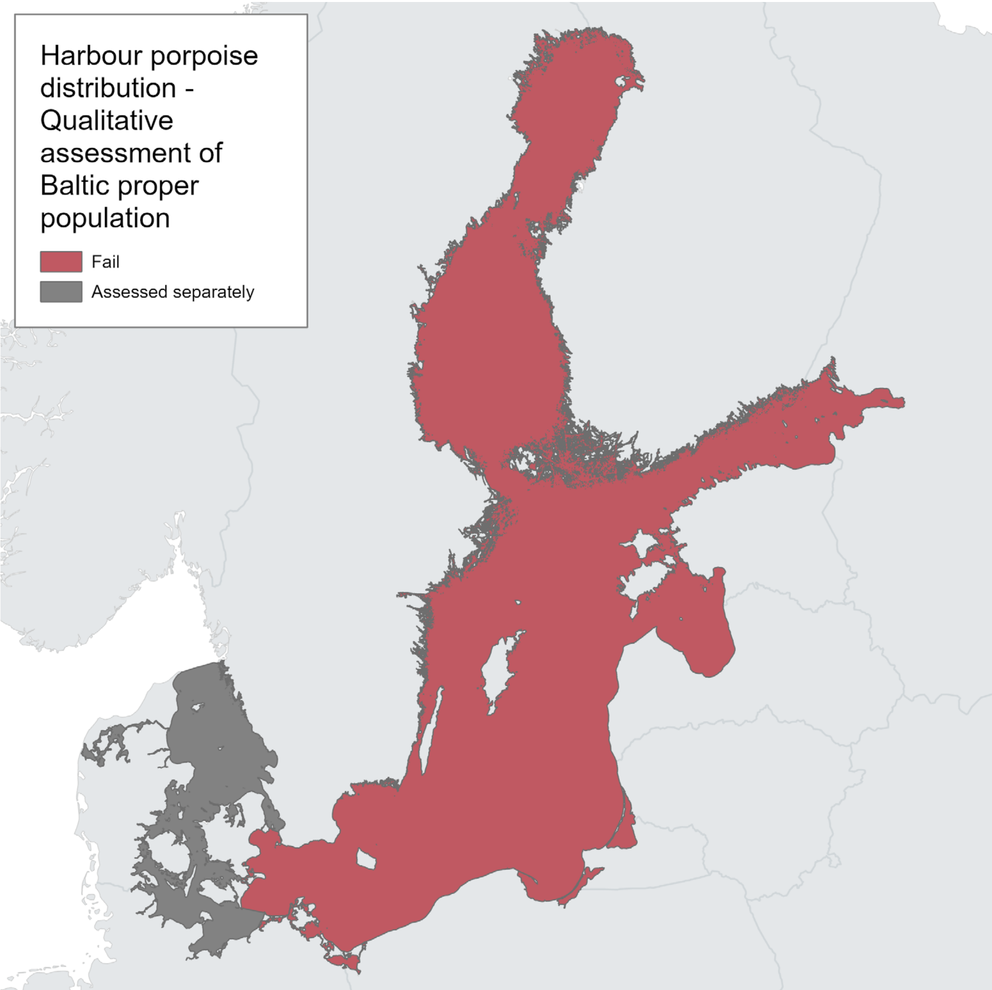


Figure 7.22. Status qualitative evaluation results based on an evaluation of the distribution and frequency of historical records of harbour porpoises within the May-October management range of the Baltic Proper harbour porpoise. The evaluation is carried out using Scale 2 HELCOM assessment units. (Source: HELCOM 2023l).

7.2.3 Threatened mammal species included in the assessment

Three of the four mammals species are considered threatened in at least part of their distributional area in the Baltic Sea. For the rational behind the threat assessment please see HELCOM Red List of Baltic Sea species in danger of becoming extinct (HELCOM 2013c).

Phoca hispida botnica	Baltic ringed seal	Mammals	VU
Phoca vitulina (Kalmarsund population)	Harbour seal	Mammals	VU
Phocoena phocoena (Baltic Sea population)	Harbour porpoise	Mammals	CR
Phocoena phocoena (Western Baltic subpopulation)	Harbour porpoise	Mammals	VU

7.3. Changes over time for marine mammals

For the trend in the integrated assessment of all seal species (Table 7.7) only one area, Kattegat, has moved from achieving good status to failing to achieve good status. However, the comparison of the results of the 2016-2021 assessment with the assessment results from the 2011-2016 assessment shows a downward trend in results for over half of the sub-basins, including all of the Northern Baltic Sea (Northern Baltic Proper, Gulf of Finland, Åland Sea, Bothnian Sea, The Quark and Bothnian Bay). In the Bornholm basin and Western Gotland Basin an improvement can be seen when comparing result, while the results indicate no change in the sub-basins Great Belt, The Sound, Kiel Bay, Bay of Mecklenburg and Arkona Basin. The confidence rating for the assessment has improved for the 2016-2021 assessment compared to the previous assessment period. The changes in assessment per indicator across the two assessment periods is presented in Annex 3 under Indicator evaluations for marine mammals.

Table 7.7. Overview of trends in the results and status of the integrated assessment for all seal species combined across the 2011-2016 and 2016-2021 assessments.

Assessment scale	Assessment Unit Code	Biological Quality Ratio 2016-2021	Status 2016-2021	Confidence	Biological Quality Ratio 2011-2016	Status 2011-2016	Confidence	Trend
2	Kattegat	0.6	fail	High	0.8	achieve	Intermediate	down
2	Great Belt	0.3	fail	High	0.3	fail	Intermediate	same
2	The Sound	0.3	fail	High	0.3	fail	Intermediate	same
2	Kiel Bay	0.3	fail	High	0.3	fail	Intermediate	same
2	Bay of Mecklenburg	0.3	fail	High	0.3	fail	Intermediate	same
2	Arkona Basin	0.3	fail	High	0.3	fail	Intermediate	same
2	Bornholm Basin	0.2	fail	High	0.1	fail	Intermediate	up
2	Gdansk Basin	0.3	fail	High	0.5	fail	Intermediate	down
2	Eastern Gotland Basin	0.3	fail	High	0.5	fail	Intermediate	down
2	Western Gotland Basin	0.2	fail	High	0.1	fail	Intermediate	up
2	Gulf of Riga	0.1	fail	High	0.3	fail	Intermediate	down
2	Northern Baltic Proper	0.1	fail	High	0.3	fail	Intermediate	down
2	Gulf of Finland	0.1	fail	High	0.3	fail	Intermediate	down
2	Åland Sea	0.1	fail	High	0.3	fail	Intermediate	down
2	Bothnian Sea	0.2	fail	High	0.3	fail	Intermediate	down
2	The Quark	0.2	fail	High	0.3	fail	Intermediate	down
2	Bothnian Bay	0.2	fail	High	0.3	fail	Intermediate	down

7.3.1 Changes over time for grey seal

Trends between assessments

While there is no change in status from good to not good or vice versa between assessments for grey seal, the results indicate a downward trend in status for the central and northern Baltic Sea (Table 7.8). The confidence rating for the assessment has improved for the 2016-2021 assessment compared to the previous assessment period.

Long term trend

Model calculation has estimated that in the beginning of the 20th century, the estimated population size was in the range of tens of thousands up to 100,000 (Kokko *et al.* 1999, Harding & Härkönen 1999). Historically, hunting of seals has been a major human pressure on all the seal species in the Baltic Sea. A coordinated international campaign with bounty systems introduced in several Baltic Sea countires was initiated in the late 19th century. The original grey seal population size is estimated at about 80,000 seals, using a model based on hunting statistics. The hunting pressure resulted in extirpation of grey seal in Germany and Poland in 1912, and grey seals were also extirpated from the Kattegat by the 1930s. Baltic grey seals were reduced to about 20,000 in the 1940s (Harding & Härkönen 1999).

Table 7.8. Overview of trends in the results and status of the integrated assessment of grey seal across the 2011–2016 and 2016–2021 assessments. An increasing Biological Quality Ratio value indicates an improving trend, decreasing Biological Quality Ratio value indicates a deteriorating trend.

Assessment scale	Assessment Unit Code	Biological Quality Ratio 2016-2021	Status 2016-2021	Confidence	Biological Quality Ratio 2011-2016	Status 2011-2016	Confidence	Trend
2	Kattegat	NA	NA	NA	NA	NA	NA	NA
2	Great Belt	0.3	fail	High	0.3	fail	Intermediate	same
2	The Sound	0.3	fail	High	0.3	fail	Intermediate	same
2	Kiel Bay	0.3	fail	High	0.3	fail	Intermediate	same
2	Bay of Mecklenburg	0.3	fail	High	0.3	fail	Intermediate	same
2	Arkona Basin	0.3	fail	High	0.3	fail	Intermediate	same
2	Bornholm Basin	0.3	fail	High	0.5	fail	Intermediate	down
2	Gdansk Basin	0.3	fail	High	0.5	fail	Intermediate	down
2	Eastern Gotland Basin	0.3	fail	High	0.5	fail	Intermediate	down
2	Western Gotland Basin	0.3	fail	High	0.5	fail	Intermediate	down
2	Gulf of Riga	0.3	fail	High	0.5	fail	Intermediate	down
2	Northern Baltic Proper	0.3	fail	High	0.5	fail	Intermediate	down
2	Gulf of Finland	0.3	fail	High	0.5	fail	Intermediate	down
2	Åland Sea	0.3	fail	High	0.5	fail	Intermediate	down
2	Bothnian Sea	0.3	fail	High	0.5	fail	Intermediate	down
2	The Quark	0.3	fail	High	0.5	fail	Intermediate	down
2	Bothnian Bay	0.3	fail	High	0.5	fail	Intermediate	down

In the beginning of the 1970s Baltic grey seals were observed aborting near full term foetuses (Helle 1980). Investigations showed a linkage to a disease syndrome including reproductive disorder, caused by organochlorine pollutions (Bergman & Olsson 1985). The reduced fertility resulted in population crashes, where numbers of grey seals dwindled to approximately 3,000 in the beginning of the 1980s (Harding & Härkönen 1999).

General hunting of grey seals was prohibited in 1974 and protective hunting in 1986. This, combined with a ban on PCBs and DDTs stopped the decline of the seal populations and promoted growth. Recent samples show that fertility is normal in grey seals (Bäcklin *et al.* 2011, Bäcklin *et al.* 2013). Protective hunting related to fishing activities was resumed again in 1997 in Finland and in 2001 in Sweden. Although the quota is rarely filled, the increased hunting, coupled with poorly known bycatch rates has the potential to impact the growth rate of the population to the extent that the grey seal population does not achieve good status. This was confirmed by a model looking at potential growth rates in the absence of hunting and bycatch, parameterized with data from grey seal growth rates based on inventories from 2003-2020 and reproduction rates, age-structure and hunting statistics from the same time-period (Sköld 2021).

The grey seal population has increased with about 5%/year since 2003 and is showing indications of continued growth (Figure 7.23).

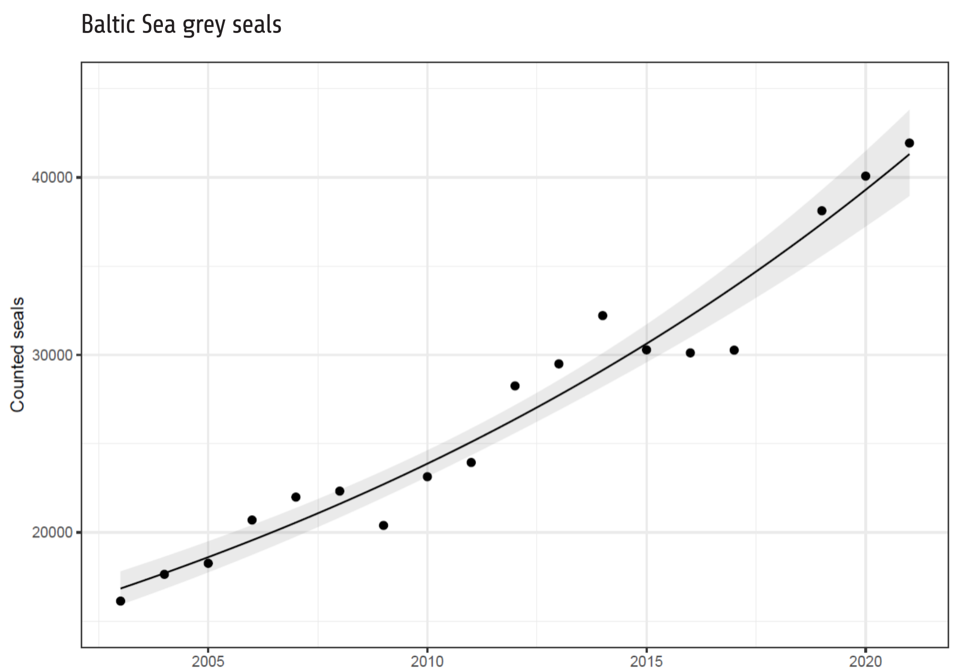


Figure 7.23. The annual number of hauled-out grey seals in the Baltic counted during the moulting surveys 2003–2021 in the Baltic Sea. The hauled-out fraction is estimated to be around 70% of the total population. The annual growth rate of Baltic grey seals during the assessment period 2003–2021 was 5.1%. The trend is not showing signs of levelling off, indicating that density-dependent factors are not limiting the population growth and the abundance is still under the TRL. Modelled count index and 95% confidence interval around index are provided with a black line and grey area. (Source: HELCOM 2023v).

7.3.2 Changes over time for ringed seal

Trend between assessments

While there is no change in status between assessments for ringed seal, the results indicate a downward trend in status for the entire distributional area (Table 7.9).

Long term trend

Population models (based on bounty statistics from Finland and Sweden, and data from Estonia) suggest a population size of roughly 180,000–220,000 at the beginning of the 20th century (Hårding & Härkönen 1999). However, the reliability of the estimates are affected by that bounty statistics may contain sources of error. The population was heavily exploited until the 1960s, after which the emerged organochlorine contamination began to cause reproductive failures. During 1970–80, the population was at its minimum: about 5000 individuals in the Baltic Sea (Hårding & Härkönen 1999). In Gulf of Riga and the Gulf of Finland there was no increase between 1996 and 2003 (Karlsson *et al.* 2007).

Table 7.9. Overview of trends in the results and status of the integrated assessment of ringed seal across the 2011-2016 and 2016-2021 assessments. An increasing Biological Quality Ratio value indicates an improving trend, decreasing Biological Quality Ratio value indicates a deteriorating trend.

Assessment scale	Assessment Unit Code	Biological Quality Ratio 2016-2021	Status 2016-2021	Confidence	Biological Quality Ratio 2011-2016	Status 2011-2016	Confidence	Trend
2	Kattegat	NA	NA	NA	NA	NA	NA	NA
2	Great Belt	NA	NA	NA	NA	NA	NA	NA
2	The Sound	NA	NA	NA	NA	NA	NA	NA
2	Kiel Bay	NA	NA	NA	NA	NA	NA	NA
2	Bay of Mecklenburg	NA	NA	NA	NA	NA	NA	NA
2	Arkona Basin	NA	NA	NA	NA	NA	NA	NA
2	Bornholm Basin	NA	NA	NA	NA	NA	NA	NA
2	Gdansk Basin	NA	NA	NA	NA	NA	NA	NA
2	Eastern Gotland Basin	NA	NA	NA	NA	NA	NA	NA
2	Western Gotland Basin	NA	NA	NA	NA	NA	NA	NA
2	Gulf of Riga	0.1	fail	High	0.3	fail	High	down
2	Northern Baltic Proper	0.1	fail	High	0.3	fail	High	down
2	Gulf of Finland	0.1	fail	High	0.3	fail	High	down
2	Åland Sea	0.1	fail	High	0.3	fail	High	down
2	Bothnian Sea	0.2	fail	High	0.3	fail	High	down
2	The Quark	0.2	fail	High	0.3	fail	High	down
2	Bothnian Bay	0.2	fail	High	0.3	fail	High	down

The seal counts for ringed seal in the northern management unit have varied significantly between 2013 and 2021. This variation is primarily based on the ice conditions in April, when the ringed seal monitoring is done. If the breaking of the ice has already started before the counting commences, large groups of ringed seals aggregate on the ice floes and are included in the counts, which raise the count number to exceptionally high levels (see Figure 7.24). The spring 2021 result, about 11,500 ringed seals in the Bothnian Bay, is lower than the previous year (about 14,600) (Table 7.10). However, the individual variations in the count results are not considered to indicate sudden changes in the ringed seal population, but are attributed to changes in the ice conditions during the count (as indicated above). The variation between years has increased to the point where it has not been possible to use the exceptionally high results of recent years in the estimation of abundance trends. The annual growth rate of ringed seals in the Bothnian Bay during 2003-2012 was 6.8%, while the Bayesian analysis showed 80% support for a growth rate ≥ 5.0%. While the exceptional survey results in most of the recent years have made it impossible to calculate the population trend for the Bothnian Bay population, the growth rate was below the threshold before and deteriorated ice conditions and increased hunting pressure do not support improved growth rate.

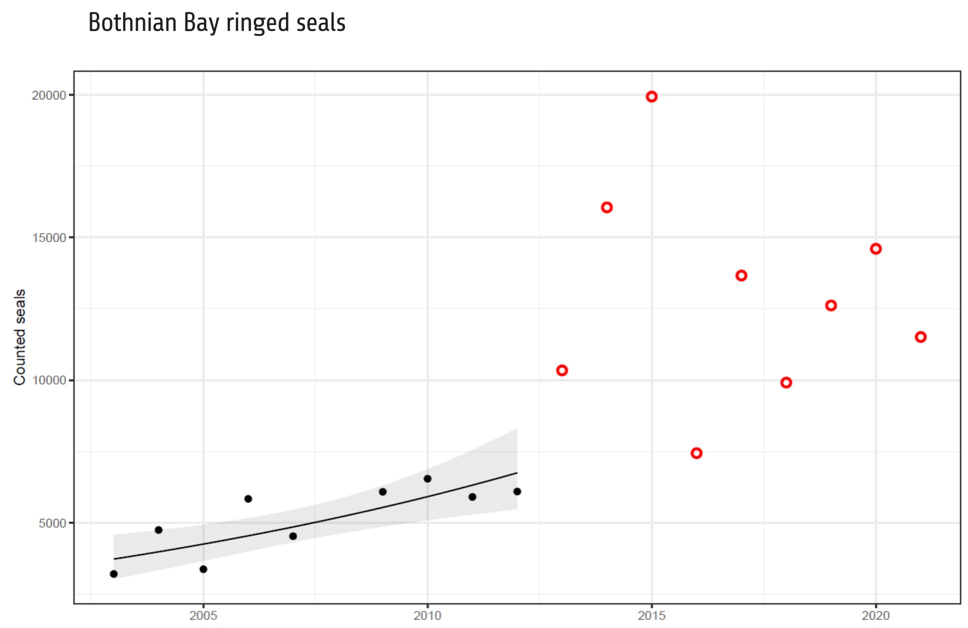


Figure 7.24. The estimated number of ringed seals hauled out on the ice during moult 2003-2021. After 2012 (red circles) the data is not comparable as a different fraction of the seal population is hauling-out, making them incomparable statistical outliers. The criteria for good status are not met based on growth rate 2003-2012 and there is no evidence of improvement. Modelled count index and 95% confidence interval around index are provided with a black line and grey area. (Source: HELCOM 2023w).

Table 7.10. Annual ringed seal survey results from the Bothnian Bay showing the number of observed ringed seals on the survey strips, fraction of the area covered with the survey strips and the estimated number of seals hauled out on the ice (calculated from the first two variables).

Year	Observed	Sampling fraction	Hauling out
2003	426	13.3	3203
2004	631	13.3	4744
2005	448	13.3	3368
2006	776	13.3	5835
2007	602	13.3	4526
2008			
2009	809	13.3	6083
2010	1740	26.6	6541
2011	785	13.3	5902
2012	3241	53.2	6092
2013	1375	13.3	10338
2014	4222	26.3	16053
2015	3441	17.26	19936
2016	502	6.75	7437
2017	2332	17,07	13664
2018	1331	13,43	9911
2019	1842	14,6	12615
2020	3154	21,6	14602
2021	2486	21,6	11509

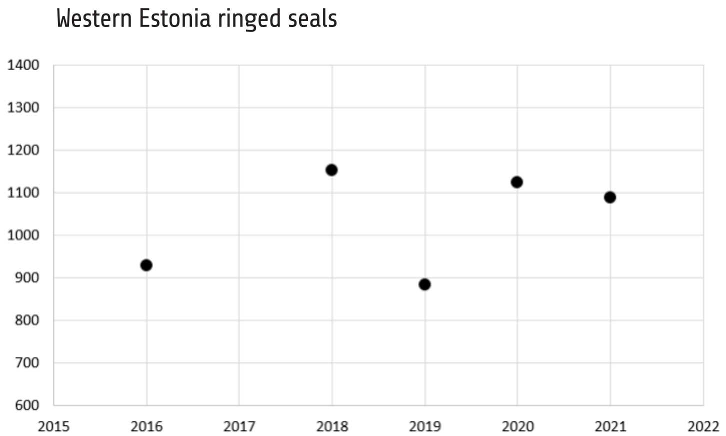


Figure 7.25. The number of ringed seals hauled out in Western Estonia on land in ice-free years during moult 2016-2021. The few data-points do not indicate any change in the abundance, but a longer time-series is needed for drawing further conclusions. (Source: HELCOM 2023w).

In the southern ringed seal management unit (i.e. Gulf of Riga, Gulf of Finland and the Archipelago Sea) improving trends have not been observed. Due to lack of ice in most years, survey methods for ice-free circumstances have been under development in all the three areas. The western Estonia population has been surveyed with these methods five times during this assessment period (2016, 2018-2021). The results have been at approximately same level compared to the earlier surveys over ice and indicate a stable trend at around 1000 ringed seals and the total population size is estimated to 1500 individuals (Figure 7.25, Jüssi & Jüssi 2017). In the Archipelago Sea, ice-free methods are still under development. Based on the sporadic surveys over ice and the incomplete counts in ice-free winters, no indication of an increasing trend can be derived (M. Ahola, pers. comm.). The best estimates for the total population size in the area are at the level of 200 animals (Ahola & Nordström, 2017). In the Gulf of Finland three traditional aerial surveys in sufficient ice conditions have been conducted (2017, 2018, 2021). The results varied around 100 ringed seals, with no sign of increase, (M. Verevkin & M. Jüssi unpublished data). These are considered alarmingly low numbers and trends.

7.3.3 Changes over time for harbour seal

Trend between assessments

In Kattegat the status has shifted from good to not good between assessments for harbour seal, however for the majority of the southwestern Baltic population (assessment units Great Belt, The Sound, Kiel Bay, Bay of Mecklenburg and Arkona Basin) the results indicate no change in status between assessments (Table 7.11). For the sub-basins Bornholm and Western Gotland Basin a positive trend can be seen based on the integrated assessment results. The latter of these corresponds to the area of occupancy of the Kalmarsund population of harbour seals.

Long term trends

According to Schwarz *et al.* (2003) and Harder (2011), historically, harbour seal breeding sites as well as haul-out sites could be found along the German coast, it is thus expected that the harbour seal population size and structure within the southern Baltic Sea are still far away from historic abundance and distribution.

In the beginning of the 20th century, the population in the Skagerrak, Kattegat and the Danish Straits exceeded 17,000 but declined to some 2500 in the 1930s as a consequence of hunting (Heide-Jörgensen & Härkönen 1988). The hunting pressure resulted in extirpation of harbour seals in Germany and Poland in 1912 (Harding & Härkönen 1999). In times from the 19th to the 20th century the part of the population found in the western Baltic Proper was about 5000 compared to ca. 1000 in 2007 (Karlsson *et al.* 2008). The Skagerrak/Kattegat population has been hit by three mass mortalities. The two first, in 1988 and 2002 were caused by PDV virus and killed half the population on both occasions. A third epidemic in 2007 killed some 3,000 seals and was caused by an unknown pathogen. The latest influenza A epidemic occurred in 2014 and was of similar proportion. The recovery rate in the Kattegat has been low ever since the 2002 epidemic.

In the Kattegat, the Danish Straits and the Southwestern Baltic Sea an estimated 60% of the population is observed at haul-outs during the surveys. The mean number of seals by sea area seen during the repeated surveys are used for the abundance and trend index in this area. This is to smooth the variation between the survey days that are a result of heavy disturbance by boats and tourists during the moulting season that impact the number of seals hauling out. Combining Kattegat and the SW Baltic gives a minimum estimated population size of 14,500 individuals in this management unit.

In the SW Baltic, approximately 1,200 seals have been observed hauling out in the most recent years (Figure 7.26), giving a total estimated population size of 2,000 harbour seals. In the SW Baltic, the average annual rate of increase during the period 2003-2021 was 6.6%. According to the Bayesian analysis there is 80% support for a growth rate ≥ 6.1%, which is below the threshold value of 9%. Thus, the SW Baltic unit does not achieve good status for the population trend evaluation.

In Kattegat, the number of seals hauled out range between 7,500 – 11,000 individuals during the assessment period 2016-2021 (Figure 7.27). As such, the lowest estimated population size for Kattegat is 12,500 individuals. The population appeared to in-

Table 7.11. Overview of trends in the results and status of the integrated assessment of ringed seal across the 2011-2016 and 2016-2021 assessments. An increasing Biological Quality Ratio value indicates an improving trend, decreasing Biological Quality Ratio value indicates a deteriorating trend.

Assessment scale	Assessment Unit Code	Biological Quality Ratio 2016-2021	Status 2016-2021	Confidence	Biological Quality Ratio 2011-2016	Status 2011-2016	Confidence	Trend
2	Kattegat	0.6	Fail	High	0.8	Achieve	High	down
2	Great Belt	0.3	Fail	High	0.3	Fail	High	same
2	The Sound	0.3	Fail	High	0.3	Fail	High	same
2	Kiel Bay	0.3	Fail	High	0.3	Fail	High	same
2	Bay of Mecklenburg	0.3	Fail	High	0.3	Fail	High	same
2	Arkona Basin	0.3	Fail	High	0.3	Fail	High	same
2	Bornholm Basin	0.2	Fail	High	0.1	Fail	High	up
2	Gdansk Basin	NA	NA	NA	NA	NA	NA	NA
2	Eastern Gotland Basin	NA	NA	NA	NA	NA	NA	NA
2	Western Gotland Basin	0.2	Fail	High	0.1	Fail	High	up
2	Gulf of Riga	NA	NA	NA	NA	NA	NA	NA
2	Northern Baltic Proper	NA	NA	NA	NA	NA	NA	NA
2	Gulf of Finland	NA	NA	NA	NA	NA	NA	NA
2	Åland Sea	NA	NA	NA	NA	NA	NA	NA
2	Bothnian Sea	NA	NA	NA	NA	NA	NA	NA
2	The Quark	NA	NA	NA	NA	NA	NA	NA
2	Bothnian Bay	NA	NA	NA	NA	NA	NA	NA

crease until 2019, with a growth rate of 5.2%. In 2020 and 2021 the counts dropped to a markedly lower level. In 2020 there was a heat wave with an unprecedented number of boats in the archipelago during the survey period, factors that likely lead to fewer seals hauling-out and thus a lower count. However, such extreme conditions were not observed in 2021 where the counts still remain lower than before. As such, these data cannot be considered outliers. However, more data is needed to confirm if there is a declining trend or if the growth rate is levelling off. The observed decline is mainly driven by a drop in counted seals in the Swedish waters of the Kattegat. No signs of increased mortality have been observed. During the period 2003-2021 the annual growth rate of counted seals in the Kattegat harbour seal population was 3.8% with a Bayesian analysis showing 80% support for Kattegat harbor seal growth rate at least 3.3% from 2003 to 2021. The levelling off of population growth as a consequence of density dependence cannot be ruled out. During the last 10 years period the data shows an increase in the beginning and a decrease in the end, where a test for linear decrease fits poorly. This complicates the interpretation of the trends for this population.

The harbour seal population in Kalmarsund is genetically divergent from the adjacent harbour seal populations (Goodman 1998) and experienced a severe bottle-neck in the 1970s when only some 30 seals were counted, giving an overall population estimate of 50 seals. Long-term isolation and low numbers have resulted in low genetic variation in this population (Härkönen

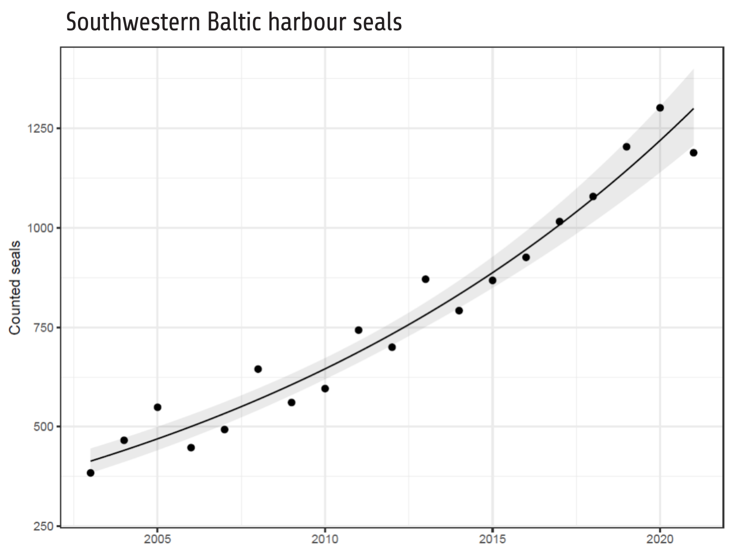


Figure 7.26. The mean annual number of hauled-out harbour seals counted during the moulting surveys in the SW Baltic 2003–2021.The annual growth rate of counted seals in the SW Baltic harbour seal subpopulation was 6.6% during the period 2003–2016. According to a Bayesian probability distribution, there is 80% support for a growth rate ≥5.9%. Modelled count index and 95% confidence interval around index are provided with a black line and grey area. (Source: HELCOM 2023x).

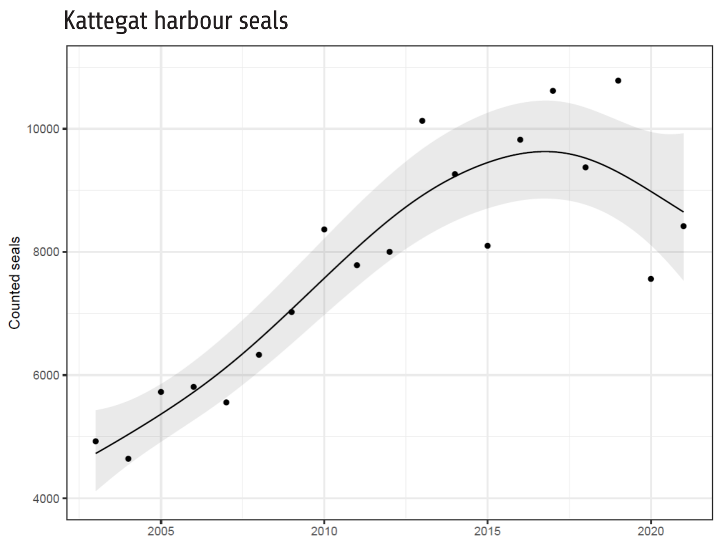


Figure 7.27. The annual mean number of hauled-out harbour seals counted during the moult survey 2003–2021 for Kattegat. The annual growth rate of counted seals in the Kattegat harbour seal subpopulation was 3.8% during the period 2003–2021 under the assumption of exponential growth. According to a Bayesian probability distribution there is 80% support for Kattegat harbour seal growth rate of ≥3.3%. Modelled count index and 95% confidence interval around index are provided with a black line and grey area. (Source: HELCOM 2023x).

et al. 2006). In the Kalmarsund area counted numbers have increased to approximately 2 000 individuals during the assessment period (2016-2021) (Figure 7.28). The value is the maximum result of repeated surveys within the survey period, which is assumed to correspond to 70% of total population size, represents an estimated total abundance of 2 900 harbour seals in the area. During the period 2003-2021, the Kalmarsund population has increased on average by 9.9 % per year. A Bayesian analysis of the trend shows that there is 80% support for a growth rate of ≥8.9%.

The counted numbers in the Limfjord harbour seal population have been fluctuating well below 1 000 individuals and the total population abundance is very uncertain as the high variance of counts indicates haul-out behaviour that is different from the harbour seals in the other areas (Figure 7.29). For the Limfjord population, the rate of increase was 2.2% during 2003-2021 and the Bayesian analysis gives 80% support for rate of >0.5%. Although the Limfjord population is also clearly below LRL, it may nevertheless be approaching carrying capacity since the annual growth rate is very low. If the population is encountering density dependence, the level of abundance indicates reduced carrying capacity and potentially deteriorated habitat as the counts were significantly higher before the 2002 PDV epidemic. Recent DNA-based studies show that Limfjord harbour seals are independent from Kattegat (Olsen *et al.* 2014, Liu *et al.* 2022). However, this assessment for Limfjord is unofficial since the unit is not specifically recognised in the HELCOM Recommendation 27/28-2.

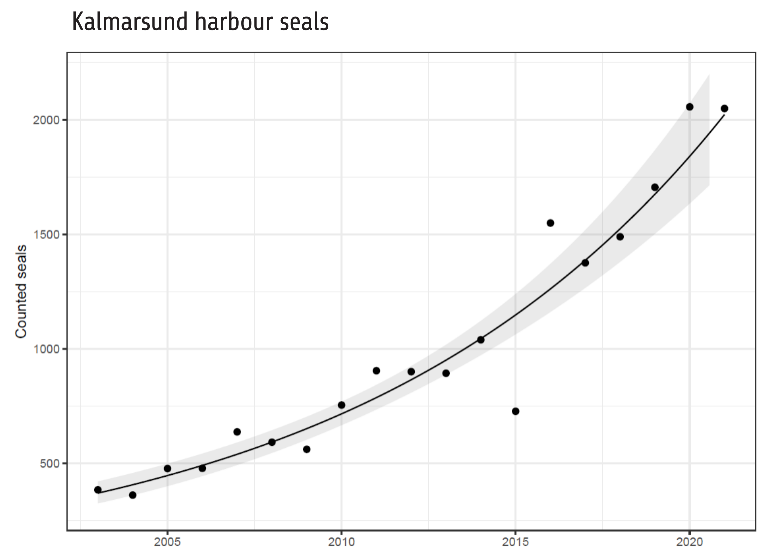


Figure 7.28. The annual maximum number of hauled out harbour seals counted during the moulting surveys. The annual growth rate of counted harbour seals in Kalmarsund was 9.9% during the period 2003–2021. The total number of individuals is approximately 2,900 animals. (Source: HELCOM 2023x)

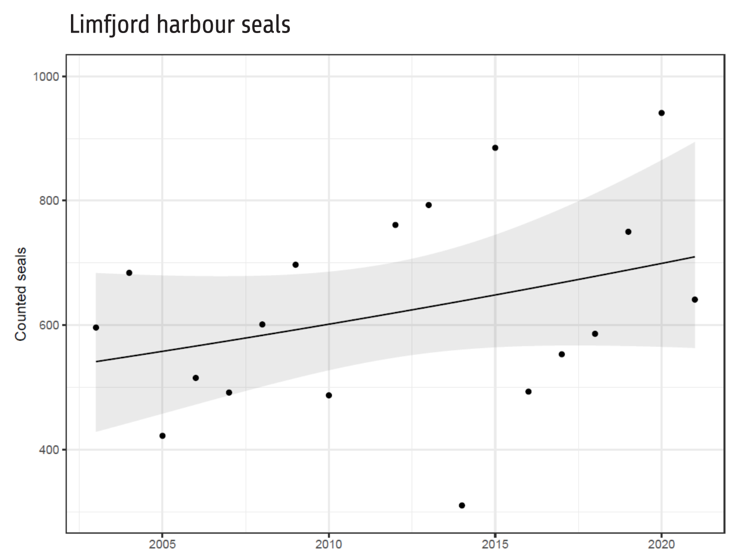


Figure 7.29. The annual growth rate of counted harbour seals in the Limfjord was 2.2% during the assessment period 2003–2021. According to a Bayesian probability distribution, 80% support for rate of ≥0.5%. Modelled count index and 95% confidence interval around index are provided with a black line and grey area. (Source: HELCOM 2023x).

7.3.4 Changes over time for harbour porpoise

Trend between assessments

As no assessment of harbour porpoise has been included in previous holistic assessment it has not been possible to include information on trends in status.

Long term trends

In the 19th and early 20th centuries harbour porpoises were widespread throughout the entire Baltic, as far as the northeast part of the Gulf of Bothnia (Kemi) and the Gulf of Finland. Today, harbour porpoise observations in the Baltic proper are very rare and it is estimated that the number of remaining individuals is at most few hundreds (HELCOM 2023l). The harbour porpoise population in the Baltic proper has declined dramatically over the past 100 years and there are indications that this population is facing extinction (HELCOM 2013c).

7.4. Relationship of marine mammals to drivers and pressures

7.4.1 Human activities and associated pressures

Removal of individuals from the population due to hunting or fishing has been a major pressure on marine mammals in the Baltic Sea historically. All species of seals in the Baltic Sea were severely reduced in the beginning of the 20th century as a result of a coordinated international campaign to exterminate seals. Seal numbers in the Baltic Sea dropped by 80-90% over the period 1920-1945. Historically there have also been large catches of harbour porpoise in the Baltic region, with 2 000 individuals taken annually in Danish waters in the late 19th century and possibly larger catches in the Baltic proper (Kinze 1995). Hunting remains a pressure on both grey and ringed seals in part of their Baltic Sea distributional range (Figure 7.30 and Table 7.12).

Table 7.12. Number of seals hunted during the assessment period 2016-2021, presented by species, country, year and, where possible, sub-basin. Informaiton is presented for the countries where hunting of seals takes place and for the areas where the species in question occurs.

Grey seal, number of seals hunted							
	Area	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
Finland	Åland	73	72	128	343	215	207
Finland	Bothnian Bay-The Quark	47	60	38	65	96	136
Finland	Gulf of Finland	86	116	109	137	99	147
Finland	Bothnian Sea	52	56	66	114	71	138
Sweden	Bothnian Sea	115	136	226	312	534	395
Sweden	Baltic proper	87	127	273	470	568	573
Sweden	West coast	0	0	0	0	0	0
Estonia	All areas	10	8	19	20	19	26
Denmark	All areas	0	0	0	3	6	0
Total per year		470	575	859	1464	1608	1622
Total for assessment period							**6598**
Ringed seal, number of seals hunted							
	Area	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
Estonia	All areas	0	0	0	0	0	0
Finland	Åland	0	0	0	0	0	0
Finland	Bothnian Bay-The Quark	87	202	210	266	310	277
Finland	Gulf of Finland	0	0	0	0	0	0
Finland	Bothnian Sea	0	0	0	0	0	0
Sweden	Bothnian Sea	89	39	130	273	289	291
Total per year		176	241	340	539	599	568
Total for assessment period							**2463**
Harbour seal, number of seals hunted							
	Area	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
Sweden	Baltic proper	0	0	0	0	0	0
Sweden	West coast	116	215	352	313	366	141
Denmark	All areas	13	30	23	43	47	31
Total per year		129	245	375	356	413	172
Total for assessment period							**1690**

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). While many of the substances which caused harm to the populations in the past have since been banned, hazardous substances remain one of the most widespread and impactful pressures in the Baltic Sea today (Slobodnik *et al.* 2022) (Figure 3.8 in Chapter 3).

For all marine mammals drowning in fishing gear is a major pressure of concern. In all, these events have resulted in severe reduction of the abundance of marine mammals in the Baltic Sea.

Marine mammals are also very receptive of underwater sound. The effects of sound on the animals depend on its different properties, such as frequency content, amplitude and duration. The probablity of high sound levels increases closer to its source. Depending on the intensity of the sound, the effects of it on marine mammals can vary. At lower levels, other biologically significant sounds in the environment can be masked, while higher levels can lead to behavioural changes or distruption of ongoing behaviour, and very high levels can lead to physiological stress effects, or even temporary or permanent changes in hearing sensitivity (HELCOM 2019). Human induced underwater sound is widespread in the Baltic Sea marine environment (Figure 7.31) and all four marine mammals included in this assessment are likely to be impacted (HELCOM 2023a).

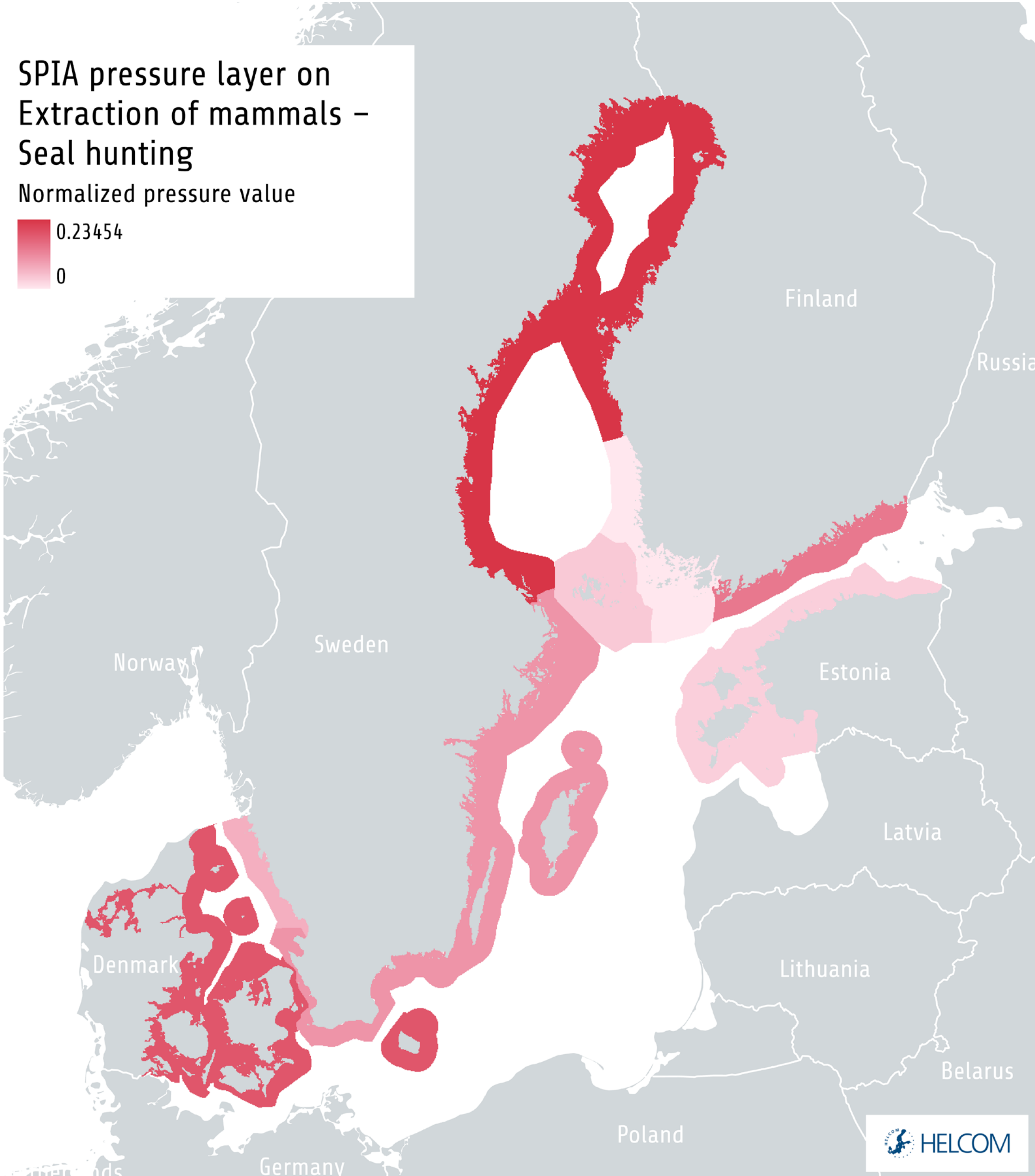


Figure 7.30. Spatial distribution and proportional intensity of hunting of seals in the Baltic Sea, based on data from 2016-2021. The map represent the normalized pressure values, where the intensity of the colour indicates higher pressure. For Danish waters, the number of hunted seals in the original data represents the regulation of seals. Map from the HELCOM HOLAS 3 report Spatial distribution of pressures and impacts (HELCOM 2023a).

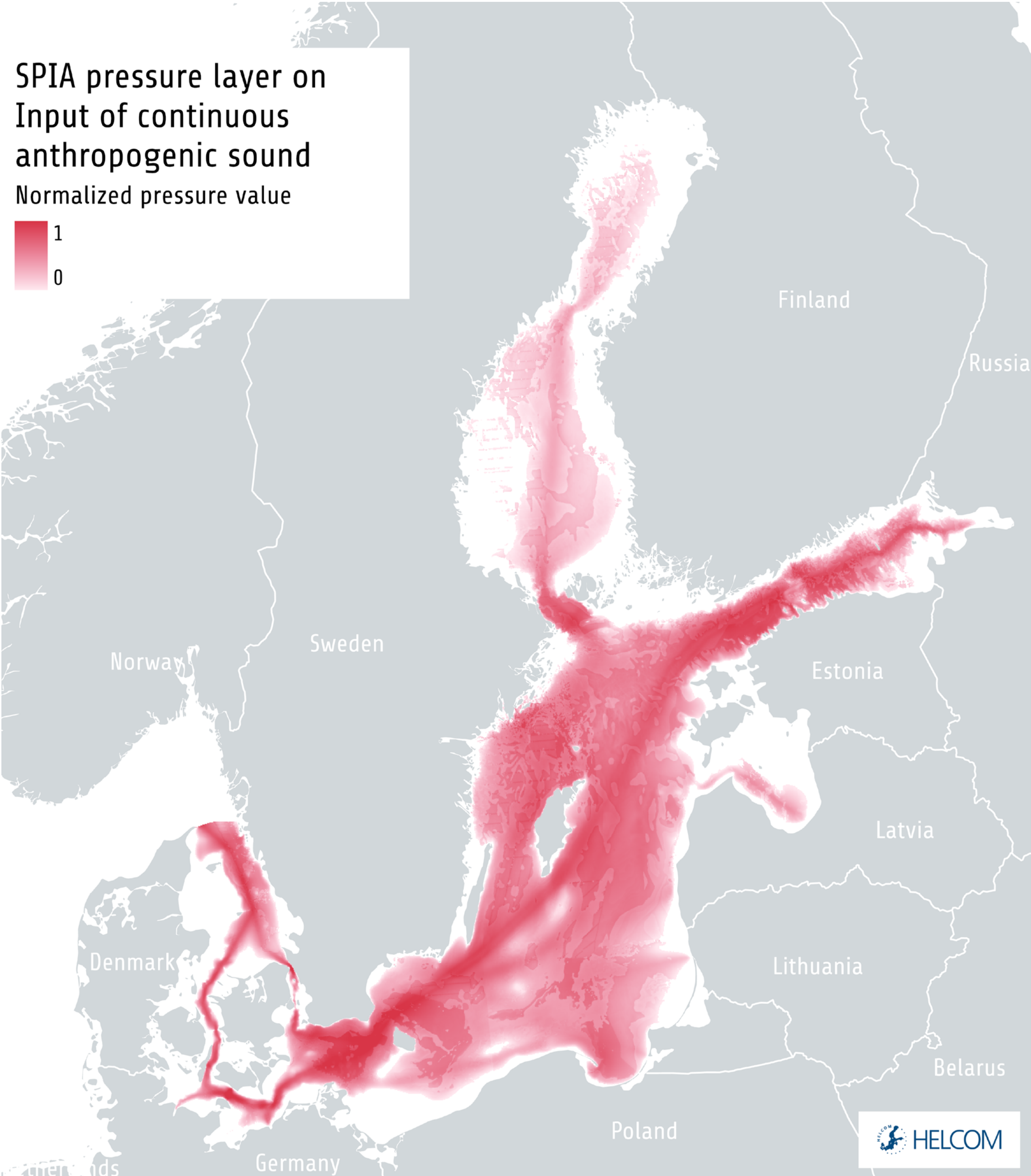


Figure 7.31. Spatial distribution and intensity of continuous underwater sound in the Baltic Sea, based on data from 2016–2021. Map from the HELCOM HOLAS 3 report Spatial distribution of pressures and impacts (HELCOM 2023a).

7.4.2 Climate change

Climate change is expected to have significant impacts on the Baltic Sea ecosystem (HELCOM/Baltic Earth, 2021). Climate change impacts could include flooding of haul out sites, changed temperature, stratification, and altered prey distribution, quality and quantity, all of which, though difficult to current predict risk impacts on marine mammals. Being at the top of the marine foodweb, these predators are sensitive to changes throughout the ecosystem, and changes in foodwebs on which they rely (and for which our current understanding is poor) may be significant with potential changes in food availability and altered transfer of contaminants. Changes in the foodweb related to climate change can affect the reproduction of all three Baltic seal species strongly. The prey and prey quality have been shown to affect body condition of Baltic seals (Kauhala *et al.* 2019) and factors affecting body condition will in turn affect reproduction. It is likely that the delayed implantation of seals serves the purpose of ensuring favorable conditions for being pregnant, hence females unable to gain weight after the previous reproductive period will not have a successful implantation and will lose their embryo. Less ice coverage may also lead to behavioral changes in the populations of ice breeding seals (in the Baltic, ringed and grey seals) that may have consequences. For example, the available territories for the females during the pupping season may decrease, affecting the available food resources and subsequent fertility. Altered prey quantity and quality (energy density) appears to impact reproductive success of female harbour porpoises (IJsseldijk *et al.* 2021) indicating that climate change effects on fish distribution and abundance would indirectly affect the harbour porpoise populations, especially if a compensatory shift in diet to prey of a similar quality is not possible.

Temperature variations across the latitudinal extent of the Baltic Sea have been suggested to influence certain biological processes or community factors, however there is currently no documented evidence for a spatial variation in regulation of blubber thickness in subadult seals. It is likely that the average fat layer variations in grey seals between years represent changes in food availability and other stressors and not sea water temperature, i.e. possibly an indirect effect of a changing climate.

Such changes may influence status evaluation and also need to be reflected in management (e.g. potentially the need to be precautionary).

7.4.3 Relationship of grey seal to drivers and pressures

Current pressures impacting grey seal include habitat loss due to coastal development, overfishing, environmental contaminants, entanglement of young seals in fishing gear and in some parts of the Baltic Sea also hunting.

Historically, hunting of seals has been a major human pressure on all the seal species in the Baltic Sea. A coordinated international campaign was initiated in the beginning of the 20th century with the aim of exterminating the seals (Anon 1895). Bounty systems were introduced in Denmark, Finland and Sweden over the period 1889-1912, and very detailed bounty statistics provide detailed information on the hunting pressure (see Section on long term trends for more information on the historical effect of hunting on grey seal population size).

In the beginning of the 1970s Baltic grey seals were observed aborting near full term foetuses (Helle 1980). Investigations showed a linkage to a disease syndrome including reproductive disorder, caused by organochlorine pollutions (Bergman & Olsson 1985). The reduced fertility resulted in population crashes, where numbers of grey seals dwindled to approximately 3,000 in the beginning of the 1980s (Harding & Härkönen 1999).

General hunting of grey seals was prohibited in 1974 and protective hunting in 1986. This, combined with a ban on PCBs and DDTs stopped the decline of the seal populations and supported growth. Recent samples show that fertility is normal in grey seals (Bäcklin *et al.* 2011, 2013). Protective hunting related to fisheries was resumed again in 1997 in Finland and in 2001 In Sweden. Sweden introduced licence hunting for grey seals in 2020 and in Finland grey seal hunt has been run by regional quota only since 2014. Numbers of grey seals that have been allowed to be hunted with these varying regulations in Sweden and Finland have increased from c. 500 seals in the early 2000's to c. 3500 in 2022. Estonia licences grey seals hunting since 2015, the annual hunting quota has been between 37-55 animals. Sweden introduced licence hunting for grey seals in 2020 and in Finland grey seal hunt has been run by regional quota since 2014.

Increased hunting pressure in certain areas has been observed to affect grey seals behaviour. In Stockholm archipelago number of grey seals observed in the moulting time surveys have dropped dramatically in recent years along with increased hunting in the area. At the same time increased numbers have been observed in Finnish SW archipelago, which does not, however, explain all of the decrease in the Stockholm archipelago. Although a certain causality between these changes cannot be shown, this may be an example of effect of disturbance on distribution of seals. Consequences of hunting in the most remote areas can be unwanted if the seals move to areas where they can cause more issues when interacting with fisheries.

Whilst the hunting statistics are well documented, the current knowledge on the level of incidental catches of Baltic seal species is limited to a few dedicated studies which suggest that this factor can be substantial. An analysis of reported incidentally caught grey seals showed that approximately 2,000 grey seals are caught annually in the Baltic fisheries (Vanhatalo *et al.* 2014). For more information on bycatch please see Chapter 9.

Climate change

Climate change poses a pressure on species breeding on ice because shorter and warmer winters lead to more restricted areas of suitable ice fields (Meier *et al.* 2004). Grey seals are facultative ice breeders and their breeding success is considerably greater when they breed on ice as compared with land (Jüssi *et al.* 2008). Consequently, grey seals are predicted to be negatively affected by a warmer climate. However, since effects of climate change should not be included in evaluations according to the Habitat Directive, these effects add additional pressure on the populations already assessed as not good.

7.4.4 Relationship of ringed seal to drivers and pressures

Similarly to grey and harbour seals hunting has been a major human pressure on ringed sea in the Baltic Sea. A coordinated international campaign was initiated in the beginning of the 20th century with the aim of exterminating the seals (Anon 1895). Bounty systems were introduced in Denmark, Finland and Sweden over the period 1889-1912, and very detailed bounty statistics provide detailed information on the hunting pressure. The original population sizes of ringed seals have been estimated to be about

180,000 ringed seals in the Baltic (Harding & Härkönen 1999) and documented singed seal breeding occurred in Stockholm county up to the beginning of the 1940s, but ceased in the mid of that decade (Hult 1943).

The hunting pressure resulted in ringed seal populations decline to about 25,000 ringed seals in the 1940s (Harding & Härkönen 1999). In the beginning of the 1970s it is estimated that only 17% of ringed seal females were fertile (Helle 1980). Later investigations showed a linkage to a disease syndrome including reproductive disorder, caused by organochlorine pollution, in both grey seals and ringed seals (Bergman & Olsson 1985). The reduced fertility resulted in population crashes, where numbers of ringed seals dwindled to approximately 3,000 in the beginning of the 1980s (Harding & Härkönen 1999). Increasing numbers of these species were recorded after levels of PCB in biota decreased by the end of the 1980s. Recent samples show that fertility is still impaired in ringed seals (Bäcklin *et al.* 2011, 2013). During the last decade, hunting pressure on ringed seals has increased again in the Bothnian Bay management unit where the combined quota for Sweden and Finland has been over 700 ringed seals and majority of the quotas have been filled.

Incidental catches of seals in fisheries are known to have substantial effects on the population growth rate of ringed seal subspecies such as the Saimaa and Ladoga ringed seals (Sipilä 2003). The current knowledge on the level of incidental catches of Baltic seal species is limited to a few dedicated studies which suggest that this factor can be substantial. An analysis of reported incidentally caught grey seals estimated that approximately 2,000 grey seals are caught annually in the Baltic fisheries (Vanhatalo *et al.* 2014), but numbers of incidentally caught ringed seals and harbour seals are not known. For more information on bycatch please see Chapter 9. Hunting of ringed seals has increased in the last few years with current quotas for in Sweden at 420 individuals (protective hunt) and 375 in Finland (quota-based regular hunt).

Climate change

Climate change poses a pressure on species breeding on ice because shorter and warmer winters lead to more restricted areas of suitable ice fields (Meier *et al.* 2004, Sundqvist *et al.* 2012, Meier *et al.* 2022). In addition to decreasing amount of habitat, the deteriorating ice-conditions are likely to reduce reproductive success of ringed seals. Ringed seals are adapted to breed in lairs they burrow in the drifted snow on ice. The lairs protect the pups both against predation and harsh weather. This feature alone will severely affect the Baltic ringed seals and the predicted rate of climate warming is likely to cause extirpation of the southern subpopulations (Sundqvist *et al.* 2012, Meier *et al.* 2022). The ringed seal also has a relatively long lactation period. Early ice break-ups may cause the pup to enter the water earlier or more often, which affects their thermoregulation due to the lanugo fur. The pups may be exposed to harsh weather conditions if there is not enough snow and ice for lairs, which poses a risk for hypothermia and a higher mortality (Stirling & Smith, 2004). A shortened period of ice has been observed to increase the number of pups with the lanugo fur still present late in the season and lower growth rates (Harwood *et al.* 2000, Smith & Harwood 2001). Consequently, ringed seals are predicted to be negatively affected by a warmer climate.

For ringed seals only a very few protected areas are established, since they are primarily hauling out on ice. However, with decreasing ice-cover ringed seals are increasingly dependent on land haul-outs especially in the southern management unit, but also in the Bothnian Bay during the ice-free times of the year. Currently land-haulouts across the range are not well known.

7.4.5 Relationship of harbour seal to drivers and pressures

The hunting campaign in the beginning of the 20th century resulted in extirpation of harbour seals along the Polish and German coasts (Harding & Härkönen 1999). The original population size was about 5,000 for the Kalmarsund population of harbour seals (Harding & Härkönen 1999; Härkönen & Isakson 2011). Similar data from the Kattegat and Skagerrak suggest that populations of harbour seals amounted to more than 17,000 seals in this area (Heide-Jørgensen & Härkönen 1988). The hunting pressure caused a rapid decline in the Kalmarsund harbour seal population with only c. 200 seals remaining in the 1960s, and c. 2,500 in Kattegat and Skagerrak in the late 1970s (Heide-Jørgensen & Härkönen 1988; Härkönen & Isakson 2011). The Kalmarsund population then entered a severe bottle-neck with surveys in the 1970s showing that only 10-20 pups were born per year. In the late 1970s early 80s the population numbered around 50 individuals. Long-term isolation and low numbers have resulted in low genetic variation in the Kalmarsund population (Härkönen *et al.* 2006). Hunting was prohibited in the 1960s and protected areas were formed in the 1970s which promoted population growth.

Environmental contaminants in the 1960s and 1970s caused infertility also in harbour seals, further reducing their numbers (Helle 1980), however no evidence of these impacts were observed in Kattegat.

The harbour seal subpopulation in Kattegat and the Northern Great Belt experienced two dramatic mass mortality events due to Phocine Distemper Virus (PDV) epidemic when more than 50% of the population died in 1988 and about 30% in 2002 (Härkönen *et al.* 2006). Unusually large numbers also died in 2007, but the reason for this mortality remains unclear (Härkönen *et al.* 2007). In the spring of 2014, some seals appearing to show signs of pneumonia found in Sweden and Denmark, and also on the North Sea coast. Avian influenza H10N7 was isolated from a number of seals (Zohari *et al.* 2014). Population surveys in August 2014 showed lower numbers at all seal localities, suggesting a total mortality of approximately 10%. The Kalmarsund population has not been affected by these epidemics, illustrating that they are isolated from the Kattegat harbour seals.

Incidental catches of seals in fisheries can have substantial effects on the population growth rates (Sipilä 2003). The current level of incidental catches of harbour seals in the HELCOM area is unknown. For more information on bycatch please see Chapter 9.

Protective hunting of harbour seals, in relation to fisheries, has occurred in Swedish waters since the early 2000s and licence hunting was introduced in 2022, with a current quota of 730 harbour seals. No hunting is allowed for the Kalmarsund harbour seal population.

The harbour seal populations were severely depleted by hunting, bycatch in fisheries, and later by diseases related to effects of pollution and the PDV virus. Other threats include habitat loss due to coastal development.

Climate change

Climate change is expected to have significant impacts on the Baltic Sea ecosystem (HELCOM/Baltic Earth, 2021). Although climate change does not have a direct impact on harbour seal abundance the environmental changes and changes in human activities associated with it will likely have widespread impacts on the Baltic Sea ecosystem, including on higher trophic levels. Such changes in the foodweb and the ecosystem may force a re-distribution of seals but a significant direct impact is the projected sea level rise which would flood many or all harbour seal haulouts in the SW Baltic (Meier *et al.* 2022).

7.4.6 Relationship of harbour porpoise to drivers and pressures

Historically, there have been large catches of harbour porpoise in the Baltic region, with 2 000 individuals taken annually in Danish waters in the late 19th century and possibly larger catches in the Baltic proper (Kinze 1995). Porpoises are threatened by a variety of anthropogenic activities and impacts. Among these, bycatch in fisheries is of greatest concern (Berggren 1994, Vinther 1999, ASCOBANS 2000, Skóra & Kuklik 2003). Gillnets are thought to be responsible for most bycatches, but porpoises are also occasionally taken in trawls (Berggren 1994). The level of bycatch was estimated to be unsustainable in2017 (NAMMCO & IMR 2019). For more information on bycatch please see Chapter 9. Pollution is also of concern in the Baltic area, where reduced fertility of seals and population decline of seal species has been attributed to high levels of organochlorines such as DDT and PCBs (Helle *et al.* 1976, Bergmann 1999). Murphy *et al.* (2010) found indications for a link between higher organochlorine concentrations and lower pregnancy rates in harbour porpoises. Porpoises in the Baltic Sea have been reported to have up to 254% higher mean levels of PCBs than samples from Kattegat and Skagerrak (Berggren *et al.* 1999, Bruhn *et al.* 1999). In later years, levels of PCBs in Baltic biota have declined, so the negative impacts of pollution may be reduced in the future. Other threats in the Baltic Marine Area include acoustic disturbances, shipping and prey depletion due to over-fishing.

In three populations in the US Pacific, population increases between 5.8 and 9.6% per year have been shown after cessation of bycatch in gilnets (Forney *et al.* 2020). As the abundance of the Baltic Proper population is critically low, it is not influenced by density dependence issues. A level of growth (or a decline) significantly lower than the level of known possible population growth for the species indicates that there is likely something within the ecosystem that is restricting the population, and that human pressures may be causing an issue in the natural state of the Baltic Sea.

Climate change

The expected change in temperature and stratification, prey distribution, quality and quantity will affect all marine mammals, including harbour porpoises, but aggregated effects on their abundance and distribution are unpredictable (HELCOM/Baltic Earth 2021). With a shorter ice season and earlier ice breakup shipping in usually ice-covered areas will be facilitated and it is predicted more maritime traffic in the Baltic Sea could lead to more underwater noise, which are relating to injuries and displacement from habitats. Implications of this also extents to the disturbance of behaviour of harbour porpoises due to the underwater noise. Changes in ecosystem structure and function could compound issues for already vulnerable populations.

7.5. Assessment methodological details

7.5.1 Seal monitoring

HELCOM common monitoring relevant for the seal population trends is documented on a general level in the HELCOM Monitoring Manual under the sub-programme: Seal abundance.

HELCOM monitoring guidelines for seals were adopted in 2014 and updated in 2018 and HELCOM monitoring guidelines for reproductive status of seals were approved by the HELCOM Expert Group on Marine Mammals in 2021.

7.5.2 Harbour porpoise monitoring

Current regional monitoring carried out in HELCOM is not directly relevant to the qualitative evaluation of harbour porpoise included in HOLAS 3. The development of optimal and harmonised monitoring is underway and will be vital for future assessments.

Monitoring of the distribution of harbour porpoises in the Contracting Parties of HELCOM is described on a general level in the HELCOM Monitoring Manual in the Harbour porpoise abundance sub-programme.

7.5.3 Assessment scales

The assessments of marine mammals at its base is using HELCOM assessment unit scale 2 (see Section 2.3).

Existing management plans for seals operate according to management units that are based on the distribution of seal populations. The management units are combinations of HELCOM level 2 spatial assessment units. Evaluations are therefore done by grouping HELCOM assessment units to align with the management units defined for each seal population.

- The Baltic grey seal (excluding Kattegat) is treated as a single management unit as the species shows extensive migration patterns, although it is worth noting that genetic data show spatial structuring (Fietz *et al.* 2013) and behavioural data also suggest some large scale structuring.
- The Baltic Ringed seal is distributed in the Gulf of Bothnia on the one hand and Southwestern Archipelago Sea, Gulf of Finland and Gulf of Riga on the other, and is represented by two different management units. This sub-division is justified by ecological data that indicate separate dynamics of these stocks (see HELCOM 2018e).
- Harbour seals in Kalmarsund, Sweden, constitute a separate management unit and is the genetically most divergent of all harbour seal populations in Europe (Goodman 1998). The genetic diversity is substantially reduced compared with other harbour seal populations.
- Harbour seals in the southwestern Baltic (Danish Straits, Danish, German and the Öresund region including Skåne county in

Sweden and Kattegat) should be managed separately, as this stock is genetically distinct from adjacent populations of harbour seals (Olsen *et al.* 2014).

— Harbour seals in Kattegat and the Limfjord are genetically distinct from adjacent populations and each other (Olsen *et al.* 2014). Work is ongoing in HELCOM to explore dividing these two areas into separate management units however, for th purpouses of HOLAS 3 these are currently treated as one management unit.

The harbour porpoise integrated assessment also aggregated HELCOM scale 2 assessment units aggregated to relevant management areas as a basis for assessment.

7.5.4 Methodology for the integrated assessment

The integrated assessmen methodology used for marine mammals is presented in Annex 1, section Marine mammal integrated assessment. Note that anseparate assessment including the bycatch indicator was performed for for mammals, adding the results from the bycatch indicator at the management unit level for the species, and then following the same integration approach as described above (see chapter 9).

7.6. Follow up and needs for the future with regards to marine mammals

To improve the status of marine mammals in the Baltic Sea measure to manage human activites causing negative impact need to be identified and implemented. Such action needs to be taken at an ecologically relevant scale, which in the case of highly mobile species frequently implies transboundary action. Such action is taken under several international frameworks, including HELCOM.

7.6.1 HELCOM actions

The status assessment of Baltic Sea marine mammals addresses the Baltic Sea Action Plan (BSAP 2021) Biodiversity segment goal of a "Baltic Sea ecosystem that is healthy and resilient" as well as the ecological objectives under this goal are also clearly relevant: 'Viable populations of all native species', 'Natural distribution, occurrence and quality of habitats and associated communities', and 'Functional, healthy and resilient foodwebs'. It is of direct relevance for the 2021 BSAP Actions:

The HELCOM Recommendation 27/28-2 Conservation of seals in the Baltic Sea area outlines the conservation goals of seals agreed on amongst the Baltic Sea countries under the auspice of HELCOM. Similarly HELCOM Recommendation 17/2 Protection of harbour porpise in the Baltic Sea area specifies the regionally agreed conservation actions and goals for harbour porpoise. These Recommendations also recommends that species specific management plans be developed. Table 7.13 provides an overview of national management plans developed under the remit of the Recommendation. In addition Poland is in the process of developing a management plan for grey seal. In addition the HELCOM Recommendations 37-2 on Conservation of Baltic Sea species categorized as threatened according to the 2013 HELCOM Red List presents agreed actions and measures for the species the species on the Red List (including all Baltic Sea mammals with the exception of grey seal). For an overview of commitments related to addressing bycatch, please see the relevant section under chapter 9.

Code	Action
B8	By 2022 at the latest, specify knowledge gaps on all threats to the Baltic Proper harbour porpoise population, and by 2023 for the western Baltic population, including by-catch and areas of high by-catch risk, underwater noise, contaminants and prey depletion. Knowledge gaps related to areas of high by-catch risk are to be addressed and by 2028 at the latest additional areas of high by-catch risk for both Baltic Sea populations are to be determined. To strengthen the Baltic harbour porpoise population, by 2025 identify possible mitigation measures for threats other than by-catch and implement such measures as they become available
B19	By 2023 finalise and implement national or local conservation and/or management plans for grey seals.
B20	By 2023 finalise and implement national conservation and/or management plans for ringed seals.
B21	By 2025 protect the ringed seal in the Gulf of Finland, including to significantly reduce by-catch and to improve the understanding of the other direct threats on the seals, and urge transboundary co-operation between Estonia, Finland and Russia to support achieving a viable population of ringed seal in the Gulf.
B22	Update the HELCOM Red List Assessments by 2024, including identifying the main individual and cumulative pressures and underlying human activities affecting the red listed species.
B23	By 2025 develop, and by 2027 implement, and enforce compliance with ecologically relevant conservation plans or other relevant programmes or measures, limiting direct and indirect pressures stemming from human activities for threatened and declining species. These will include joint or regionally agreed conservation measures for migrating species
B24	Develop tools for and regularly assess the effectiveness of other conservation measures for species besides marine protected areas (MPAs), with the first assessment to be done by 2025, as well as assess the effect on species through risk and status assessments by 2029.

Table 7.13. Status of marine mammal management plans, as reported to the HELCOM Expert Group on Marine Mammals (EG MAMA).

Country	Management Plan	Adopted in / for the years	Planned Updates	Hunting and regulation quotas	Websites	Additional information
Denmark	MPs for grey seal and harbour seal exist	Adopted in 2020 for 2020-2025		Derogation shooting of grey seals and harbour seals. No fixed quota. 48 harbour seals and 2 grey seals in 2020.	GREY SEAL and HARBOUR SEAL (In Danish only)	
Estonia	MPs for grey and ringed seals exist	Adopted in 2015 for 2015-2019				The government is revising the management plans on grey and ringed seals every five years. The grey seal is in the list of wild game in the Estonian Hunting Act, and hunting started in 2015. Hunting of grey seal is included in the management plan. Only licenced hunting is allowed and the quota is set annually based on census data.
Finland	MPs for grey and ringed seal exist Action plan for harbour porpoise exists.	2007 for 2007-2012 and are still valid.	The updates of the seal management plans are in preparation Reviewed action plan for harbour porpoise was released in 2016 (in Finnish and Swedish)	For hunting period 2021-22 the quotas were as follows: Grey seal: The quota for the Gulf of Bothnia - Kvarken stock management area is 350 greys seals, the quota for the stock management area of Southwest Finland is 400 grey seals and the quota for the stock management area of the Gulf of Finland is 300 greys seals Ringed seal: (Licensed hunting) The Quark-Bothnia Bay 300 individuals. Ringed seal: A maximum of 375 ringed seals in the Gulf of Bothnia stock management area. In other areas, the quota is 0 ringed seals.	GREY SEAL AND RINGED SEAL: ENGLISH FINNISH	Grey seal hunting requires a special licence granted by the Finnish Wildlife Agency, as referred to in section 41 of the Hunting Act; Grey seal hunt in Åland: The provincial government has decided on the guidelines for the protection hunt for grey seals for the period 15.4.2021-31.1.2022. As in recent years, a personal permit is no longer required to participate in the hunt, but it may be carried out on your own initiative. There is still a quota of 500 grey seals that may be killed, for this reason all killed seals must be reported. Of the quota of 500 grey seals, 327 grey seals remain (last updated on 17.8.2021). Ringed seal: With a hunting licence, granted by the Finnish Wildlife Agency in accordance with the Hunting Act, Sect. 10 Within the regional quota, granted by virtue of the Hunting Act, Sect. 10 Within the regional quota, granted by virtue of the Hunting Act, Sect. 10. Requires a special licence granted by the Finnish Wildlife Agency, as referred to in section 41 of the Hunting Act.
Sweden	MPs for grey seal and harbour seal in Skagerrak and Kattegat (excluding the Kalmarsund population) exist Harbour porpoise action plan exists.	For harbour seal adopted in2012. For grey seal an updated version adopted in 2020 for 2021-2025. For harbour porpoise a new action plan was published June 2021.	MP for the Kalmarsund population of harbour seal will be updated and reviewed MP for ringed seal: New draft presented for review in spring 2020.	Grey seal (licensed hunting 2021): 2000 individuals (in 12 counties from Norrbotten to Skåne.) Ringed seal (protective hunting): 420 individuals divided between the two counties Norrbotten, Västerbotten and Västernorrland (The Quark - Bothnia Bay). Harbour Seal (protective hunting): 900 individuals including the counties of Västra Götaland, Halland and Skåne.	GREY SEAL HARBOR SEAL PORPOISES	For grey seal licensed hunting was allowed for 2020 and 2021. Only protective hunting is allowed on other seal species in Sweden. Regarding protective hunting on harbour seal Skåne only includes the municipalities Båstad, Ängelholm, Höganäs and Helsingborg. Västra Götaland also includes Skagerrak.
Latvia	One MP for all Baltic Sea species	2021 for 2021-2031			https://www.daba.gov.lv/lv/sugu-un-biotopu-aizsardzibas-plani	Seals are protected species and hunting are not allowed. The law allows the acquisition of seals as nongame species with special permits.
Poland	MP for harbour porpoise (in Poland referred to as a 'conservation programm') exist	Adopted in 2015		No hunting of marine mammals takes place in Poland.	https://www.gov.pl/web/gdos/programy-ochrony-gatunkow-zagrozonych-wyginieciem (the last one on the list, in Polish only)	MP include: - description of how to perform conservation activities aimed at restoring populations of harbour porpoise; - specification of the time and place of performing conservation activities; - indication of the entity responsible for performing conservation activities; - information about costs and sources of financing.

7.6.2 Other international committments

At the EU level the MSFD and Habitats Directives, respectively, function as key commitments.

All seals in Europe, as well as habrour porpoise, are also listed under the EU Habitats Directive Annex II, and Member States are obliged to monitor the status of seal populations and take measures to ensure securing their good status. All three seal species are also listed on Annex V for the habitats directive, requiring Member States to ensure that their exploitation and taking in the wild is compatible with maintaining them in a favourable conservation status. The EU Habitats Directive (European Commission 1992) specifically states that long-term management objectives should not be influenced by socio-economic considerations, although they may be considered during the implementation of management programmes provided the long-term objectives are not compromised. Most haul-out sites of harbour and grey seals in the Baltic are protected during critical periods of time, since seals are vulnerable to disturbance during the lactation and moulting periods.

In the EU marine area, harbour porpoises are under strict protection, because they are not only listed in Annex II, but also in Annex IV of the EU Habitats Directive. The species is also part of the "Agreement on the Conservation of Small Cetaceans of the Baltic, North East Atlantic, Irish and North Seas (ASCOBANS)" under the Bonn Convention. ASCOBANS has specifically focused on the recovery of the proper Baltic Sea population with the enactment of the Jastarnia Plan (ASCOBANS 2009). The ASCOBANS conservation plan for the western Baltic Sea population has been developed and presented in 2012. Further, the Baltic Sea States have agreed in HELCOM Recommendation 17/2 to protect the harbour porpoise in the Baltic marine Area.

The assessment also has clear relevance for the EU Marine Strategy Framework Directive (MSFD) (European Commission 2008), for those Contracting Parties that are also EU Member States. In particular the relevance is high for tracking progress in relation to MSFD Descriptor 1 that addresses species and habitats, Descriptor 4 that addresses ecosystems, including foodwebs and Descriptor 8 which states that concentrations of contaminants are at levels not giving rise to pollution effects. The HELCOM holistic assessment also directly or indirectly addresses the following qualitative descriptors and criteria of the MSFD for determining Good Environmental Status (European Commission 2008a, criteria of the Commission Decision 2017/848 (European Commission 2017)).

- D1C2: The population abundance of the species
- D1C3 Population demographic characteristics of the species
- D1C4: The species distributional range
- D4C4: Productivity of the trophic guild
- D8C2: The health of species and the condition of habitats are not adversely affected due to contaminants

Subsequently, unless good status is secured, relevant EU Member States are to include measures needed to improve the status in their national MSFD Programmes of Measures. While these measures are individual for each country, regional cooperation is encouraged.

The indicator is also relevant for Sustainable Development Goal 14. For an overview of commitments related to adressing bycatch, please see the relevant section under chapter 9.

7.6.3 Needs for future assessments

Data collection and reporting on nutritional status through agreed national monitoring programs to a designated database need to be developed and expanded for all seal species in all relevant areas of their distribution aiming to to increase the spatial coverage of the data underlying the evaluation. Data on nutritional status must be collected in a more representative way as currently only blubber thickness from hunted seals are reported. Seasonal and individual variation in blubber thickness needs to be taken into account (Siebert *et al.* 2022). Further health indicators accounting for other variables than blubber thickness must be developed.

Assessment development needs with regards to grey seal

For the grey seal populations there is some uncertainty whether they are close to carrying capacity of the environment which introduces uncertaintly in the indicator evaluation on abundance and has implications on the threshold value to be used. For more information please see the indicator report (HELCOM 2023v).

In relation to the abundance and distribution there is currently no coordinated effort to monitor land pupping sites for grey seal in the Baltic. These sites are likely to become of increasing importance in the future when the extent of the sea ice decreases. Recent breeding distribution on ice is also poorly known, as well as which proportion of the animals are breeding on ice when it is available. A coordinated survey during a good ice year would be beneficial to improve the robustness of future assessments. There is also no coordinated monitoring of at-sea occupancy for grey seal.

In relation to evaluation of nutrietional status of grey seals criticism for the current indicator outline is the exclusion of large amount of data by not incorporating animals of additional age classes in addition to the current juveniles, for example age class 0 (pups of the year) and sexually mature females and males that could be included if care is taken to account for their reproductive status. In addition, hunting only occurs in a subset of countries around the Baltic Sea and in areas where hunting does not occur collection of seals found dead is the major source of data, so several countries can only contribute with data on live-caught, bycaught or even stranded animals. A wider sampling scope with stranded seals will increase the variation of the data (as they have as a group different causes of death), which in turn complicates the setting of a new threshold. There is currently no consensus on how to include stranded seals into the indicator and this needs to be further discussed. For the grey seal, spatially different threshold values for blubber thickness and changes due to population dynamics should be investigated. Initiatives to measure the body condition using drones are underway, which could result in a novel way of gathering large amounts of data.

The current threshold of 90% for reproductive status is set based on literature findings across species. However, there could be species differences and appropriate age ranges must be compared and applied. In addition, literature reporting reproductive rates based on ovarian CA (or CL) only, is probably not relevant for this indicator. Thus, a revision of the threshold values is recommended towards future evaluations.

There is ongoing work to define the Precautionary Approach Level for grey seals in order to gain a better understanding of when seals approach carrying capacity.

Assessment development needs with regards ringed seal

The HELCOM Red List of Species (HELCOM 2013c) recommends that national seal conservation and management plans should be developed for ringed seal in order to ensure a proper conservation and management of all sub-populations during all life stages (ICES 2005). According to ICES WGMME Report (2005), it is important to address possible impacts on ringed seals when planning the use and exploitation of marine areas such as infrastructure development (e.g. shipping, oil transit, fixed links and wind parks). Regulations for shipping should in particular be implemented for ice breaking vessels during wintertime. Further improvement of long-term monitoring and research programmes is needed. HELCOM Recommendation 27-28/2 further recommends the Contracting Parties to collaborate within the HELCOM EG MAMA to identify and establish a network of protected areas for important actual and potential seal habitats across the Baltic Sea area (re. the EU Habitat Directive, Annex II), and attempt to harmonise the regulations and monitoring of these conservation areas.

As ringed seals breed on ice they are highly susceptible to the effects of climate change and warmer winters, which cannot be alleviate through direct management but has a direct effect on their status. With regards to abundance of ringed seal further research and relevant quantitative measures for the ice quality are needed to gain a better understanding the haulout behaviour of ringed seals, calibrating the survey results in different ice-conditions to establish reliable trend indexes and for estimating the true population size. Haul-out distribution on land is currently not fully documented for Sweden and Finland. On-land haul-out sites are likely to become of increasing importance in the future as the ice-cover decreases. Determining the on-land haul-out sites will help identify critical areas in the distribution range. Results from ongoing work on this are expected in near future.

Ringed seals from both management areas have shown a high degree of site fidelity (Härkönen *et al.* 2008) and it is unlikely that extensive migrations occur at current low population numbers, although some individuals may show more extensive movements during foraging season (Oksanen *et al.* 2015). However, more research is needed to understand the population structure and possible gene flow between the management units. Current degree of gene-flow and connections even between the three southern areas are poorly known. Therefore, it is unclear if they should be assessed separately or kept as one unit. Monitoring on all of them have been challenged by the degraded ice-conditions which have also likely negatively affected reproductive success in these subpopulations. Thus, better knowledge on the population structure in the southern management unit is needed. Still, it is clear that the status of abundance and population trend of the southern sub-populations is not good.

The current threshold of 90% for reproductive status is set based on literature findings across species. However, there could be species differences and appropriate age ranges must be compared and applied. In addition, literature reporting reproductive rates based on ovarian CA (or CL) only, is probably not relevant for this indicator. Thus, a revision of the threshold values is recommended towards future evaluations.

Major methodological developments are also required to develop and agree on suitable threshold values for nutrional status for ringed seals. Aspects of this work will require new methodological approaches to the existing data and research initiatives.

Assessment development needs with regards harbour seal

The HELCOM Red List of Species (HELCOM 2013c) recommends that national harbour seal conservation and management plans should be developed in order to ensure conservation of the populations. These should include continuation of long-term monitoring and research programs, the restoration of suitable habitats where appropriate, as well as the establishment and proper management of seal sanctuaries. Further, the responsible national authorities should coordinate their conservation and monitoring strategies regarding shared seal populations with neighbouring countries.

For the Kattegat harbour seal populations there is some uncertainty whether they are close to carrying capacity of the environment, which introduces uncertainty in the abundance indicator evaluation results and has implications on what threshold value to use. For more information please see the indicator report (HELCOM 2023x).

Pup counts covering the whole breeding distribution would improve the geographical and temporal resolution of the breeding data for harbour seal and subsequently improve future assessments. Regular telemetry studies in all populations would provide more accurate information on the foraging grounds and movement behaviour as well as potential changes in them. The proposed approach to re-evaluate harbour seal management units (i.e. developing of more and smaller relevant management areas based on latest science and re-evaluating relevant Limit Reference Levels), needs to be carried out to improve future assessments.

Major methodological developments are also required to develop and agree on suitable threshold values for nutritonal status for harbour seals. Aspects of this work will require new methodological approaches to the existing data and research initiatives.

Data for harbour seal was insufficient for the species to be included in the evaluation and assessment of reproductive status in the assessment period 2016-2021. Improved data collection and reporting would therefore be a prerequisite for an improved assessment for the next assessment period.

Assessment development needs with regards harbour porpoise

The 2013 HELCOM Red List (HELCOM 2013c) identifies that national conservation and management plans should be developed and implemented in order to ensure conservation of the populations. These should include continuation of long-term monitoring and research programs, the restoration of suitable habitats where appropriate, as well as the establishment and proper management of marine protected areas. Further, the responsible national authorities should coordinate their conservation and monitoring strategies with neighbouring countries. Immediate action to reduce bycatches is also needed.

While the current assessment is a significant step forward to provide an initial assessment results there is need for significant further work to improve future assessments. There is currently a lack of harmonisation in the passive acoustic monitoring used to monitor harbour porpoises and this issue needs to be addressed to advance future assessments. There is variation in the filtering and processing methods used by different countries, and some variation in the device used. This prevents comparability between countries. There is a need for future harmonisation to facilitate population level assessments of indicators, particularly for the critically endangered Baltic Proper population. In addition, further work is needed to establish a full and working understanding of relevant conservation objectives to support the development and agreement on quantifiable threshold values against which future assessments can be applied. This process would require the application of relevant methodologies to achieve the establishment of such threshold values (for example Limit Reference Values, LRL, and Target Reference Limits, TRL) and require suitable monitoring to be implemented to achieve the needed data sets for the evaluations.

In the case of the harbour porpoise population in the Belt Sea, no trend was observed over the study period of 15 years, which is likely due to the large confidence intervals of the earlier surveys and the fact that the 1994 data could not be incorporated due to lack in geographical overlap. Additional work resources are needed to evaluate how these survey data could be (spatially) extrapolated and, thus, included in the trend analysis, which would be extremely valuable for the trend assessment as we would then have 26 years of data, i.e. more than three generations (=22.5 yrs).