HOLAS II

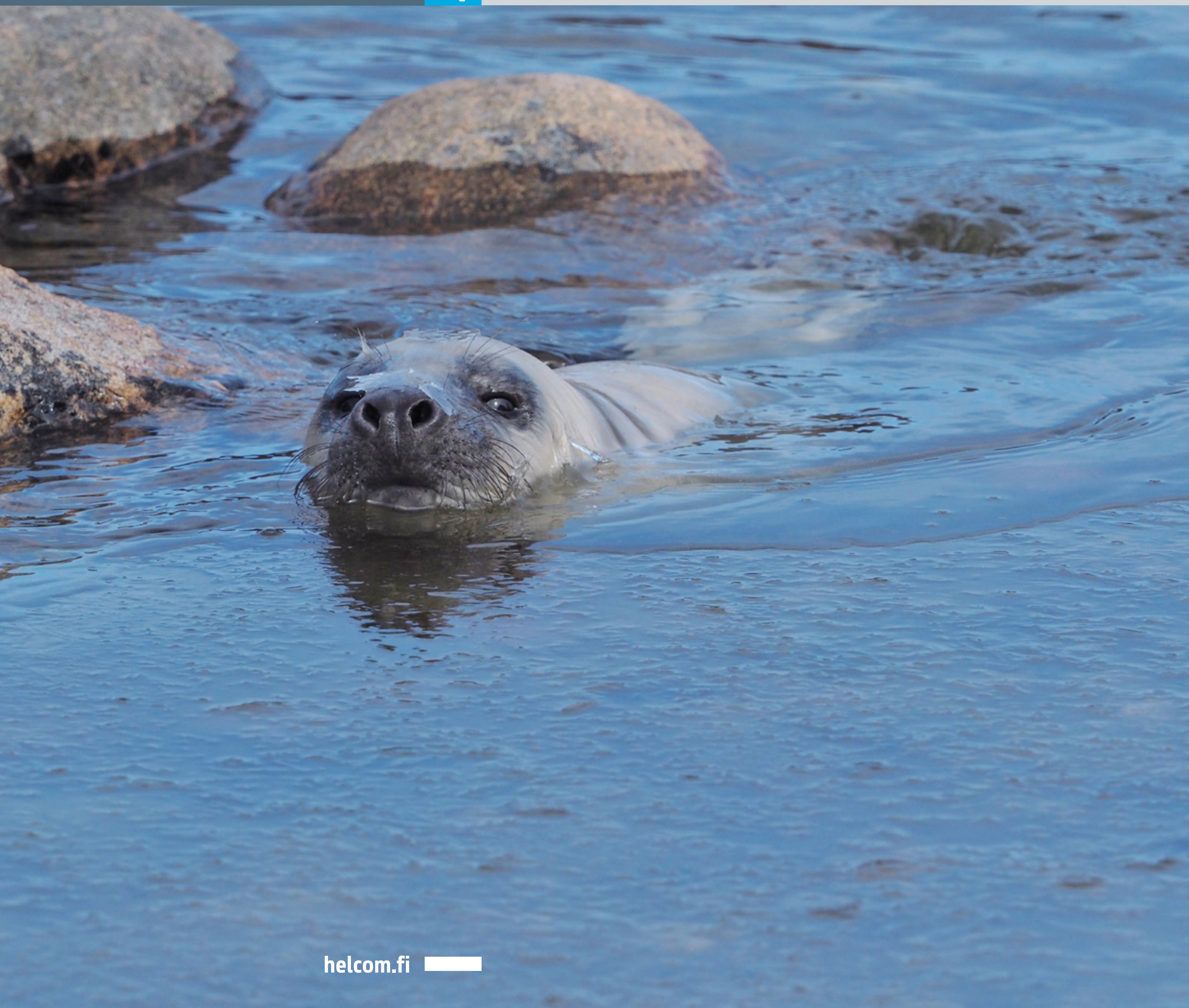
Thematic assessment of biodiversity 2011–2016

Supplementary report to the HELCOM 'State of the Baltic Sea' report

Baltic Marine Environment Protection Commission

Biodiversity

Baltic Sea Environment Proceedings 158



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

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

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

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Table of contents

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

The status of Baltic Sea biodiversity during 2011-2016 was assessed as part of the second HELCOM holistic assessment of ecosystem health in the Baltic Sea. The current report provides a description of the assessment method, focusing on the integrated assessment of biodiversity using the BEAT tool, and gives assessment results at overarching and detailed level based on core indicators and complementary data. The main results are also presented in the 'State of the Baltic Sea' report (HELCOM 2018a).

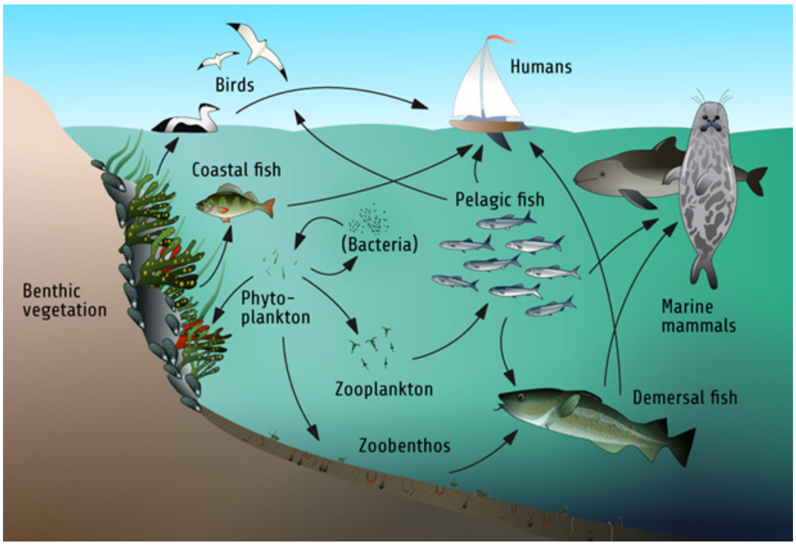

Figure ES1.
A simplified illustration of the food web structure in the Baltic Sea.(eutrophication, hazardous substances, benthic habitats, pelagic habitats, fish, and seals) are shown in five categories. Assessment results based on indicators (commercial fishing, non-indigenous species, and waterbirds) are shown in two status categories.

Results in brief

Many species and communities do not achieve good status. Although recently implemented measures may lead to an improvement during years to come, continued and even intensified efforts to improve the environmental status of all studied ecosystem components are of key importance.
Integrated assessment results for the five studied ecosystem components show that:

- For benthic habitats, at least half of the assessed areas do not have good status, based on an assessment representing only soft-bottom habitats.
- For pelagic habitats, the majority of open sea areas do not have good integrated status.
- Around half of the assessed coastal areas have good status for coastal fish. Five out of eight assessed commercial fish stocks do not have good status. The migrating species show good status in about half of the assessed rivers.
- For marine mammals, the population sizes of grey seal are increasing. Of the three management units of harbour seal, only the Kattegat population shows good status. Ringed seal shows inadequate status with a constrained distribution. Harbour porpoise in the Baltic Sea are still threatened.
- The overall status of waterbirds could not be assessed for the whole Baltic Sea. Based on the core indicators, it was assessed as good during both breeding and wintering seasons

Indicators included

HELCOM biodiversity core indicators were used as the cornerstone of the assessment. These indicators represent five key ecosystem components of the Baltic Sea: benthic habitats, pelagic habitats, fish, marine mammals, and waterbirds (Figure ES1) However, some important aspects of these components are not currently covered by core indicators, and continued development is needed in order to achieve a more complete assessment in the future. The biodiversity core indicators were supplemented with selected HELCOM eutrophication core indicators to cover some of the aspects of pelagic and benthic habitats for which no corresponding biodiversity indicators were yet available. The assessment of commercial fish species was based on information from the International Council for the Exploration of the Sea (ICES). In coastal areas, national indicators were also used.

The Baltic Sea is home to about 2,700 macroscopic species and innumerable smaller microscopic species (Figure 2). Around 1,600 macroscopic species are found in the Kattegat, which is the most marine sub-basin of the Baltic Sea. In the most freshwater-influenced area, the Bothnian Bay, only around 300 species occur (HELCOM 2012, 2013a). This change reflects the effect of low salinity on the distribution of many species of marine origin (See also Figure 1.2 in Chapter 1 of HELCOM 2018a).

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

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

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

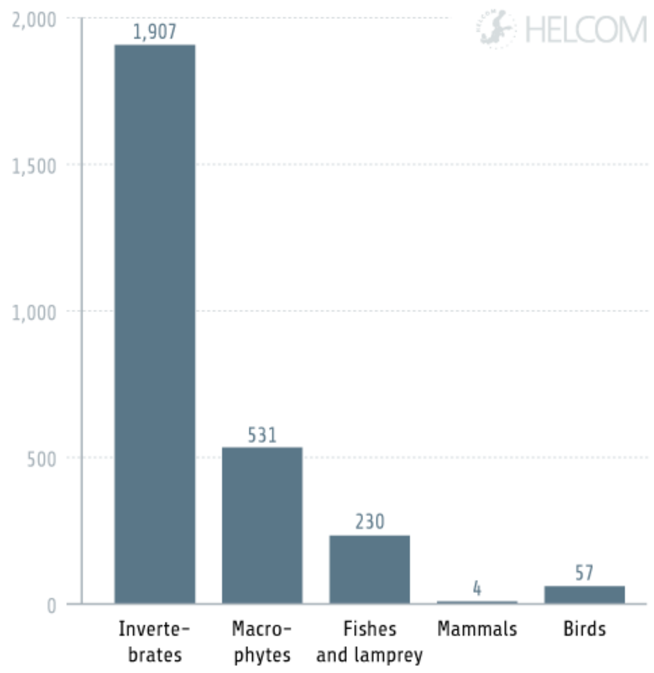

Figure 2.
Number of macroscopic taxa in the Baltic Sea within different species groups. Based on HELCOM (2012).

Chapter 2. Indicators used in the integrated assessment

2.1. Assessment overview

The integrated assessments were carried out using the BEAT tool, separately for the five key ecosystem components benthic habitats, pelagic habitats, fish, mammals, and water birds. The biodiversity core indicators were supplemented with additional indicators in this assessment, with the aim to achieve an evaluation that is as comprehensive as possible, and representative at Baltic Sea scale (Figure 3). Selected core indicators of eutrophication were included in cases where no directly corresponding biodiversity indicators are currently available. In coastal areas, national indicators have been used for benthic and pelagic habitats. Results for commercial fish were obtained from the International council for exploration of the sea (ICES). Descriptions of the core indicators are found in the core indicator reports (HELCOM 2018b-r).

Using the BEAT tool for the integrated assessment, the results were being presented by so called biological quality ratios (BQR). The biological quality ratios are used as a way to scale indicators and make them comparable with each other, as the indicators are originally assessed by a variety of assessment approaches and measured by different units. Biological quality ratios are presented in five equal-distance categories between 0 and 1, where values above 0.6 are interpreted as reflecting good integrated status (For details, see Chapter 3.3).

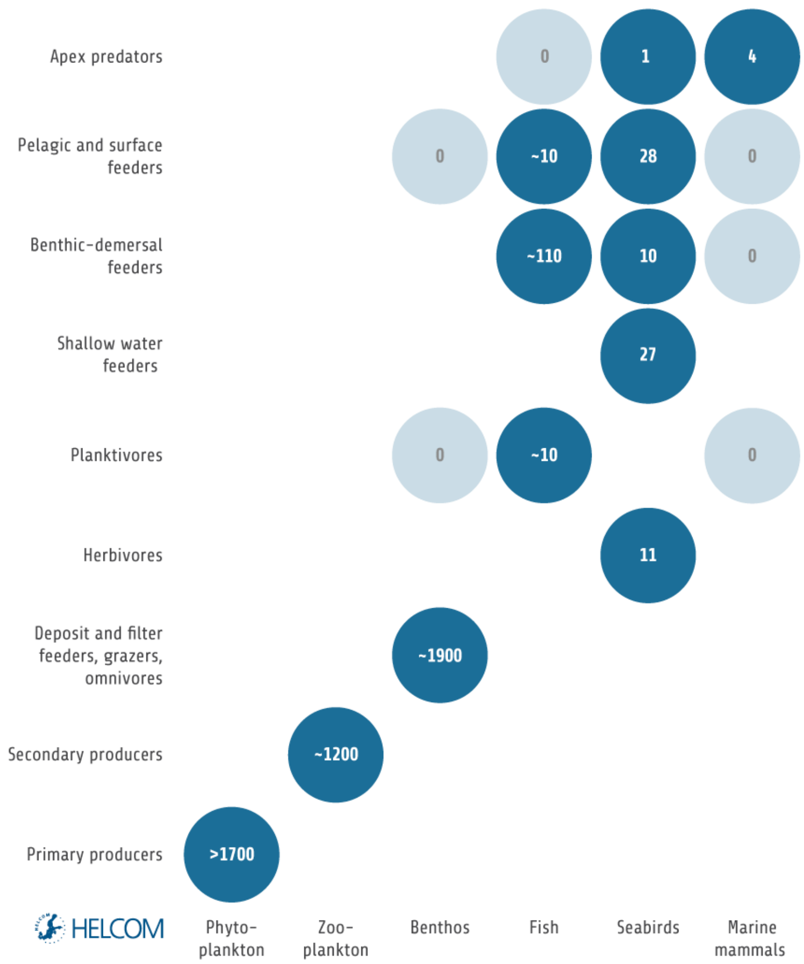

Figure 3.
Estimated numbers of species in the Baltic Sea. HELCOM core indicators are operational to address ecosystem components in all dark blue fields, to different level of extent depending on development status of the regionally agreed indicators. Light blue fields indicate species groups which do not occur in the Baltic Sea, although they are typical to marine waters in general. The numbers are shown in relation to functional groups on the vertical axis and by taxonomy on the horizontal axis. Data sources for phytoplankton and zooplankton: Ojaveer *et al.* (2010); benthic fauna: HELCOM (2012); fish (HELCOM 2012); birds: ICES (2016b). 'Fish' includes species classified as regularly or temporarily occurring by HELCOM (2012) and are biologically classified based on Fishbase (2017).

An overview of the indicators which were included in the integrated assessment is presented in Table 1. In addition, results for the core indicators 'Abundance of salmon spawners and smolt" and 'Abundance of sea trout spawners and parr' are reflected in this report. The indicators 'Diatom/ dinoflagellate index' and 'Phytoplankton biomass or biovolume' are under development, and results for these for are presented descriptively for some sub-basins.

Table 1.
Overview of indicators used in the integrated biodiversity assessment. More detailed information is provided further down in this chapter. In addition, assessment results for the core indicators 'Abundance of salmon spawners and smolt' and 'Abundance of sea trout spawners and parr' are presented in the report, and results for 'Diatom/dinoflagellate index", 'Seasonal succession of phytoplankton", which are included as test, are given desciptively. The corresponding core indicator reports are identified as HELCOM 2018b-r).

Indicator	Description
Benthic habitats	
State of the soft-bottom macrofauna community	— Biodiversity core indicator. Applied above the permanent halocline in the open sea.
Oxygen debt	— Eutrophication core indicator. Applied below the permanent halocline in the open sea.
Macrofauna indices	— National indicators were used in coastal areas, including DKI (Denmark), ZKI, KPI, FDI (Estonia), BBI (Finland), MarBIT (Germany), BQI (Latvia, Lithuania, Sweden) and B (Poland).
Macrophytes	— National indicators were used in coastal areas, including indicators for: Depth limit of eelgrass (Denmark), Benthic macroflora depth distribution (Estonia), Fucus vesiculosus depth distribution (Estonia, Finland), Proportion of perennial species (Estonia), PHYBIBCO (Germany), BALCOSIS (Germany), Phytobenthos Ecological Quality Index (Latvia), Furcellaria lumbricalis depth distribution (Lithuania), SM1 (Poland), Depth distribution of macrophytes and angiosperms (Sweden).
Water clarity	— Included as proxy for the depth distribution of benthic vegetation, applied in some national coastal areas.
Oxygen	— Oxygen concentration was used in Sweden as proxy for benthic macrofauna in coastal area, using a national indicator.
Pelagic habitats	
Zooplankton mean size and total stock	— Biodiversity core indicator. Applied in open sea.
Chlorophyll-a	— Eutrophication core indicator reflecting total pelagic primary production. Applied in the open sea. — National results for the metric were used for coastal areas.
Cyanobacterial bloom index	— Biodiversity pre-core indicator included as test. Applied in open sea.
Fish	
Abundance of key coastal fish species	— Biodiversity core indicator. Only applicable in coastal areas.
Abundance of coastal fish key functional groups	— Biodiversity core indicator. Only applicable in coastal areas. The indicator has two components which were included separately in the integrated assessment.
Commercial demersal fish	— Based on assessment results from ICES: Western Baltic cod, Eastern Baltic cod, plaice in the Western Baltic and sole included separately in the integrated assessment.
Commercial pelagic fish	— Based on assessment results from ICES. Five herring stocks and sprat stocks included separately in the integrated assessment.
Mammals	
Population trends and abundance of seals	— Biodiversity core indicator. Assessed separately for grey seal, harbour seal and ringed seal.
Distribution of Baltic seals	— Biodiversity core indicator. Assessed separately for grey seal, harbour seal and ringed seal.
Nutritional status of seals	— Biodiversity core indicator. Available only for grey seal.
Reproductive status of seals	— Biodiversity core indicator. Available only for grey seal.
Waterbirds	
Abundance of waterbirds in the breeding season	— Biodiversity core indicator.
Abundance of waterbirds in the wintering season	— Biodiversity core indicator.

2.2. Assessment scale

To achieve a regional coherence, the Baltic Sea is sub-divided by a hierarchical structure with four scales in HELCOM monitoring and assessment:

1. HELCOM marine area. No division. The whole Baltic Sea encompasses the entire HELCOM area.
2. HELCOM sub-basins. Division of the Baltic Sea into 17 sub-basins.
3. HELCOM sub-basins with coastal and off-shore division. Division of the Baltic Sea into 17 sub-basins and further division into coastal and off-shore areas, including in total 40 coastal areas.
4. HELCOM sub-basins with coastal WFD water types or water bodies. 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 Water Framework Directive (WFD) water types or water bodies, including in total 240 coastal areas.

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 2013c).

The appropriate assessment scale for each core indicator is agreed on based on ecological relevance. The assessment units can be further aggregated within one assessment scale. For example, several sub-basins at scale 2 taken together may comprise the assessment unit with respect to a certain indicator. This approach is applied for example in the case of core indicators representing the abundance and distribution of seal populations.

2.3. Threshold values

The HELCOM core indicators are assessed in relation to regionally agreed threshold values. Due to the complexity of the assessed biodiversity aspects, different assessment approaches are used for different core indicators. The threshold values are also typically identified separately for each assessment unit in which the indicator is applied.

The threshold values for biodiversity core indicators have been developed by HELCOM experts on benthic and pelagic habitats, coastal fish, seals and waterbirds, and agreed on by the HELCOM countries (See Annex 1).

In the integrated assessment, information on the threshold values is used together with indicator-specific minimum and maximum values in order to provide estimates of status which are quantitatively comparable across indicators, so called biological quality ratios (BQR; see Chapter 3.3).

2.4. Description of the ecosystem components and indicators

The HELCOM core indicators are assessed in relation to regionally agreed threshold values. Due to the complexity of the assessed biodiversity aspects, different assessment approaches are used for different core indicators. The threshold values are also typically identified separately for each assessment unit in which the indicator is applied.

The threshold values for biodiversity core indicators have been developed by HELCOM experts on benthic and pelagic habitats, coastal fish, seals and waterbirds, and agreed on by the HELCOM countries (See Annex 1).

Benthic habitats

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

The conspicuous salinity gradient is reflected in the species composition of Baltic Sea benthic communities, and there is a decreasing species diversity along with decreasing salinity towards the inner sub-basins (Gogina *et al.* 2016). The southern Baltic Sea is dominated by marine species, such as polychaete worms and molluscs, including the bivalves *Arctica islandica* and *Astarte borealis*. Eel grass (*Zostera marina*) is an important macrophyte species on shallow sandy bottoms in the southern and central Baltic Sea. The benthic vegetation on hard substrates is dominated by brown and red seaweeds.

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

The depth distribution of *Fucus* species, and hence the spatial extent of the habitat created by these, is for example dependent on water clarity (Figure 4).

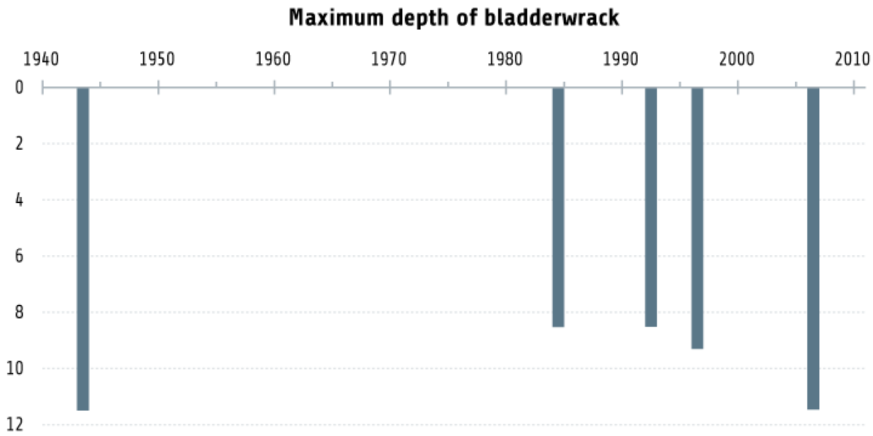

Figure 4.
Living environments at benthic hard bottoms are in many cases shaped by structure-forming seaweeds. These are affected by various environmental factors, including changes in water clarity and sedimentation rates. Due to the indirect of eutrophication, the distribution and density of macroalgae is diminished in many coastal areas of the Baltic Sea. This figure shows an example of how the depth distribution of bladderwrack (*Fucus vesiculosus*) has changed over time in the Singö Archipelago, Åland Sea. In this case, an improvement is seen in more recent years. Based on monitoring data from Stockholm and Uppsala University, Sweden.

Indicators

The assessment of benthic habitats in the open sea was limited to soft bottoms and was based on the biodiversity core indicator 'State of the soft- bottom macrofauna community' which assesses changes in the species diversity and species sensitivity composition based on how sensitive different species are to disturbance (Core indicator report: HELCOM 2018b; see also Figure 5). In addition, the eutrophication core indicator 'Oxygen debt' was used in order to give information on living conditions for macrofauna in deeper areas (Core indicator report: HELCOM 2018c). The indicators are not yet operational in all sub-basins.

The oxygen debt indicator addresses the relative deficiency of oxygen, compared to a fully saturated water column. The indicator reflects indirect effect of eutrophication, since oxygen deficiency is linked to the amount of organic matter descending to the seafloor, which in turn is connected to anthropogenic nutrient loading. As the indicators is only applicable in deep basins with a permanent halocline, and thus stratification, this indicator is not applicable in the southern Baltic Sea from the Kattegat to the Arkona Basin due to the dynamic hydrographic conditions and a different seafloor morphology, nor in the Gulf of Riga, Åland Sea or in the Gulf of Bothnia. Importantly, hypoxia can occur in these sub-basins areas as well, mostly seasonal hypoxia, even though the oxygen debt indicator is not applicable there.

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

The applied indicators are biased towards addressing impacts from eutrophication, and the assessment may overlook the influence of other pressures on benthic habitats. For example, impacts on benthic habitats from physical loss and disturbance are not directly assessed with the currently available indicators. HELCOM is currently developing a core indicator on 'Condition of benthic habitats' aiming to evaluate the area, extent and quality of specific benthic habitats in relation to a quantitative threshold value and on 'Cumulative impact on benthic biotopes' to assess adverse effects from physical disturbance. In addition, the development of indicators for benthic communities on hard bottoms is identified as a priority (Box 1).

The benthic habitats were assessed at assessment scale 4, namely the Baltic Sea sub-basins for the open sea and the water bodies and water body types as used under the Water Framework Directive (WFD) for coastal waters.

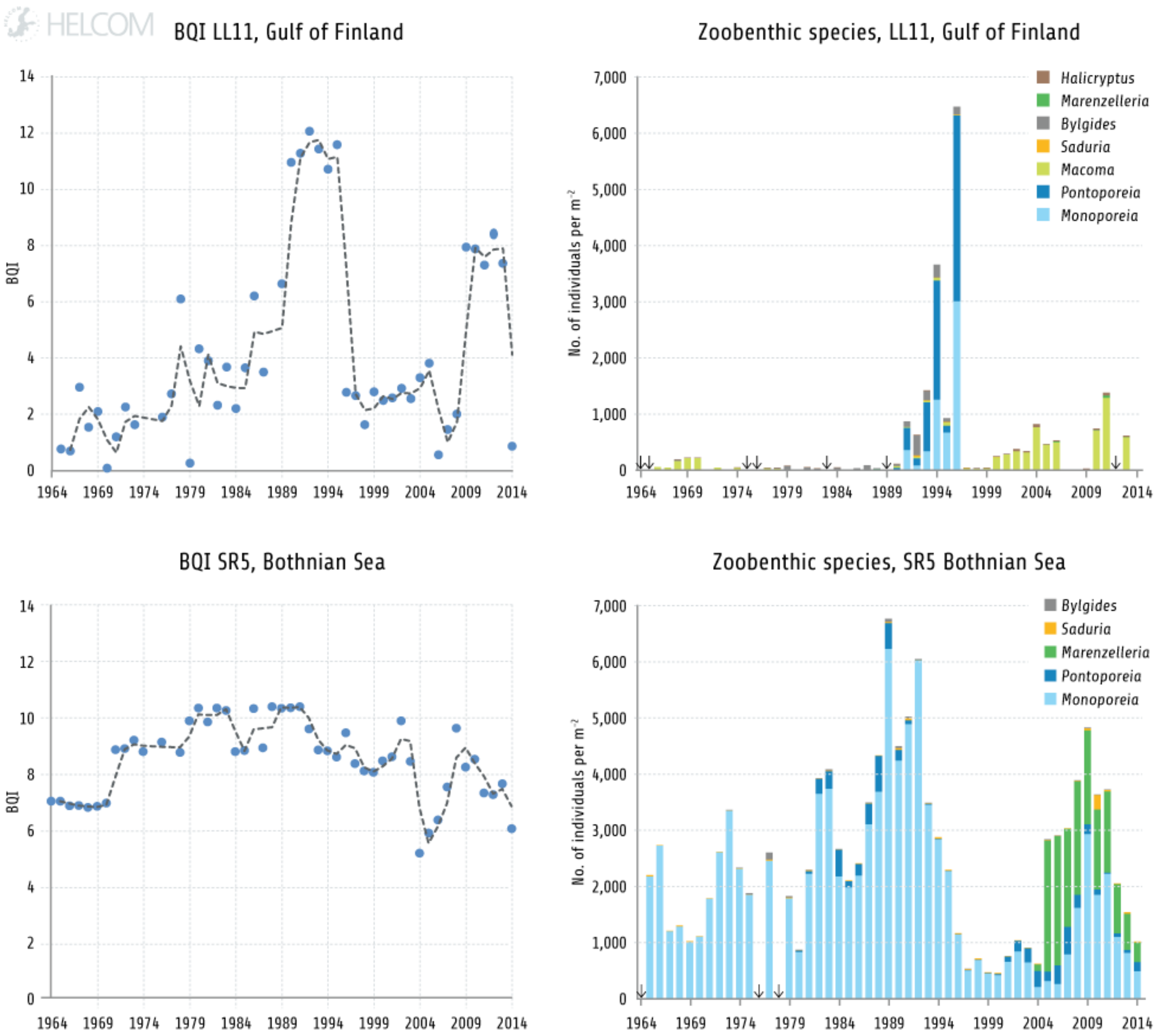

Figure 5.
The biodiversity core indicator 'State of the soft-bottom macrofauna community' is evaluated at the level of assessment units by the Benthic Quality Index (BQI). This index addresses the species composition of benthic fauna while accounting for the relative proportion of sensitive and tolerant species, species richness and abundance of benthic animals. This figure shows examples of the index at the underlying station level. At the station in the Gulf of Finland (LL1), there is a peak in the index in the early 1990s, reflecting improved oxygen conditions at the seabed. A similar peak is also seen at other monitoring stations in the Gulf of Finland during the same years (data not shown). Data from the Bothnia Sea station (SR5) show strong variability over time in the abundance of the amphipod *Monoporeia affinis*. In addition, the introduction of the non-indigenous species Marenzelleria sp. can be noted in 2004. The dashed lines represent five-year moving averages. Arrows point to years with no data.

Pelagic habitats

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

Phytoplankton form the base of the pelagic food web. They support the growth of species at higher trophic levels via being food for zooplankton, or by a more complex route including the microbial loop. Phytoplankton blooms are a natural phenomenon in the Baltic Sea ecosystem, with blooms in late summer dominated by nitrogen-fixing cyanobacteria. However, due to eutrophication the phytoplankton blooms become more frequent and extensive (Vahtera *et al.* 2007).

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

Indicators

The status of the pelagic habitats in the open sea was assessed using the biodiversity core indicator 'Zooplankton mean size and total stock', (HELCOM 2018d) which evaluates the zooplankton community structure (Figure 6). In good status, zooplankton is dominated by large-bodied species. Not all open sea areas could be assessed due to lack of agreed threshold values.

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

Additionally, indicators representing changes in the species and size structure of phytoplankton are under development in HELCOM and are presented descriptively for testing in a few sub-basins: the 'Diatom/dinoflagellate index' (HELCOM 2018g), which measures the relative abundance of diatoms and dinoflagellates in the water column, and the 'Seasonal succession of phytoplankton' (HELCOM 2018h).

Coastal areas were assessed using national indicators on chlorophyll-a, and phytoplankton bio-volume, as used for assessments under the Water Framework Directive. The corresponding indicators are also used in the assessment of eutrophication (HELCOM 2018s). However, the results of the biodiversity assessment may differ from results of the eutrophication assessment in coastal areas, due to differences in the scaling methods of the BEAT tool as applied here, and in the HEAT tool used for eutrophication assessment.

The pelagic habitats were assessed at assessment scale 4, encompassing Baltic Sea sub-basins in the open sea and water bodies or water body types as used nationally under the Water Framework Directive in coastal areas.

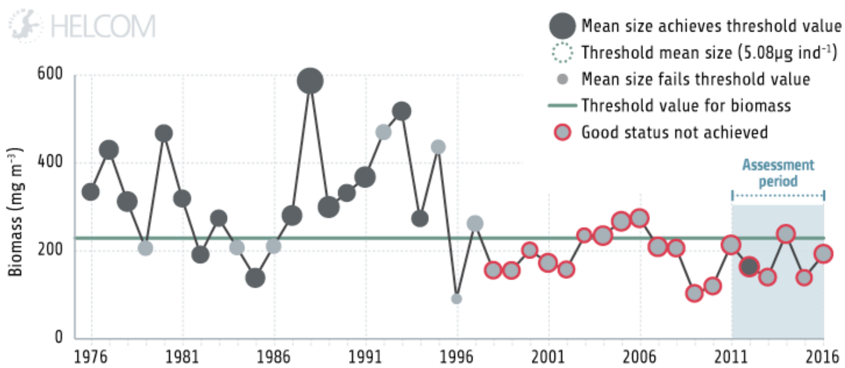

Figure 6.
The assessment of the core indicator 'Zooplankton mean size and biomass' requires that a minimum level of both the total biomass and the mean size of the zooplankton community is reached. The figure shows the long term trend in the core indicator in the Western Gotland Basin, as an example. The size of the circles corresponds to mean size of the zooplankton community, which ranged from 2 to 13 µg per individual. Black circles denote years when the mean size achieves the threshold value, and grey circles denote years when the mean size is below the threshold value. Circles marked with a red outline indicate years significantly below the threshold value for the core indicator, considering both mean size and biomass.

Fish

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

Coastal and open sea areas are characterized by different species of fish, and there are also clear differences in species composition among sub-basins due to the salinity differences. About 230 fish species are recorded in the Baltic Sea (HELCOM 2012). Marine species are the most common in the southwestern Baltic Sea and in open sea areas. Coastal areas are the key habitats for freshwater species, such as perch *(Perca fluviatilis)* and cyprinids *(Cyprinidae)*, and are also spawning and feeding areas for many marine species, such as cod *(Gadus morhua)*, flounder *(Platichtys flesus)*, and herring *(Clupea harengus)*. The anadromous migrating species, such as salmon and sea trout *(Salmo salar, Salmo trutta)*, but also sea lamprey *(Lampetra fluviatilis)* and some populations of whitefish (*Coregoniidae)*, are born and spawn in rivers but spend most of their growth phase in the Baltic Sea. The European eel *(Anguilla anguilla)* is a diadromous migrating species spawning in the Sargasso Sea, with Baltic Sea eel being part of the same population as all other European eels.

Indicators

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

— The ‘Abundance of key coastal fish species’ is based upon changes over time in perch (Perca fluviatilis) or flounder (Platichtys flesus), with the species chosen depending on the natural distribution of these species. Perch is used in the eastern and northern coastal areas, and flounder in the south. Good status is achieved when the abundance is above a site-specific threshold value (HELCOM 2018i).

— ‘Abundance of coastal fish key functional groups’ evaluates the abundance of selected functional groups of coastal fish in the Baltic Sea: piscivores and a lower trophic level component (cyprinids/mesopredators). Low values in the core indicator component on ‘piscivores’ indicates disturbed food webs. The ‘lower trophic level’ component is most often measured as the abundance of fish from the taxonomic family cyprinids, for which high values are associated with eutrophication. Good status is achieved when the abundance of piscivores is above a site-specific threshold value, and the abundance of cyprinids or mesopredators is within an acceptable range for the specific site (HELCOM 2018j).

- The open sea assessment was based on results for internationally assessed commercial fish stocks, using information on spawning stock biomass and fishing mortality from ICES (2017a-b). Data for cod (*Gadus morhua*), sole (*Solea solea*), plaice (*Pleuronectes platessa*), herring (*Clupea harengus*) and sprat (*Sprattus sprattus*) were included in the integrated assessment, as these were the ones for which assessment results in relation to both spawning stock biomass and fishing mortality were available (For more information on the indicators and reference point to define good status for open sea fish, see Figure A.2.1 in Annex 2).

  Further, the two core indicators on migrating fish, 'Abundance of salmon spawners and smolt' and 'Abundance of sea trout spawners and parr' represent species which migrate between freshwater and sea areas: salmon (*Salmo salar*) and sea trout (*Salmo trutta*; see also Box 1.2 in Chapter 1 of the State of the Baltic Sea report; HELCOM 2018a).

  — 'Abundance of salmon spawners and smolt' is based on the production of smolt in rivers with wild salmon stocks. It is applicable in all HELCOM countries except Denmark, Germany, Poland and Russia. The estimated smolt production is compared to an estimated potential smolt production capacity of the rivers, with the threshold value defined as 75 % of the production capacity (HELCOM 2018k).
  — The indicator 'Abundance of sea trout spawners and parr' is based on a comparison of the observed parr densities in rearing habitats with reference potential parr densities in the specified habitats. The indicator is applicable in all HELCOM countries. Good status is achieved when the moving parr densities average over 4-5 years remains above 50 % of the reference parr density (HELCOM 2018l).

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

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

Since the biodiversity assessment includes all fish species in the Baltic Sea area covered by operational indicators and for which data was available, the total list of assessed species differs from that assessed under the assessment of commercial fishing as a pressure (as presented in Chapter 4.6 of the State of the Baltic Sea report: HELCOM 2018a).

Fish were assessed at assessment scale 3 in coastal areas, which separates the Baltic Sea by sub-basins along the coastline. In the open sea, the ICES sub-divisions were used, in order to align with the scale at which the assessment results from ICES were provided. However, assessment results for sprat and cod were not applied to the Bothnian Bay due to their very limited occurrence in this sub-basin.

Marine mammals

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

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 Baltic Sea and the Kattegat, and ringed seal to the eastern and northern Baltic Sea. Harbour porpoise occurs mainly in the Kattegat and the southern parts of the Baltic Sea.

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

Indicators

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

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

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

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

There is currently no operational core indicator for harbour porpoise. HELCOM is developing indicators on the abundance and distribution of harbour porpoise, as well as on the number of drowned mammals caught in fishing gear. However, at present there are no defined threshold levels against which the status can be assessed, and these aspects are presented descriptively.

Waterbirds

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

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

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

There are also some differences between geographic areas. Whereas some of the assessed bird species occur all over the region, such as breeding common terns *(Sterna hirundo)* and wintering long-tailed ducks, others are restricted to smaller parts of the Baltic or only selected sites, for example breeding pied avocets *(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 calculated from land based survey data, whilst species in the open sea are not adequately assessed. Therefore, an overall assessment of waterbirds in the Baltic Sea has not been carried out, and coastal areas are the major focus of the assessment. Many open sea species are known to show strong declining trends in the Baltic Sea (Skov *et al.* 2011).

Indicators

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

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

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

Chapter 3. Method for the integrated biodiversity assessment

The integrated assessment of biodiversity was carried out using the HELCOM BEAT 3.0 tool. The tool integrates individual indicator results into estimates of the overall status of each ecosystem component and assessment unit. A description of the tool and how to run it is given in Annex 3.

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 indicators were grouped according to the ecological objectives of the Baltic Sea Action Plan. 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 the current results.

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). The HELCOM BalticBOOST project had the task to further develop an integrated biodiversity assessment tool that could be used in the second HELCOM holistic assessment. After a review of existing methods, the original BEAT and the related NEAT (Nested environmental status assessment tool), which was developed in the EU FP7 project DEVOTES (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 the second HELCOM holistic assessment, BEAT 3.0.

The development of a coherent system of environmental indicators in the Baltic Sea was initiated by the CORESET project (HELCOM 2013b). A basic criterion for HELCOM core indicators is that their underlying monitoring data and assessment approaches are comparable across the Baltic Sea. Hence, they are also suited for the integrated assessment. The indicator threshold values are set according to common principles, increasing the comparability across regions and indicators. However, due to variability in indicator properties and restrictions in underlying data, the identification of threshold values has been challenging, leading to variable approaches, and in some cases it has not been possible to identify fully quantitative threshold values. In some cases, the desired direction of change (trend) has been agreed on as the best available approach. BEAT 3.0 has been developed into being able to include indicators with various types of assessment approaches.

3.1. Structure and assessment approach of beat 3.0

BEAT 3.0 assesses the integrated status of biodiversity based on indicators following a nested structure. The assessment is conducted separately for the five key ecosystem components of the Baltic Sea: benthic habitats, pelagic habitats, fish, marine mammals and waterbirds. Each indicator is assigned to its relevant species group or species (or broad habitat type), and the indicators are integrated in a nested system (Figure 7).

The default integration rule applied in BEAT 3.0 is weighted averaging. However, the one-out-all-out principle can also be applied e.g. when adhering assessment rules of the Habitats Directive such as for marine animals (Figure 8). BEAT 3.0 follows a balanced structure, so that all groups at the same level in the structure are weighted equally, regardless of the number of indicators included (in order to ensure balance also in the case that some group is not represented at all, the elements are only included if they are represented by at least one indicator. No spatial aggregation is done within the BEAT tool. Instead, the results are presented directly at the ecologically relevant scales for each ecosystem component, and assessment results for the ecosystem components are presented separately.

To accommodate for the different types of indicators among the HELCOM core indicators, 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 (See chapter 3.3).

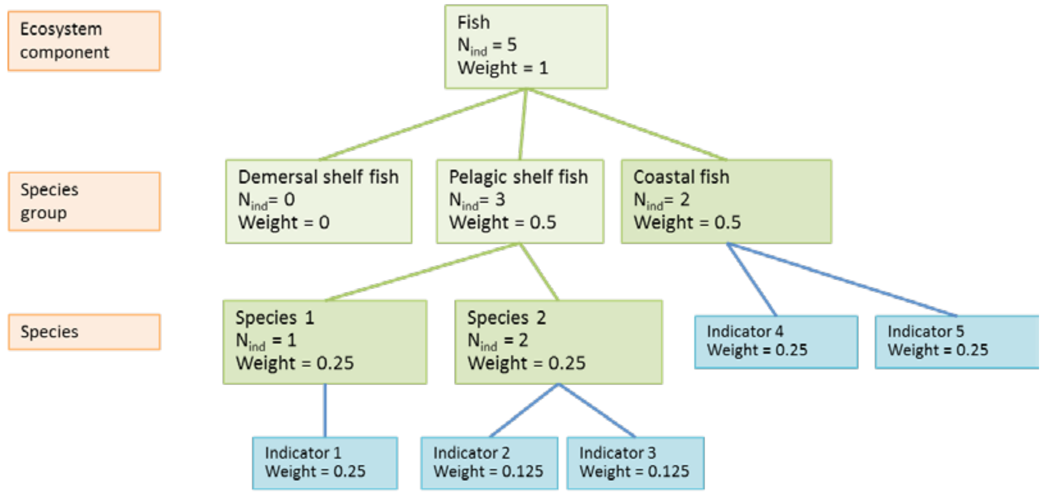

Figure 7.
Theoretical example of how weights are distributed in BEAT 3.0 in order to give a balanced design when different numbers of indicators are used for different groups and when indicators are assigned at different hierarchical levels. The example is shown for the ecosystem component fish, where coastal fish indicators are assigned to the species group level, and the indicators for pelagic shelf fish are assigned to species level. Biological quality ratios are based on weighted averaging at each hierarchical level.

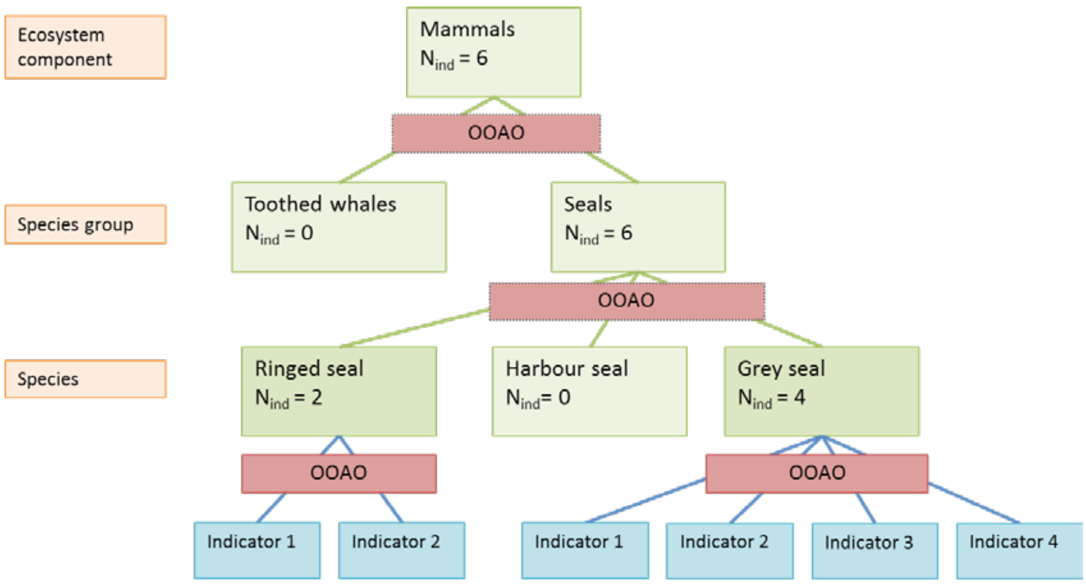

Figure 8.
Example of the one-out-all-out approach applied in BEAT. For marine mammals, the assessment results with the poorest status is transferred further at all steps in the integration.

3.2. Confidence assessment methodology of the beat tool

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 national experts participating in the indicator development. The basic integrated confidence is calculated following the same assessment structure and integration rules as for the corresponding status assessment. 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.

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). For coastal fish, the criteria were defined as presented in (HELCOM 2018t). The experts were asked to as far as possible based their answers on quantitative information.

Table 2.
Aspects considered in the assessment of confidence in the integrated assessment of biodiversity using BEAT 3.0, and definitions for 'high', 'intermediate' or 'low' confidence. For coastal fish, confidence was assessed as presented in HELCOM 2018t.

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.

Subsequently, the integrated confidence was calculated. The integrated confidence was calculated following the same assessment structure and integration rules as used in the corresponding biodiversity assessment for the concerned ecosystem component. For example, if averaging was used to assess integrated status, it was also used for assessing integrated confidence. 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. The BEAT output gives the integrated results for all confidence aspects taken together.

Finally, the overall assessment confidence was evaluated based on how well the indicators included were able to represent important species groups of 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.

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.

Table 3.
Cases were overall confidence penalties were applied in the integrated biodiversity assessment.

Ecosystem component	Penalty applied
Benthic habitats	Confidence was lowered by one step compared to the BEAT output in open sea sub-basins only assessed by a eutrophication core indicator.
Pelagic habitats	Confidence was lowered by one step compared to the BEAT output in open sea sub-basins only assessed by a eutrophication core indicator.
Fish	none applied
Marine mammals	Confidence was lowered by one step in the assessment units where indicators on population condition were lacking for ringed seal or harbour seal.
Waterbirds	none applied

3.3. Beat assessment data

The indicators included in the biodiversity assessment are developed based on different approaches and different kinds of data, regarding the applied units and scales, for example. To enable inclusions of different types of data in the same assessment, the BEAT 3.0 tool first normalizes the indicators to a common scale and unit, and thereafter calculates the Biological Quality Ratio (BQR) for each indicator.

Normalization based on minimum and maximum values

The normalization transfers all indicator assessment values to a scale from 0 to 1, where the threshold value is set to 0.6. The normalization is based on information that is imported to the BEAT tool together with the other indicator data (Table 4). A key issue for the normalization is to identify minimum and maximum values of each indicator. Identifying these is straightforward when data covering the whole potential range of the indicator is available. In cases where only information on the minimum value is available, this can be used to derive the maximum value, provided that a linear response can be assumed. The minimum value is then set to 0, the threshold value is scaled to 0.6 and the maximum value is defined as shown in Figure 9. Indicators assessed in five classes, such as national indicators assessed under the Water Framework Directive, can be directly used so that the assessment status class boundaries for Bad/Poor = 0.2, Poor/Moderate = 0.4, Moderate/Good = 0.6 and Good/High = 0.8.

For the current assessment, information on the minimum and maximum values were provided directly from the indicator experts based on a shared guidance (See also next section for cases when the minimum-maximum approach was not applicable).

Further, the indicator is characterized as being either monotonic or unimodal. The monotonic (linear) response is the default (Figure 9). For unimodal indicators, which have both an upper and a lower threshold, the normalization is done in relation to the threshold value lying closer. Conditional indicators are assessed in the same way, so that all parameters are considered, and then the parameter with the lowest biological quality ratio (BQR) is used in the integration process. The BEAT 3.0 tool can accommodate for indicators with both a positive and a negative response, meaning that both indicators that increase with improving status and indicators that decrease with improving status can be included.

Table 4.
Example input data table to the BEAT tool. The example shows the first rows of the input data for the assessment of benthic habitats. SAUD = ID number for the spatial assessment unit, Indicator ID= ID number for the indicator represented by that row, Unit = unit for the entered metric, IndType = Indicator type (code for monotonic or unimodal), Bad = Min value, ModGood = Threshold value, High = Max value, Obs= Indicator assessment value, ConfA = confidence in the assessment based on accuracy, ConfT = confidence in the assessment based on temporal aspect, ConfS = confidence in the assessment based on spatial aspect, ConfM = confidence in the assessment based on monitoring aspect. The output tables give the resulting biological quality ratios in addition to the integrated results (See Chapter 4 and Annexes 4–5).

SAUID	IndicatorID	Assessment area	Indicator	Unit	IndType	Bad	ModGood	High	Obs	ConfA	ConfT	ConfS	ConfM
23	127	Bay of Mecklenburg	Zoob	A	1	0	0.5	1	0.41	h	h	h	h
28	127	Western Gotland Basin	Zoob	A	1	0	4	10.9	4.99	i	h	l	h
29	127	Gulf of Riga	Zoob	B	1	0	0.5	1	0.55	i	h	h	i

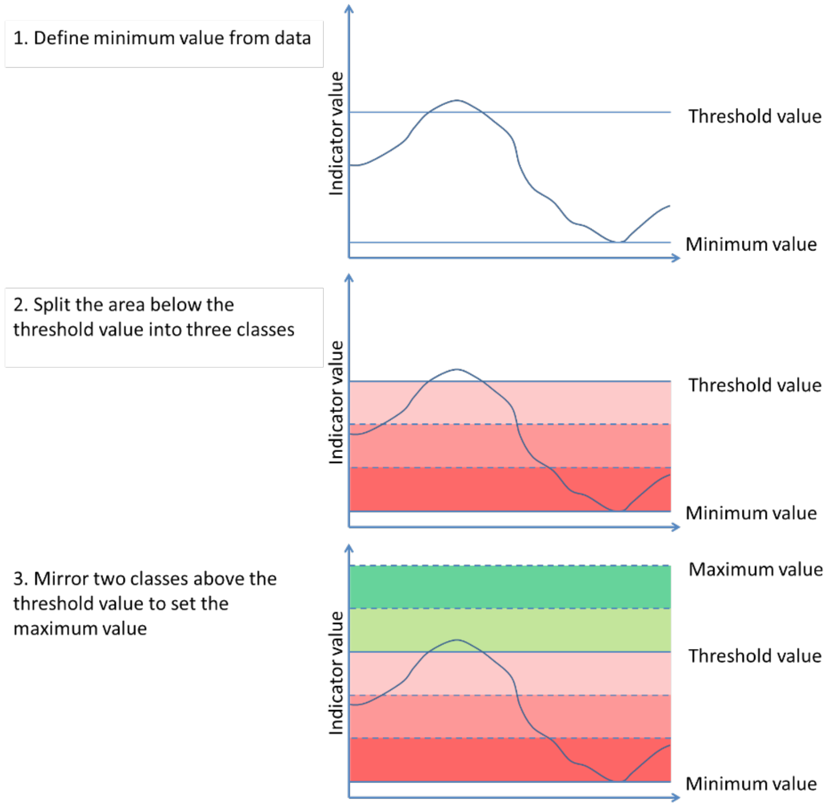

Figure 9.
Example for an indicator time-series with threshold value and data available for deteriorated conditions, assuming linearity.

The following example illustrates how indicators are normalized and biological quality ratios (BQR values) obtained for a monotonic indicator, using data for the indicator 'State of the soft-bottom macrofauna community':

If the observed indicator value is below the threshold value, indicating not good status, the following equation (1) is used:

BQR=0.6(Observed value-Minimum value)/(Threshold value-Minimum value)*

If the observed indicator value is above the threshold value, indicating good status, the following equation (2) is applied:

BQR=0.6+0.4(Observed value-Threshold value)/(Maximum value-Threshold value).*

Thus, using the information in Table 4 as an example, biological quality ratios for the indicator in the Bay of Mecklenburg and Western Gotland Basin are calculated as follows:

Bay of Mecklenburg (observed value below threshold value): BQR = 0.6(0.41-0)/(0.5-0) = 0.49*

Western Gotland Basin (observed value above threshold value): BQR=0.6+0.4(4.99-4)/(10.9-4) = 0.66*

Other ways for normalization

For some indicators, minimum and maximum values cannot be defined. For example, assessment results for trend-based indicators were entered as either of four classes using a decision tree (Figure 10). A four-class scale was also used for the integrated assessment of commercial fish, since the 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 5). Indicators which have results presented only as achieving or not achieving the threshold value are included as 0.25 (not achieving) or 0.75 (achieving threshold value) with 0.5 as the threshold value.

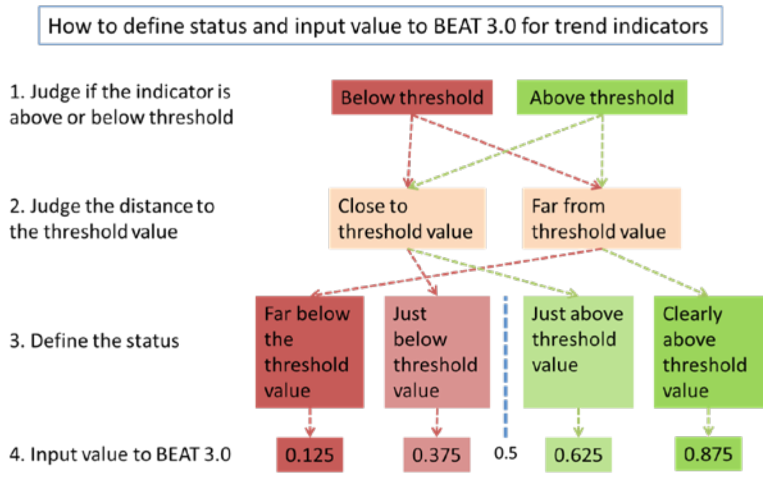

Figure 10.
Classification of indicator results derived based on trends. In this example, the assessment is done using an indicator for which increasing values mean improved status.

Table 5.
Classification of indicators results applied to 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 for 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

3.4. Assessment structure by ecosystem component

Benthic habitats

Benthic habitats in the open sea were assessed using the core indicators 'State of the soft-bottom macrofauna community' and 'Oxygen debt' (See Chapter 2.1). Therefore the assessment is mainly restricted to soft bottom habitats in the open sea. In most countries hard- and mixed bottoms could not be assessed in the open sea due to lack of data and core indicators but in the coastal areas national macrophyte indicators covered these habitat types. The assessment structure is shown in Table 6.

The indicator was not included for the Kattegat, Great Belt, Sound, Gdansk Basin, Bornholm Basin and Arkona Basin, due to lack of agreed threshold values.

The 'Oxygen debt' indicator is not applicable in the southern assessment units from the Kattegat to the Arkona Basin, in the Gulf of Riga, in Åland Sea, or in the Quark. It was not included in the Bothnian Sea or the Bothnian Bay as these basins do not suffer from oxygen deficiency.

Coastal areas were assessed by national indicators representing status of macrophytes and macrozoobenthos', as well as additionally by water clarity was measured by the Secchi depth and oxygen conditions (HELCOM 2018s; Table 6).

The indicators representing benthic habitats were assessed at assessment scale 4, which is the most detailed HELCOM spatial scale for results in coastal areas.

Table 6.
Assessment structure for benthic habitats, showing indicators included and the weights applied for each integration level.

Indicator used in BEAT	Core/WFD	Weight	Integrated level
Open sea areas			
State of the soft-bottom macrofauna community	Core	0.5	Open sea benthic
Oxygen debt	Core	0.5	
Coastal areas			
Macrofauna indices	national	0.25	Coastal benthic
Oxygen concentration	national	0.25	
Macrophyte indices	national	0.25	
Water clarity	national	0.25	

Pelagic habitats

Pelagic habitats were assessed by the biodiversity core indicator 'Zooplankton mean size and total stock' and the eutrophication indicators 'Chlorophyll-a' and 'Cyanobacterial bloom index'[6] (See Chapter 2.2). The assessment structure is shown in Table 7.

The 'Zooplankton mean size and total stock' indicator is currently only assessed for the Bothnian Bay, Bothnian Sea, Åland Sea, Gulf of Finland, Western Gotland Basin and Gdansk Basin due to a lack of agreement on threshold values for other sub-basins. The indicator was applied in open sea areas.

The 'Chlorophyll-a' indicator was assessed in all assessment units. The 'Cyanobacterial bloom index' is a pre-core indicator agreed to be included for testing in this assessment. Threshold values for the 'Cyanobacterial bloom index' indicator are yet to be commonly agreed in HELCOM. The indicator is currently not relevant in the Kattegat, the Sound areas, the Bothnian Bay and the Quark due to the absence of cyanobacterial bloom formations, and in its present form it is not either applicable in the Åland Sea or in coastal areas. It is not used in the Kiel Bay as the relevance of the indicator is unvalidated.

Pelagic habitats were assessed at assessment scale 4, which is the most detailed HELCOM spatial scale for results in coastal areas.

Table 7.
Assessment structure for pelagic habitats, showing indicators included and the weights applied for each integration level.

Indicator used in BEAT	Core/national	Weight	Integrated level 1
Open sea areas			
Zooplankton mean size and total stock	Core	0.33	Open sea pelagic
Chlorophyll a	Core	0.33	
Cyanobacterial blooms	Pre-core	0.33	
Coastal areas			
Chlorophyll a	national	0.33	Coastal pelagic
Phytoplankton biovolume	national	0.33	

[6] Included as test.

Fish

Fish in the open sea were assessed based on the status of internationally assessed commercial fish. Coastal fish and migrating species were assessed based on HELCOM core indicators (Table 8).

The assessment of fish in open sea areas was based on data from ICES (2017a-c), using indicators representing stock size and fishing mortality. The assessment only included fish stocks for which assessment results in relation to a threshold value were available for both of these aspects, and the indicator showing the worst status was used for each stock. Details on how the input data to BEAT 3.0 was defined is given in Annex 2. Results for the following pelagic species were included: sprat (assessment for one stock applicable to all parts of the Baltic Sea) and herring (data available for all geographic areas, separated over four different stocks). For demersal fish, the following species were included: plaice (one stock covering the Kattegat, Sound and Belt Sea areas), cod (separated for Western and Eastern Baltic Sea stock, respectively) and sole (applicable to the Kattegat and Western Baltic Sea). The assessment was first made separately for demersal and pelagic species, and they were subsequently integrated with each other (Table 8). Assessment results for sprat and cod were not included for the Bothnian Sea, as these species are not typically observed there.

In coastal areas the core indicators 'Abundance of key coastal fish species' and 'Abundance of coastal fish key functional groups' were used. The latter indicator is composed of two components, the functional groups 'Abundance of piscivores' and 'Abundance of cyprinids or mesopredatory fish', which were included as separate indicators in BEAT. Data for the assessment of the 'Abundance of key coastal fish species' was available for 21 of the 40 coastal assessment units at scale 3. For the indicator 'Abundance of coastal fish key functional groups' data was available for 16 assessment units.

Open sea fish were assessed using the spatial delineation of subdivisions used by ICES (2017d; see map in Annex 2), and coastal fish at scale 3. Assessment results for sprat and cod were not applied to the Bothnian Bay due to very limited occurrence in this sub-basin.

Table 8.
Assessment structure for fish, showing indicators included and the weights applied for each integration level.

<table>
<tr><th>Indicator used in BEAT</th><th>Weight1</th><th>Integrated level 1</th><th>Weight2</th><th>Integrated level 2</th></tr>
<tr><td colspan="5">Open sea areas</td></tr>
<tr><td>Herring</td><td>0.25</td><td rowspan="2">Pelagic fish</td><td rowspan="2">0.5</td><td rowspan="5">Open sea fish</td></tr>
<tr><td>Sprat</td><td>0.25</td></tr>
<tr><td>Cod</td><td>0.167</td><td rowspan="3">Demersal fish</td><td rowspan="3">0.5</td></tr>
<tr><td>Plaice</td><td>0.167</td></tr>
<tr><td>Sole</td><td>0.167</td></tr>
<tr><td colspan="5">Coastal areas</td></tr>
<tr><td>Abundance of key coastal fish species –perch</td><td>0.25</td><td rowspan="2">Abundance of key coastal fish species</td><td rowspan="2">0.5</td><td rowspan="4">Coastal fish</td></tr>
<tr><td>Abundance of key coastal fish species - flounder</td><td>0.25</td></tr>
<tr><td>Abundance of coastal fish key functional groups-cyprinids/mesopredators</td><td>0.25</td><td rowspan="2">Abundance of coastal fish key functional groups</td><td rowspan="2">0.5</td></tr>
<tr><td>Abundance of coastal fish key functional groups-piscivores</td><td>0.25</td></tr>
</table>

Marine mammals

The status of seals were assessed using the indicators ‘Population trends and abundance of seals’, ‘Distribution of Baltic seals’ and for grey seals additionally the ‘Nutritional status of seals’ and ‘Reproductive status of seals’ (See Chapter 2.5).

Marine mammals were assessed at the first step by integrating the indicator results to the species level using the one-out-all-out principle. Hence, the integrated result at species level shows the status according to the indicator with the lowest biological quality ratio in each assessment unit. The indicators ‘Population trends and abundance of seals’ and ‘Distribution of Baltic seals’ were assessed using several parameters and following the approach for conditional indicators. That is, all parameters were included in BEAT 3.0 and the parameter with the lowest biological quality ratio was subsequently used in the integration.

In the second step, the integrated assessment at the level of marine mammals (seals) was also done following the one-out-all-out principle. Hence, the integrated result in each assessment unit shows the status for the seal species showing the lowest biological quality ratio in that unit.

Marine mammals were assessed at assessment scale 2. The assessment structure is shown in Table 9.

For ringed seal, no estimate of population size was available for the southern management unit (covering the Archipelago Sea, Gulf of Finland and Gulf of Riga), and hence this parameter was treated as qualitative with a BQR of 0.3. The indicator on seal distribution was treated as qualitative with a BQR of 0.8 where the criteria are met and 0.3 where criteria are not met.

Table 9.
Assessment structure for seals, showing indicators included and the weights applied for each integration level. OAOO=”one-out-all-out”

<table>
<tr><th>Indicator used in BEAT</th><th>Integrated level 1</th><th>Integrated level 2</th></tr>
<tr><td>Grey seal</td><td></td><td rowspan="11">Seals (OAOO)</td></tr>
<tr><td>Population trends and abundance of seals</td><td rowspan="4">Grey seals (OAOO)</td></tr>
<tr><td>Distribution of Baltic seals</td></tr>
<tr><td>Nutritional status of seals</td></tr>
<tr><td>Reproductive status of seals</td></tr>
<tr><td>Ringed seal</td><td></td></tr>
<tr><td>Population trends and abundance of seals</td><td rowspan="2">Ringed seal (OAOO)</td></tr>
<tr><td>Distribution of Baltic seals</td></tr>
<tr><td>Harbour seal</td><td></td></tr>
<tr><td>Population trends and abundance of seals</td><td rowspan="2">Harbour seal (OAOO)</td></tr>
<tr><td>Distribution of Baltic seals</td></tr>
</table>

Waterbirds

Waterbirds of the Baltic Sea were assessed by the core indicators 'Abundance of waterbirds in the breeding season' and 'Abundance of waterbirds in the wintering season' (See Chapter 2.5).

The integration was carried out at assessment scale 1, which is the whole Baltic Sea. The assessment structure for waterbirds is shown in Table 10. In addition, assessment results at scale 2 are presented separately for each of the waterbirds core indicators.

Table 10.
Assessment structure for waterbirds, showing indicators included and the weights applied for each integration level.

Indicator used in BEAT	Weight1	Integrated level 1
Abundance of waterbirds in the breeding season	0.5	Waterbirds
Abundance of waterbirds in the wintering season'	0.5	

3.5. Outputs from the BEAT tool

The BEAT tool generates output tables for the integrated assessment of biological status and the confidence assessment separately. In both tables, 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, and also for relevant MSFD criteria. The integrated confidence output follows the same structure. BEAT also generates tables with the number of indicators included in each assessment unit and calculated BQR values and confidence for indicators used. When presenting the results in maps, the resulting integrated scores are classified into status categories as outlined in Table 11, and confidence categories as shown in Table 12.

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 11.
Result categories of the integrated biodiversity assessment.

QR score	Integrated status category
0.8-1.0	Good – Highest score
0.6-0.8	Good – High score
0.4-0.6	Not Good – Low score
0.2-0.4	Not Good – Lower score
0-0.2	Not Good – Lowest score

Box 12.

Table 12.
Confidence classes applied in the integrated biodiversity assessment.
The colours in column two are those used in the associated confidence maps.

Confidence Score	Confidence category
> 0.75	Class I (High)
between 0.5 and 0.75	Class II (Moderate)
<0.50	Class III (Low)

3.6. Data sources

The data used in the current assessment gives results for the years 2011-2016. The data for the HELCOM core indicators was identical to the data used in the evaluations at indicator levels, and more detailed descriptions of the data sources are available in each of the core indicator reports. For the additional indicators, only data approved at national level were included, via a data acceptance process.

A summary of the data sources is given below. Biodiversity data not falling under the COMBINE programme have been collected within specific HELCOM expert groups/indicator leads for the purposes of the second holistic assessment, or by ad-hoc data calls. The coverage of data stemming from these data collection activities (outside of COMBINE) has not been complete, and there may exist restrictions to data use for this kind of data, preventing open access of the complete underlying indicator dataset.

Benthic habitats

Data on benthic macrofauna was extracted from the COMBINE database, and supplemented by national data from Estonia, Latvia, Lithuania, Germany, and Poland. No assessment was made for Kattegat, Great Belt, The Sound or the Arkona Basin.

Pelagic habitats

Zooplankton data for the assessment were reported nationally. The indicator is currently only assessed for the Bothnian Bay, Bothnian Sea, Åland Sea, Western Gotland Basin, Gulf of Finland and Gdansk Basin.

Fish

Data on coastal fish were extracted from the HELCOM coastal fish database. The commercial fish indicators were based on data collection and assessments coordinated by ICES (2017a-c) ad-hoc data calls. The coverage of data stemming from these data collection activities (outside of COMBINE) has not been complete, and there may exist restrictions to data use.

Marine mammals

Data on seal abundance was extracted from the HELCOM seal database developed in the BalticBOOST project. For the indicators 'Nutritional status of seals' and 'Reproductive status of seals', data has been reported by Finland and Sweden and only for grey seal there is sufficient data for an assessment.

Waterbirds

Waterbird count data have been reported nationally and stored in the HELCOM bird database.

Eutrophication core indicators

Data for the eutrophication core indicators, which were used in the assessment of benthic and pelagic habitats, were obtained from the HELCOM eutrophication assessment workspace. For open sea areas, the data were based on the COMBINE database and supplemented with Russian data from the Gulf of Finland year project. The coastal indicator results were reported nationally as either assessment values, ecological quality ratios or eutrophication ratio, depending on country. For the coastal indicators, the assessment period varies with two countries exclusively using data from 2011-2016.

Chapter 4. Results from the integrated assessment

The biodiversity core indicators show cases of inadequate status in all levels of the food web. A few core indicators reach their threshold values in parts of the Baltic Sea, and none of the indicators show good status in all assessed areas. The results for different indicators are not directly comparable as the assessment methods have been developed independently. However, the overall result suggests that environmental impacts on species in the Baltic Sea are wide-reaching and not restricted to certain geographic areas or certain parts of the food web. Integrated assessment results in more detail are provided below for each of the assessed ecosystem components.

4.1. Integrated assessment results for benthic habitats

The integrated assessment of benthic habitats shows good status in six of the thirteen open sea assessment units that were assessed (Figure 11). Good integrated status coincide with sub-basins assessed only by the benthic community indicator, representing soft-bottom habitats. Based on the results, over half of the Baltic Sea open sea area is assessed as not achieving good status in 2011-2016 (Figure 12).

Although a high share of the Baltic Sea is covered by the assessment, both core indicators included have only partial coverage. The indicator 'State of the soft-bottom macrofauna community' (Figure 5) is only applied above the halocline in assessment units with a permanent halocline. The indicator achieves the threshold value in all areas where it is assessed except in the Bay of Mecklenburg. The indicator 'Oxygen debt' does not achieve the threshold value in any of the assessment units where it is included. Long term data show that the oxygen debt below the halocline has increased over the past century in the Baltic Proper, and also in the Bornholm Basin (See Chapter 4.1). Coastal hard bottoms are widely monitored around the Baltic Sea but currently there is no common core indicator for macrophytes (See also Figure 4).

Coastal areas have good integrated status in around half of the area that was assessed, measured by area covered, or in 39 out of 128 assessed units (Figure 12).

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

A penalty was applied to open sea sub-basins only assessed by a eutrophication core indicator.

An extract on the BEAT output for the assessment of open sea benthic habitats is shown in Table 13. The corresponding results for coastal areas are shown in Annex 4.

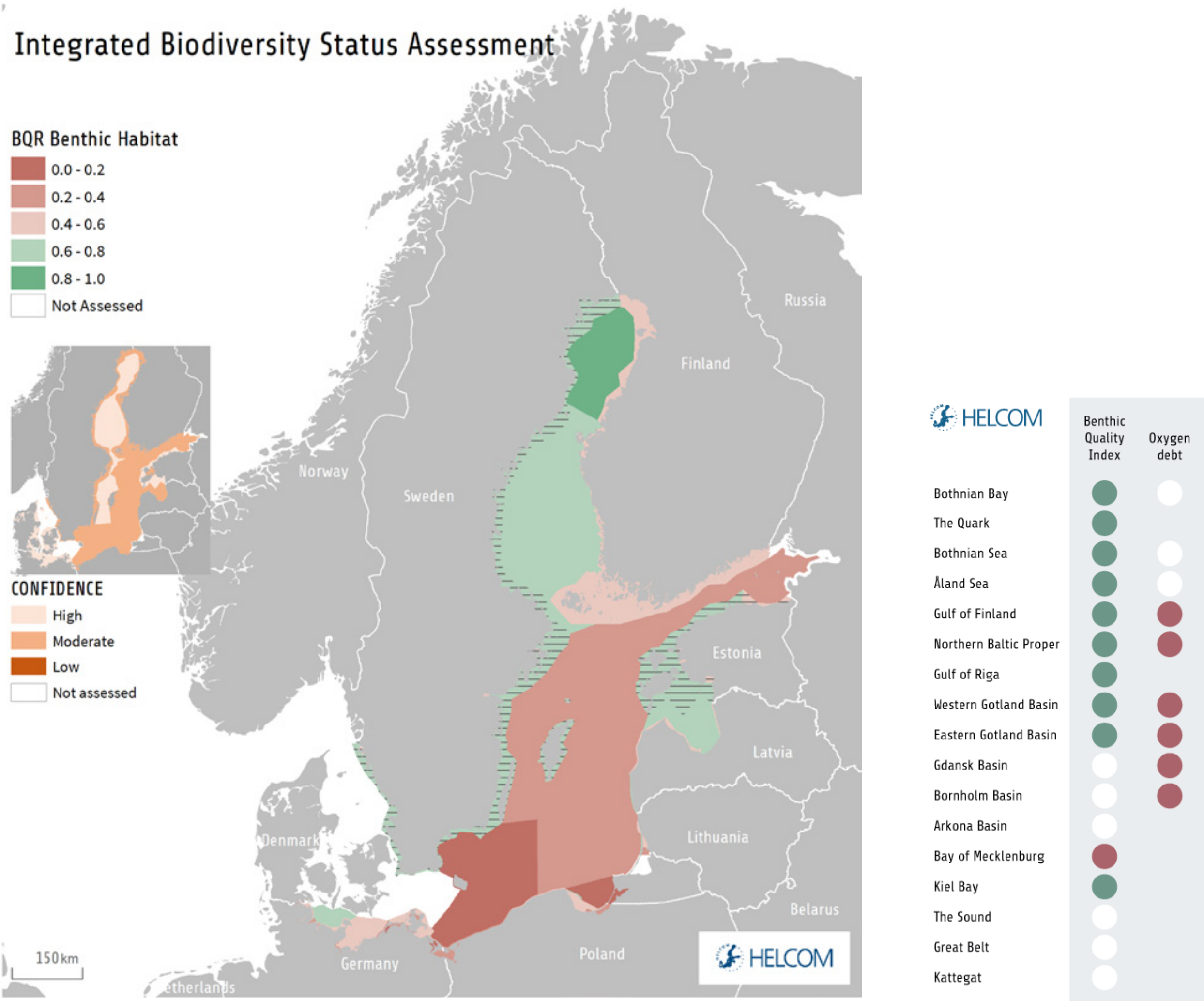

Figure 11.
Integrated biodiversity status assessment for benthic habitats. Status is shown in five categories based on integrated biological quality ratios (BQR). Values of at least 0.6 correspond to good status. The assessment os based on the core indicators 'State of the soft-bottom macrofauna community' and 'Oxygen debt'[7] in open sea areas, with some variability among sub-basins (See table). Coastal areas were assessed by national indicators, and may not be directly comparable with each other (striped areas). The integrated confidence assessment result is shown in the smaller map, with darker shaded areas indicating lower confidence. The table (right) shows corresponding assessment results for the core indicators in each open sea assessment unit, with green denoting 'good status' and red 'not good status''. White circles denote that the area is not assessed by the indicator and empty points that the indicator is not applicable.

[7] The scaling of the eutrophication core indicator oxygen debt is based on BEAT principles (See chapter 3.3). Thus, the result differs from the integrated eutrophication assessment [ref to be added] which integrates ratios only. The BEAT minimum value is defined as the 2007-2011 average + two times the standard deviation and the maximum value is defined as the long-term maximum.

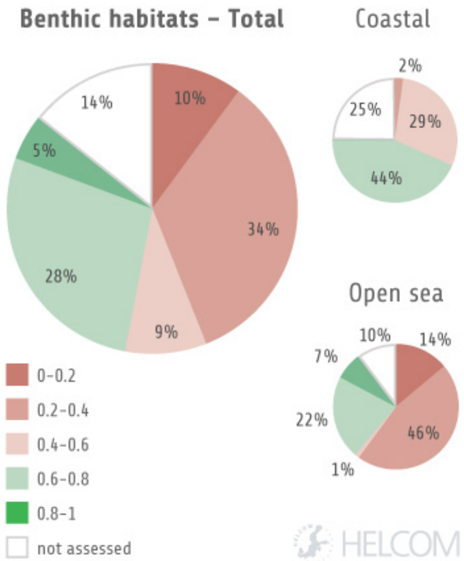

Figure 12.
Summary of the integrated assessment result for benthic habitats, showing the proportion of the Baltic Sea, by areal coverage, within each of the five BEAT assessment categories. The assessment is focused on soft bottom habitats, and does not reflect the status for all benthic habitat types. The legend shows the status categories in relation to the integrated biological quality ratios (BQR). Values of at least 0.6 correspond to good status. White sectors represent not assessed areas, including areas not assessed due to the lack of indicators or data and all Danish coastal areas.

Table 13.
BEAT output from the integrated assessment of benthic habitats in the open sea. BQR= integrated biological quality ratio. The confidence is the integrated confidence of all indicators included in the assessment unit, and is lowered one step in assessment units assessed without any biodiversity core indicator (marked *). The two last columns show BQR values for the indicators included. Values above 0.6 indicate that the indicator threshold value is achieved. Results for coastal areas are presented in Annex 4.

Spatial assessment unit	BQR	Integrated Confidence	Soft-bottom macrofauna community	Oxygen debt
Kiel Bay - open sea	0.69	high	0.69	
Bay of Mecklenburg - open sea	0.49	high	0.49	
Bornholm Basin - open sea	0.00	intermediate*		0.00
Gdansk Basin - open sea	0.00	intermediate*		0.00
Eastern Gotland Basin - open sea	0.34	Intermediate	0.69	0.00
Western Gotland Basin - open sea	0.33	intermediate	0.66	0.00
Gulf of Riga - open sea	0.64	intermediate	0.64	
Northern Baltic Proper - open sea	0.34	intermediate	0.68	0.00
Gulf of Finland - open sea	0.30	intermediate	0.61	0.00
Åland Sea - open sea	0.75	high	0.75	
Bothnian Sea - open sea	0.71	high	0.71	
The Quark - open sea	0.71	high	0.71	
Bothnian Bay - open sea	0.82	high	0.82	

Red-listed benthic species and habitats

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

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

Future perspectives

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

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

Reducing pressures and 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). The large distribution of areas with poor oxygen conditions in the open sea is a key area of concern for the future status of benthic habitats (Casini *et al.* 2016, Villnäs *et al.* 2012).

4.2. Integrated assessment results for pelagic habitats

Good status for pelagic habitats is achieved in the Kattegat, but not in any other open sea sub-basin in 2011-2016 (Figure 13). The most deteriorated status is seen in the Arkona Basin, Gulf of Riga, Gulf of Finland, Åland Sea, and the Western Gotland Basin.

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

In general, the indicators assessing primary producers do not show good status, with the exception of the Kattegat where the core indicator 'Chlorophyll-a' achieves the threshold value. 'Chlorophyll-a' indicates the worst status for the Arkona Basin, relative to other basins (Table 14). Historically, chlorophyll-a concentrations have increased in most sub-basins east of the Bornholm Basin since the 1970s, but the increase levelled off in the late 1990s at the levels seen today. In the Kattegat and Danish Straits the chlorophyll-a concentrations have decreased since the late 1980s (HELCOM 2018d).

The 'Cyanobacterial bloom index'[8] fails the threshold value in all sub-basins where it is assessed. Long-term data from the Eastern Gotland Basin, the Northern Baltic Proper and the Gulf of Finland, however, indicate an improving trend during the past decades in the 'Cyanobacterial bloom index' in the Baltic Proper (HELCOM 2018s).

The results for coastal areas show slightly higher geographical variability than those for the open sea. Good status is indicated in 26 out of 128 assessed coastal areas, corresponding to 20 % of the area assessed of the Baltic Sea region[9] (Figure 14).

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

In relation to compatibility with the MSFD Commission decision, it should be observed that if the indicators 'Chlorophyll-a', 'Cyanobacterial blooms' and 'Water clarity' are not in a good condition, pelagic habitats can be assumed to be affected by eutrophication, according to the MSFD Commission Decision. Since the whole suite of these indicators is not used in the assessment of pelagic habitats, eutrophication effects are not adequately reflected. For instance, the German coastal waters are eutrophic but the assessment of pelagic habitats indicated a good status for some water bodies. Future assessments of pelagic habitats should better take account of eutrophication effects,

An extract on the BEAT output for the assessment of open sea pelagic habitats is shown in Table 14. The corresponding results for coastal areas are shown in Annex 5.

[8] Included as test.
[9] Not including coastal areas of Denmark.

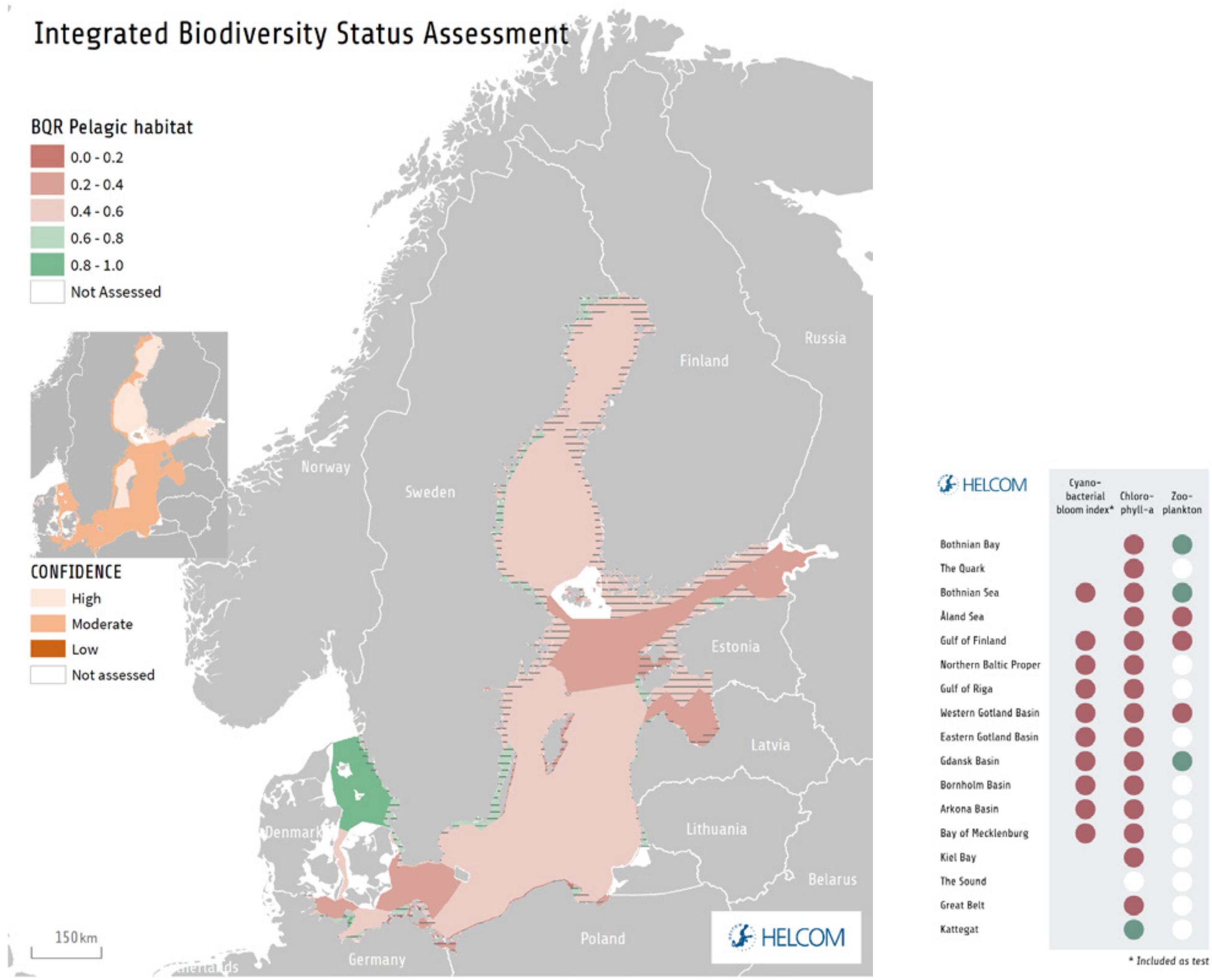

Figure 13.
Integrated biodiversity status assessment for pelagic habitats. Status is shown in five categories based on the integrated biological quality ratios (BQR). Values of at least 0.6 correspond to good status. Open sea areas were assessed based on the core indicators 'Zooplankton mean size and total stock' and 'Chlorophyll-a', as well as the pre-core indicator 'Cyanobacterial bloom index'[10]. Coastal areas were assessed by national indicators. The integrated confidence assessment result is shown in the smaller map, with darker shaded areas indicating lower confidence. The table (right) shows corresponding assessment results for the core indicators in each open sea assessment unit, with green denoting 'good' and red 'not good' statuses. White circles denote that the area is not assessed by the indicator and empty points that the indicator is not applicable.

[10] Included as test.

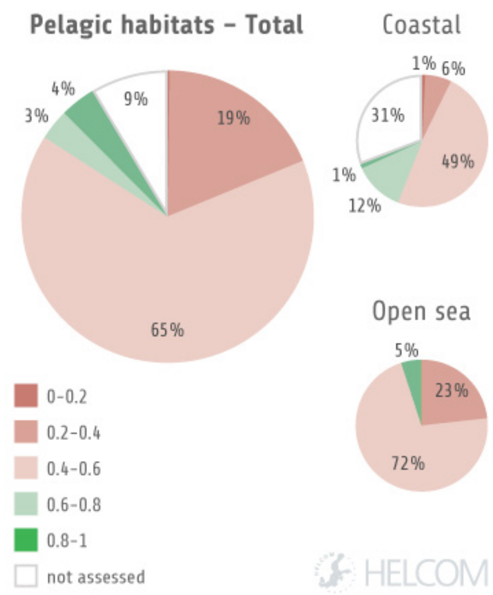

Figure 14.
Summary of the integrated assessment result for pelagic habitats, showing the proportion of the Baltic Sea area, by areal coverage, within each of the five BEAT assessment categories. The legend shows the status categories in relation to the integrated biological quality ratios (BQR). Values of at least 0.6 correspond to good status. White sectors represent unassessed areas, including areas not assessed due to the lack of indicators or data and all Danish coastal areas.

Table 14.
BEAT output from the integrated assessment of pelagic habitats in the open sea. BQR= integrated biological quality ratio. The confidence is the integrated confidence of all indicators included in the assessment unit, and is lowered one step in the assessment units assessed without any biodiversity core indicators (marked *). The three last columns show BQR values for the indicators included. Values above 0.6 indicate that the indicator threshold value is achieved. Results for coastal areas are presented in Annex 5.

Spatial assessment unit	BQR	Integrated Confidence	Zooplankton mean size and total stock	Chlorophyll-a	Cyano-bacterial bloom index[11]
Kattegat - open sea	1.00	Intermediate*		1.00	
Great Belt - open sea	0.50	Intermediate*		0.50	
The Sound - open sea	0.58	Intermediate*		0.58	
Kiel Bay - open sea	0.40	Intermediate*		0.40	
Bay of Mecklenburg - open sea	0.46	Intermediate*		0.45	0.47
Arkona Basin - open sea	0.33	Intermediate*		0.10	0.57
Bornholm Basin - open sea	0.46	Intermediate*		0.36	0.55
Gdansk Basin - open sea	0.55	Intermediate	0.73	0.23	0.51
Eastern Gotland Basin - open sea	0.41	Intermediate*		0.27	0.55
Western Gotland Basin - open sea	0.41	High	0.42	0.27	0.54
Gulf of Riga - open sea	0.38	Intermediate*		0.41	0.35
Northern Baltic Proper - open sea	0.25	Intermediate*		0.15	0.35
Gulf of Finland - open sea	0.38	High	0.39	0.26	0.46
Åland Sea - open sea	0.33	High	0.39	0.27	
Bothnian Sea - open sea	0.54	High	0.71	0.36	0.39
The Quark - open sea	0.41	Intermediate*		0.41	
Bothnian Bay - open sea	0.54	High	0.61	0.47	

[11] Included as test.

Changes in species and size structure

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

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

Whereas dinoflagellates stay longer in the water column, diatoms produced in the pelagic habitat are additionally important for the benthos, as they sink quickly after the bloom. In the Eastern Gotland Basin, an indicator comparing the ratio of diatoms to dinoflagellates has been tested, showing that good status is not achieved in the assessment period (Figure 15).

Understanding the seasonal succession of phytoplankton groups may offer additional insights into ongoing changes in the marine environment, including potential effects of human induced pressures. By comparing the coincidence of seasonal succession of dominating phytoplankton groups against a reference period, it is possible to evaluate the number of occurrences when the regular successional pattern deviates, and this can be measured against a specific threshold value. The challenge is to find a suitable reference period as it is difficult to find historical data from unaffected ecosystems. In those areas where the seasonal succession of dominating phytoplankton groups[12] has been evaluated, the proposed threshold values are not achieved in the Bay of Mecklenburg[13] Arkona Basin open sea, Bornholm Basin open sea, Eastern Gotland Basin open sea, Gulf of Riga including Estonian and Latvian coastal waters, Northern Baltic Proper including Swedish coastal waters, or the Gulf of Finland Estonian coastal waters, but are achieved in Lithuanian coastal waters in the Eastern Gotland Basin and the Gdansk Basin open sea areas (HELCOM 2018h).

Among the zooplankton, cladocerans and copepods are dominating important food sources for fish. Since zooplankton of larger sizes are typically more nutritious, the biomass and size distribution of the zooplankton community, as evaluated by the zooplankton core indicator (Figure 5) is a useful measure of the status of the pelagic food web (Gorokhova *et al.* 2016). The indicator 'Zooplankton mean size and total stock' shows variable results in different sub-basins. Changes over time observed in the Gulf of Finland have been attributed to a decline in cladocerans, whereas decreases in total zooplankton biomass in the Western Baltic Sea and the Bornholm Basin have been attributed to a decline in copepods. At the general level, an increase in the proportion of small-sized taxa and groups is observed in all sub-basins where good status is not achieved.

[12] Included as test.
[13] Assessed together for open sea and coastal areas.

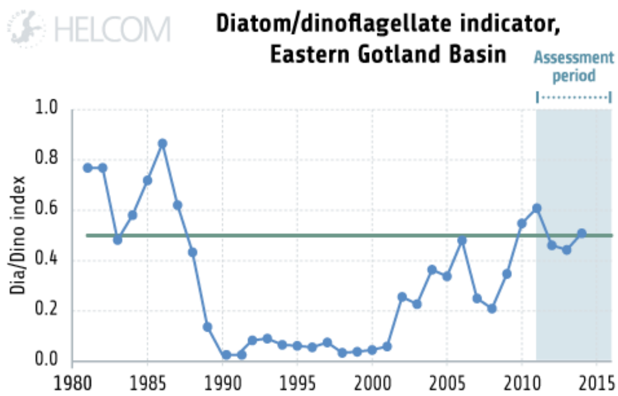

Figure 15.
Trend over time in the 'Diatom/Dinoflagellate index'[14] in the Eastern Gotland Basin. The green line shows the minimum threshold value, which is set at 0.5 in this basin (Source: HELCOM 2018g, Wasmund *et al.*, 2017a).

Future perspectives

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

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

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

[14] Included as test.

4.3. Integrated assessment results for fish

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

The status of commercial fish in the open sea is assessed as good in the Bothnian Bay, where only herring is included (Figure 16). In the other open sea sub-basins, the integrated results reflect a deteriorated status of cod *(Gadus morhua)*, and in some cases also of sprat or herring *(Sprattus sprattus, Clupea harengus)*. The group of demersal fish is only represented by cod and does not show good status in any sub-basin where it is included. The group of pelagic fish is below good status west of Bornholm, in the Bothnian Sea or Gulf of Riga. Results for the different stocks are shown in more detail in Chapter 4.6 of the State of the Baltic Sea report (HELCOM 2018a).

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

The corresponding results for coastal areas are shown in Annex 5.

More detailed assessment outputs for open sea areas are shown in Table 15, and for coastal fish in Table 16.

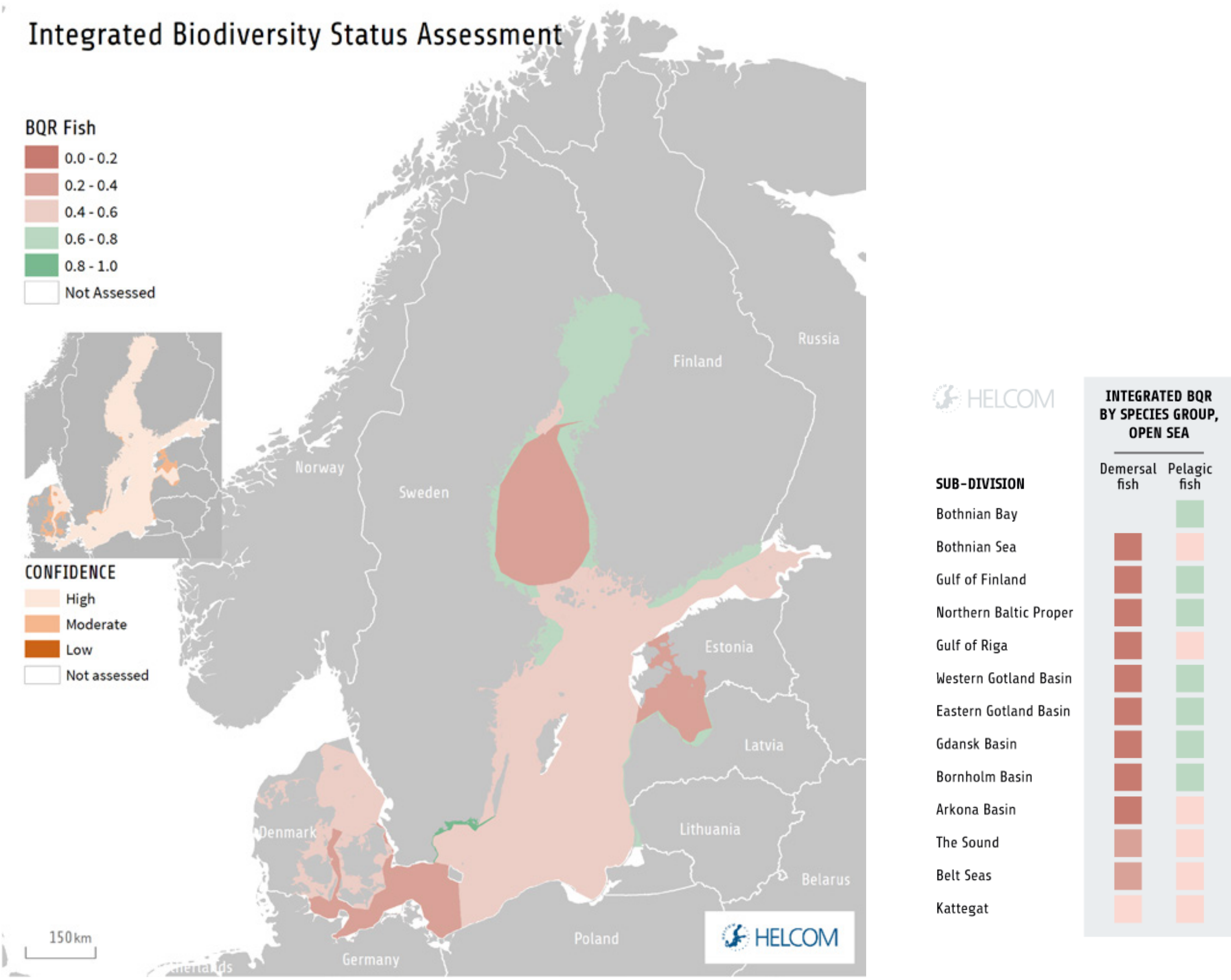

Figure 16.
Integrated biodiversity status assessment for fish. Status is shown in five categories based on the integrated biological quality ratios (BQR). Values of at least 0.6 correspond to good status. Open sea areas were assessed based on data from ICES (for more details, see Annex 2). Coastal areas were assessed based on core indicators. Assessment units for the open sea are ICES subdivisions, and are not shown where they overlap with coastal areas. The assessment of commercial fish is provisional. It does not comply with the multiannual plans and needs to be developed further for the next assessment period. The integrated confidence assessment result is shown in the smaller map, with darker shaded areas indicating lower confidence. The table (right) shows corresponding integrated assessment results separately for the groups of demersal and pelagic species, by the same five level scale as used in the map. Grey Empty pointscells denote that the assessment is not applicable.

Table 15.
BEAT output from the integrated assessment of open sea fish. BQR= integrated biological quality ratio. The confidence is the integrated confidence of all indicators included in the assessment unit. The two last columns show the BQR values for the groups of demersal shelf fish and pelagic shelf fish, respectively. Values above 0.6 indicate that the indicator threshold value is achieved. Assessment results for each of the stocks are shown in Annex 2. The spatial assessment units are the ICES subdivisions, see Annex 2 for a map. NA=not applicable in the integrated assessment of that sub-basin.

Spatial assessment unit	BQR	Integrated Confidence	Demersal shelf fish	Pelagic shelf fish
21	0.44	High	0.43	0.45
22	0.39	High	0.33	0.45
23	0.39	High	0.33	0.45
24	0.30	High	0.15	0.45
25	0.41	High	0.15	0.68
26	0.41	High	0.15	0.68
27	0.41	High	0.15	0.68
28_2	0.41	High	0.15	0.68
28_1	0.30	High	0.15	0.45
29	0.41	High	0.15	0.68
30	0.36	High	0.15	0.58
31	0.36	High	NA	0.70
32	0.41	High	0.15	0.68

Table 16.
BEAT output from the integrated assessment of costal fish. BQR= integrated biological quality ratio. The confidence is the integrated confidence of all indicators included in the assessment unit. The two last columns show the BQR values for the indicators included. Values above 0.6 indicate that the indicator threshold value is achieved.

Spatial assessment unit	BQR	Integrated Confidence	Abundance of key coastal fish species	Abundance of coastal fish key functional groups
Bothnian Bay Finnish Coastal waters	0.77	High	0.90	0.70
Bothnian Bay Swedish Coastal waters	0.70	High	0.70	0.70
The Quark Finnish Coastal waters	0.62	High	0.70	0.58
The Quark Swedish Coastal waters	0.45	High	0.45	0.45
Bothnian Sea Finnish Coastal waters	0.62	High	0.70	0.58
Bothnian Sea Swedish Coastal waters	0.70	High	0.70	0.70
Åland Sea Swedish Coastal waters	0.52	Intermediate	0.70	0.43
Åland Sea - Archipelago Sea Finnish coastal water	0.52	High	0.70	0.43
Northern Baltic Proper Swedish Coastal waters	0.70	High	0.70	0.70
Gulf of Finland Finnish coastal waters	0.62	High	0.70	0.58
Gulf of Riga Estonian Coastal waters	0.35	Intermediate	0.45	0.30
Gulf of Riga Latvian Coastal waters	0.62	Intermediate	0.70	0.58
Western Gotland Basin Swedish Coastal waters	0.51	High	0.45	0.58
Eastern Gotland Basin Latvian Coastal waters	0.75	Intermediate	0.90	0.68
Eastern Gotland Basin Lithuanian Coastal waters	0.70	Intermediate	0.70	0.70
Bornholm Basin Swedish Coastal waters	0.83	Intermediate	0.90	0.80
Arkona Basin Danish Coastal waters	0.45	Intermediate	0.45	
Mecklenburg Bight Danish Coastal waters	0.45	Intermediate	0.45	
Belts Danish Coastal waters	0.45	Intermediate	0.45	
The Sound Danish Coastal waters	0.45	Intermediate	0.45	
Kattegat Danish Coastal waters	0.45	Intermediate	0.45	

Coastal fish

At core indicator level, 'Abundance of key coastal fish species' shows good status in 13 out of 21 assessed coastal areas. For the indicator 'Abundance of key coastal fish functional groups', the component addressing piscivores achieves the threshold value in most of the assessed coastal areas (13 out of 16), and the group cyprinids/mesopredators achieves the threshold valued in about half of them (7 out of 16; Figure 17).

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

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

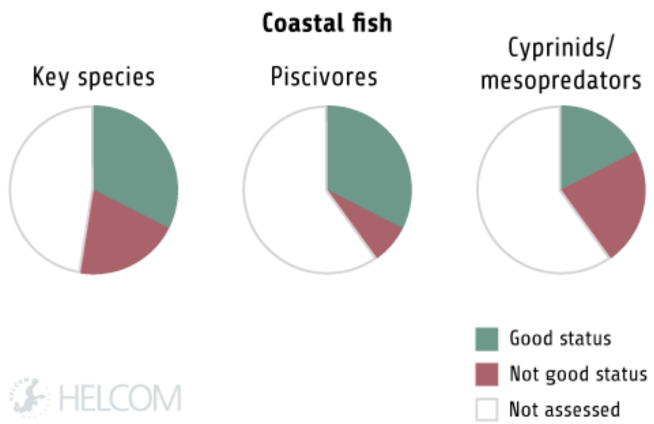

Figure 17.
Core indicator results for coastal fish showing the shares of assessment units, out of 40 in total, achieving good status (green), not good status (red) and not assessed due to lack of data (white; see also Core indicator reports: HELCOM 2018i–j)

Migrating fish species

Salmon (*Salmo salar*) and sea trout (*Salmo trutta*) spend the first few years of their life cycle in the river as parr. After this, they become smolt and start their feeding migration to the sea. The two core indicators 'Abundance of salmon spawners and smolt' and 'Abundance of sea trout spawners and parr' show different results in different parts of the Baltic Sea (Figure 18).

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

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

For both species, there is an additional number of rivers around the Baltic Sea which have lost their salmon and sea trout populations due to damming of rivers for hydropower, or because of dredging. The number of currently unsuitable rivers for salmon and trout reproduction is not reflected in the indicators. Both species are also affected by targeted fishing as well as by being incidental by-catch in other types of fisheries. The restoration of river habitats and management of river fisheries to strengthen Baltic Sea salmon and sea trout is a regional commitment of the Baltic Sea Action Plan (HELCOM 2007).

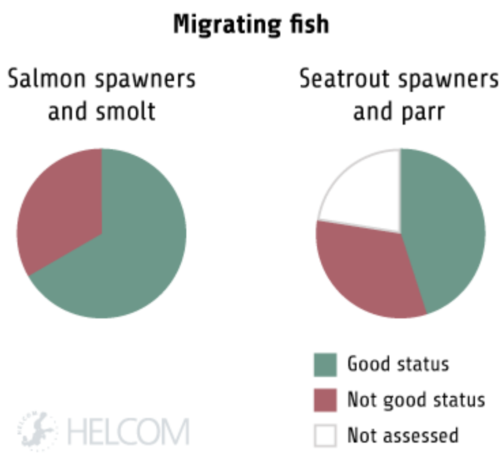

Figure 18.
Core indicator results for migrating fish showing shares of assessment units, out of 6 for salmon and 31 for sea trout, achieving good status (green), not good status (red) and not assessed due to lack of data (white; see also Core indicator reports: HELCOM 2018k–l).

Commercial fish species in the open sea

Internationally assessed commercial fish in the Baltic Sea encompass seventeen demersal and pelagic fish stocks, representing nine species. The stocks were assessed in relation to the objective that both the spawning stock biomass and the fishing mortality should be at levels that are consistent with long term sustainability.

Six of the assessed stocks do not show good status, and three show good status on average during 2011-2016. Eight stocks lack assessment results (Figure 19). Plaice (*Pleuronectes platessa*) in the Kattegat is the only demersal stock achieving good status. Its spawning stock biomass has shown an increasing trend over the past decade (Figure 20). Sole (*Solea solea*), as well as Western and Eastern Baltic cod (*Gadus morhua*), dp not achieve good status.

Among pelagic stocks, sprat (*Sprattus sprattus*), herring (*Clupea harengus*) in the Gulf of Riga, and herring spring spawners in the Western Baltic and Kattegat do not achieve good status. These stocks fail the reference value with respect to fishing mortality, and the herring spring spawners also show too low stock size. Their spawning stock biomasses have been at relatively constant levels over the past decade. The herring stocks of the Gulf of Bothnia and Central Baltic Sea show good status, and increasing spawning stock biomass over the past decade (Figure 20)[15].

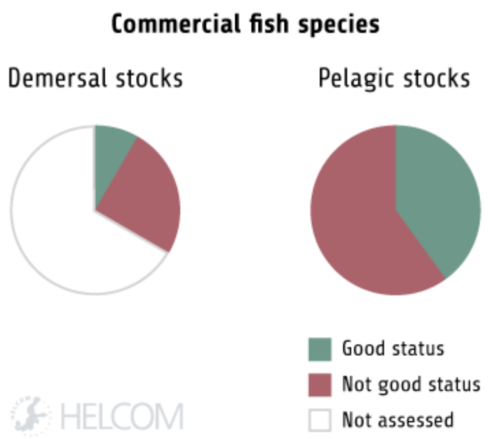

Figure 19.
Results for internationally assessed commercial species showing the number of demersal and pelagic stocks in good status (green), not good status (red) and not assessed (white; see also Chapter 4.6 in HELCOM 2018a).

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

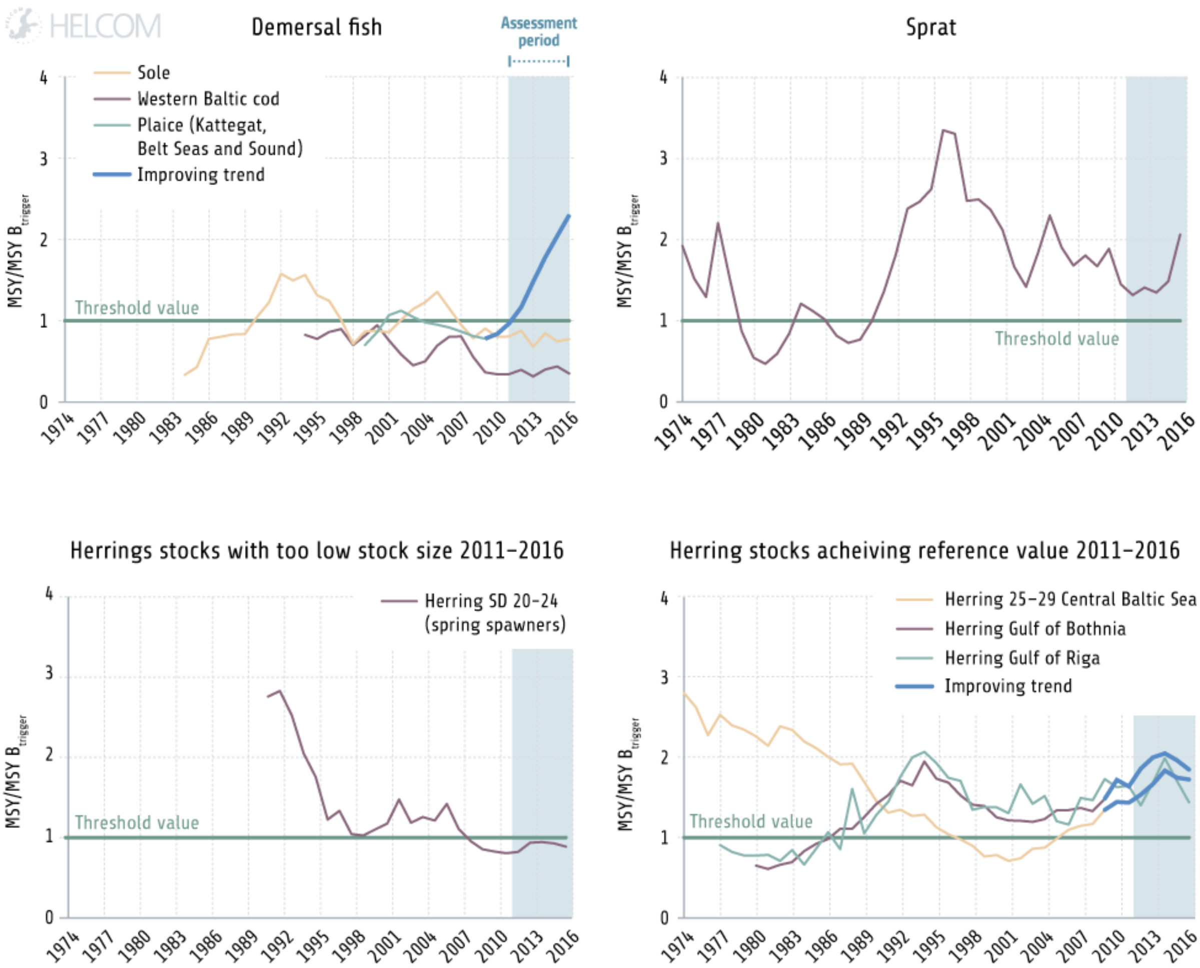

Figure 20.
Development over time in the spawning stock biomass of internationally assessed fish species. Upper left: Demersal fish including plaice and sole; Upper right: Sprat; Lower row: herring. Values above 1 mean that the spawning stock biomass achieves the reference value, as indicated by the green line. The overall status of each stock is assessed by additionally considering the level of fishing mortality. For trends in fishing mortality, see Chapter 4.6 in the State of the Baltic Sea report (HELCOM 2018a). Source: ICES.

Size structure and condition of fish

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

Most noticeably in the Baltic Sea, the condition factor and proportion of larger individuals of Eastern Baltic cod is continuously declining, and the latter has decreased sharply in particular since 2013 (Figure 21). The condition and mean weight of pelagic fish declined substantially in the 1990s, after which it has remained at a lower level (Casini *et al.* 2011).

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

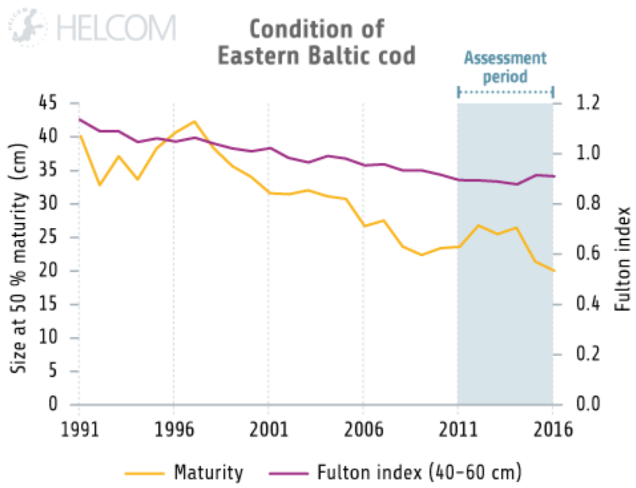

Figure 21.
The size structure and condition of Eastern Baltic cod are sharply decreasing. The dark blue line shows the size at which half of the fish population is mature. The light blue line shows changes over time in the condition of cod. The condition is calculated as the Fulton's index[16] for cod between 40 and 60 cm length. Based on data from the Baltic International Trawl Survey, Quarter 1.

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

Red-listed species of fish and lamprey

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

The list of critically endangered species includes the European eel (Box 1), as well as grayling *(Thymallus thymallus)* in coastal areas of the Bothnian Sea. The sharks porbeagle *(Lamna nasus)* and spurdog *(Squalus acanthias)* in the Kattegat are also listed in this category, likely reflecting impacts of pressures occurring outside of the Baltic Sea region to a large extent, as the species are represented by populations that are widely distributed in the Northeast Atlantic.

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

Box 1.

The red-listed eel

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

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

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

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

Future perspectives

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

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

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

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

4.4. Integrated assessment results for seals

The status of seals is not good in most parts of the Baltic Sea, according to the integrated assessment. Seals show good status in the Kattegat, where the harbour seal population is assessed based on indicators of abundance and distribution (Figure 22). The assessment approach for seals requires that all included indicators and populations should achieve their threshold values in order for seals to have good status in the assessed spatial unit. Confidence in the integrated assessment of seals is classified as intermediate. Results for each species in separate are presented further below.

Integrated assessment results for the three seal species are summarized in Table 17, and presented in more detail for grey seal, harbour seal and ringed seal in Figures 23, 25 and 27.

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

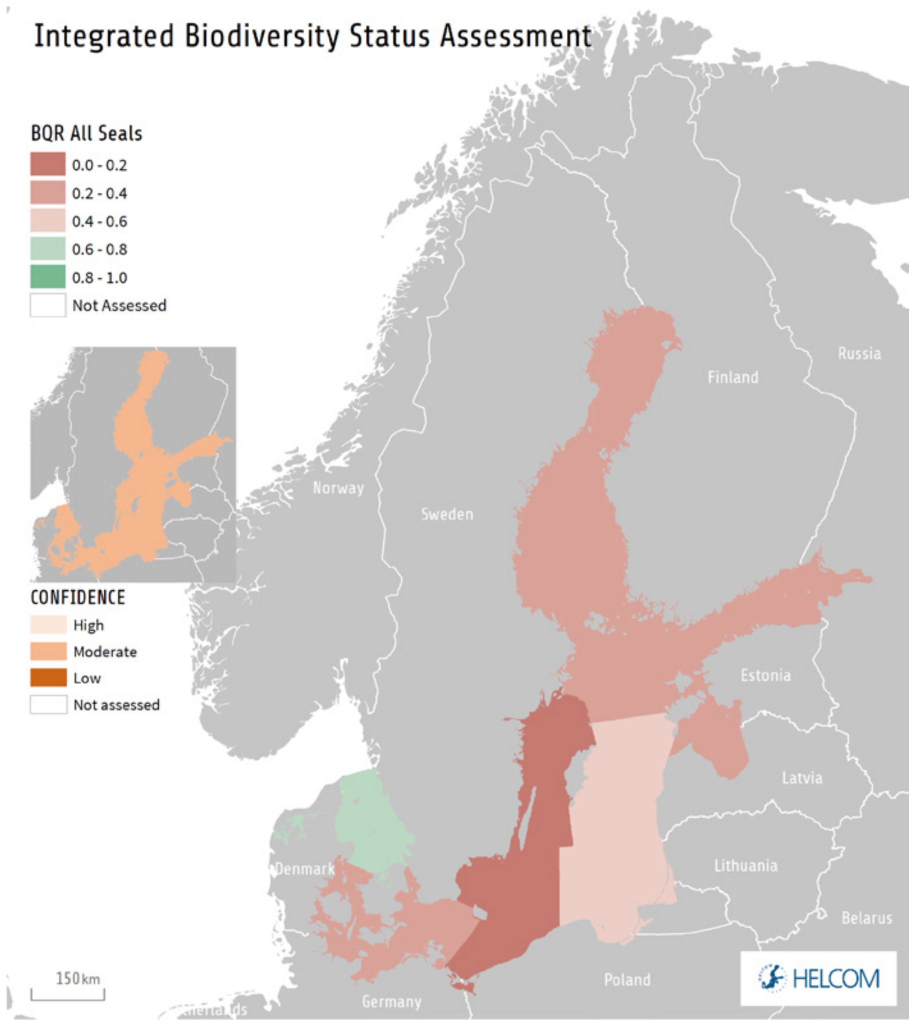

Figure 22.
Integrated biodiversity status assessment for seals. Status is shown in five categories based on the integrated biological quality ratios (BQR). Values of at least 0.6 correspond to good status. The assessment of seals is based on the one-out-all-out approach, which means that indicator reflecting the worst status determines the status. The map reflects the BQR for the indicator furthest away from good status in each assessment unit. See Figures 23, 25, and 27 for corresponding results by species. The integrated confidence assessment result is shown in the smaller map, with darker shaded areas indicating lower confidence.

Table 17.
BEAT output from the integrated assessment of seals. BQR= biological quality ratio. The three last columns show the corresponding integrated assessment results at species level. The integrated assessment result (column 2) gives the result for the species showing poorest status out of these three. The last column shows the total number of parameters considered. A penalty was applied to the confidence in areas marked *, as no indicators on population condition were available for ringed seal and harbour seal. The assessment includes the entire populations of all seal species in the Baltic Sea region. NA= not applicable.

Spatial assessment unit	BQR	Integrated Confidence	Grey seal	Harbour seal	Ringed seal	Parameters
Kattegat	0.80	Intermediate*	NA	0.80	NA	5
Great Belt	0.30	Intermediate*	0.30	0.30	NA	13
The Sound	0.30	Intermediate*	0.30	0.30	NA	13
Kiel Bay	0.30	Intermediate*	0.30	0.30	NA	13
Bay of Mecklenburg	0.30	Intermediate*	0.30	0.30	NA	13
Arkona Basin	0.30	Intermediate*	0.30	0.30	NA	13
Bornholm Basin	0.06	Intermediate*	0.46	0.06	NA	13
Gdansk Basin	0.46	Intermediate*	0.46	NA	NA	8
Eastern Gotland Basin	0.46	Intermediate*	0.46	NA	NA	8
Western Gotland Basin	0.06	Intermediate*	0.46	0.06	NA	13
Gulf of Riga	0.30	Intermediate*	0.46	NA	0.30	13
Northern Baltic Proper	0.30	Intermediate*	0.46	NA	0.30	13
Gulf of Finland	0.30	Intermediate*	0.46	NA	0.30	13
Åland Sea	0.30	Intermediate*	0.46	NA	0.30	13
Bothnian Sea	0.30	Intermediate*	0.46	NA	0.30	13
The Quark	0.30	Intermediate*	0.46	NA	0.30	13
Bothnian Bay	0.30	Intermediate*	0.46	NA	0.30	13

Assessment results for grey seal (*Halichoerus grypus*)

The number of grey seals counted in the whole Baltic Sea region in 2016 is 30,000 individuals, compared to the limit reference level of 10,000 individuals, and the population trend is assessed as achieving the threshold value. However, the overall status of grey seal is estimated as not good, since the indicators on reproductive and nutritional status do not achieve the threshold values (Figure 23).

The low reproductive and nutritional condition of grey seal may be connected to density dependent effects, if the seal population is approaching its ecological carrying capacity, which is likely the case for the grey seal population (See also Figure 24 and Table 18).

The grey seals of the Baltic Sea all belong to the same management unit, as they forage across the entire region. However, the abundance of grey seals varies between sub-basins. The number of grey seals in their core area of moulting distribution (covering the Bothnian Sea, Archipelago Sea and Western Estonian waters), is counted to over 25,000 in 2016. Around 1,300 grey seals are estimated for the other parts of the Gulf of Bothnia, 2,000 for the southern Baltic Sea and less than 1,000 for the Gulf of Finland. Monitoring along the Polish coast show a count of less than 200 individuals in a recently established haul-out. Some known historic grey seal haul-outs in the southern Baltic Sea are currently not used, and some have vanished due to exploitation of sand. According to the core indicator on the distribution of grey seals, good status is not achieved in the southwestern Baltic Sea.

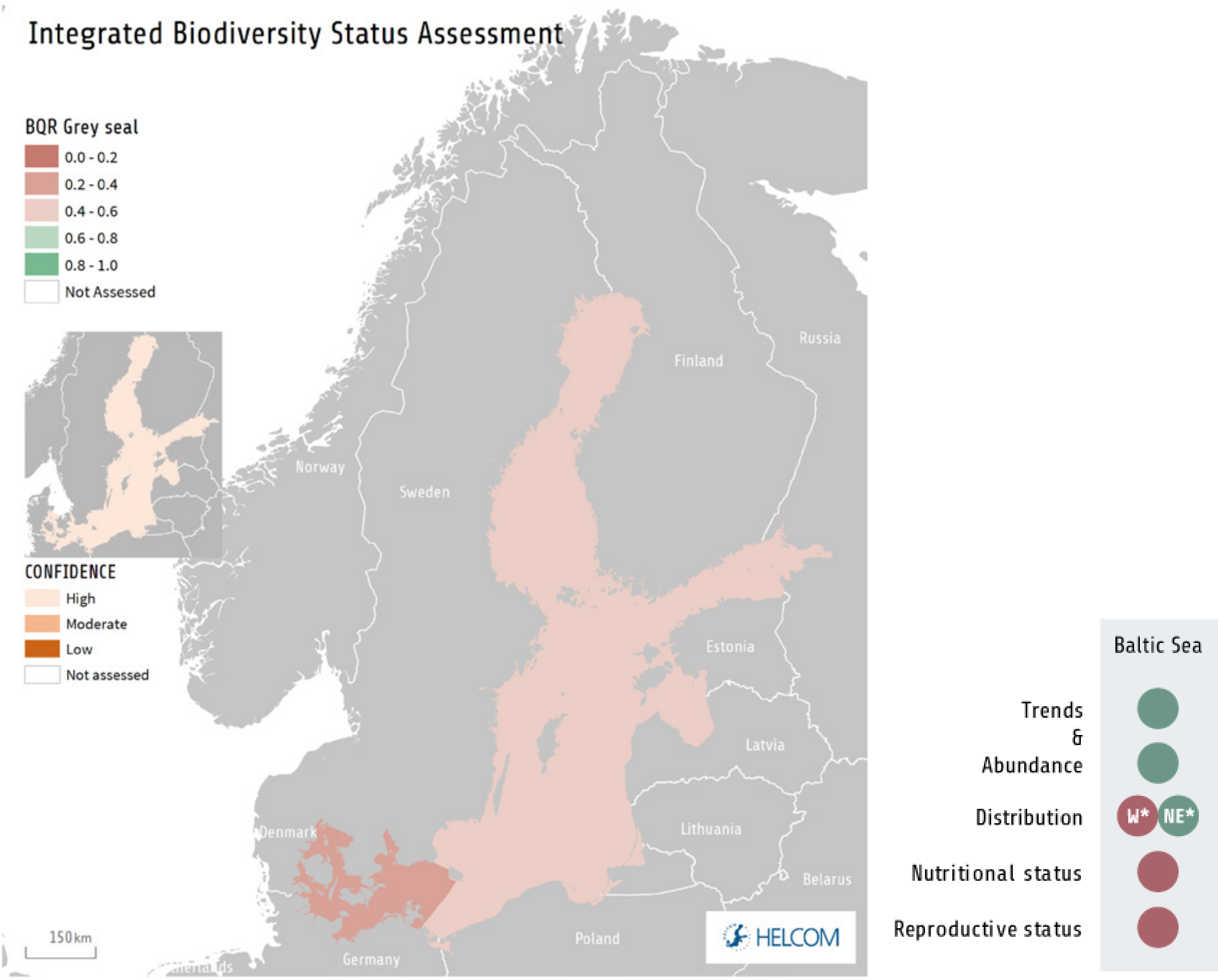

Figure 23.
Integrated status of grey seals. Status is shown in five categories based on the integrated biological quality ratios (BQR). Values of at least 0.6 correspond to good status. The assessment is based on the one-out-all-out approach, which means that the indicator reflecting the worst status determines the status of the species. The map reflects the BQR for the indicator furthest away from good status in each assessment unit. The integrated confidence assessment result is shown in the smaller map, with darker shaded areas indicating lower confidence. The table (right) shows corresponding assessment results for the core indicators, with green denoting 'good' and red 'not good' statuses. The indicator 'Trends and abundance' consists of two parameters, and results for these are shown separately. However, 'good status' for the indicator requires that the threshold value is achieved for both parameters. All assessed grey seals belong the same management unit (Baltic Sea), but the indicator grey seal distribution is assessed separately for two areas: West of Bornholm, as well as east and north of Bornholm. The assessment is not applicable in the Kattegat.

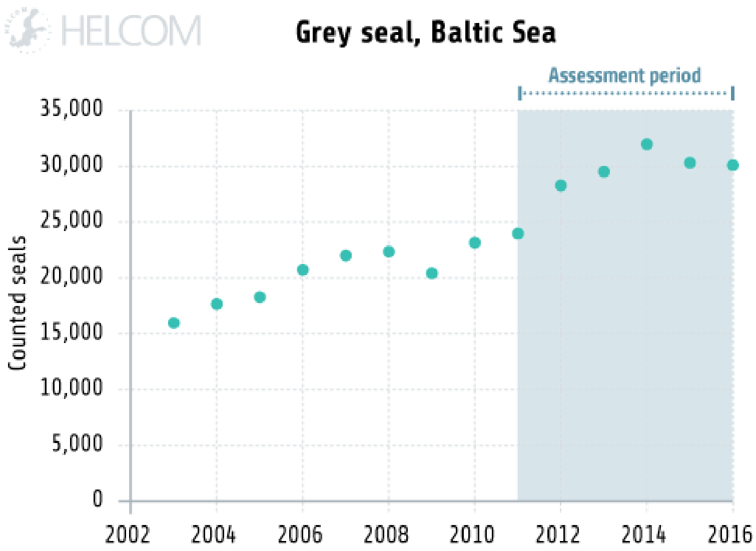

Figure 24.
Counted number of grey seals during 2003–2016, based on monitoring at haul-outs during moulting time. Although the population development can be followed reliably, it should be noted that not all seal individuals are encountered in the monitoring. The growth rate has levelled off in recent years, suggesting that grey seal is approaching its carrying capacity. This management unit is currently assessed against so called second criteria (HELCOM 2018m) according to which the 'trends' parameter is considered to be in good status.

Table 18.
BEAT output from the integrated assessment of grey seal. The assessment includes the entire populations of grey seal in the Baltic Sea region. BQR= biological quality ratio. The four last columns show the corresponding BQR values for core indicators. The integrated assessment result (column 2) gives the result for the indicator showing poorest status out of these.

Spatial assessment unit	BQR	Integrated Confidence	Nutritional status	Reproductive status	Distribution	Population trends and abundance
Great Belt	0.30	Intermediate	0.46	0.54	0.30	0.73
The Sound	0.30	Intermediate	0.46	0.54	0.30	0.73
Kiel Bay	0.30	Intermediate	0.46	0.54	0.30	0.73
Bay of Mecklenburg	0.30	Intermediate	0.46	0.54	0.30	0.73
Arkona Basin	0.30	Intermediate	0.46	0.54	0.30	0.73
Bornholm Basin	0.46	Intermediate	0.46	0.54	0.80	0.73
Gdansk Basin	0.46	Intermediate	0.46	0.54	0.80	0.73
Eastern Gotland Basin	0.46	Intermediate	0.46	0.54	0.80	0.73
Western Gotland Basin	0.46	Intermediate	0.46	0.54	0.80	0.73
Gulf of Riga	0.46	Intermediate	0.46	0.54	0.80	0.73
Northern Baltic Proper	0.46	Intermediate	0.46	0.54	0.80	0.73
Gulf of Finland	0.46	Intermediate	0.46	0.54	0.80	0.73
Åland Sea	0.46	Intermediate	0.46	0.54	0.80	0.73
Bothnian Sea	0.46	Intermediate	0.46	0.54	0.80	0.73
The Quark	0.46	Intermediate	0.46	0.54	0.80	0.73
Bothnian Bay	0.46	Intermediate	0.46	0.54	0.80	0.73

Assessment results for harbour seal *(Phoca vitulina)*

Three management units of harbour seal occur in the HELCOM area; the Kattegat-southwestern Baltic metapopulation, the Kalmarsund and the Limfjord. Only harbour seal in the Kattegat show good status, while harbour seal in the management units of the southwestern Baltic and Kalmarsund do not achieve the threshold value for one or both core indicators included (Figure 25, Table 19). For harbour seals in the Limfjord, knowledge regarding stock structure and connectivity to other areas is insufficient to evaluate the status.

Harbour seals in the southwestern Baltic and the Kattegat are connected, and are assessed as one so called metapopulation with respect to abundance. The size of this metapopulation achieves the threshold value . For example, it was estimated at about 16,000 animals in 2015. However, the two sub-populations are assessed separately with respect to growth rate, and the threshold value for this parameter is not achieved in the southwestern Baltic Sea (See also Figure 26). Population studies suggest that the Limfjord harbour seal is an independent sub-population from the Kattegat population, but there is currently a lack of data on its genetic composition (Olsen *et al.* 2014).

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

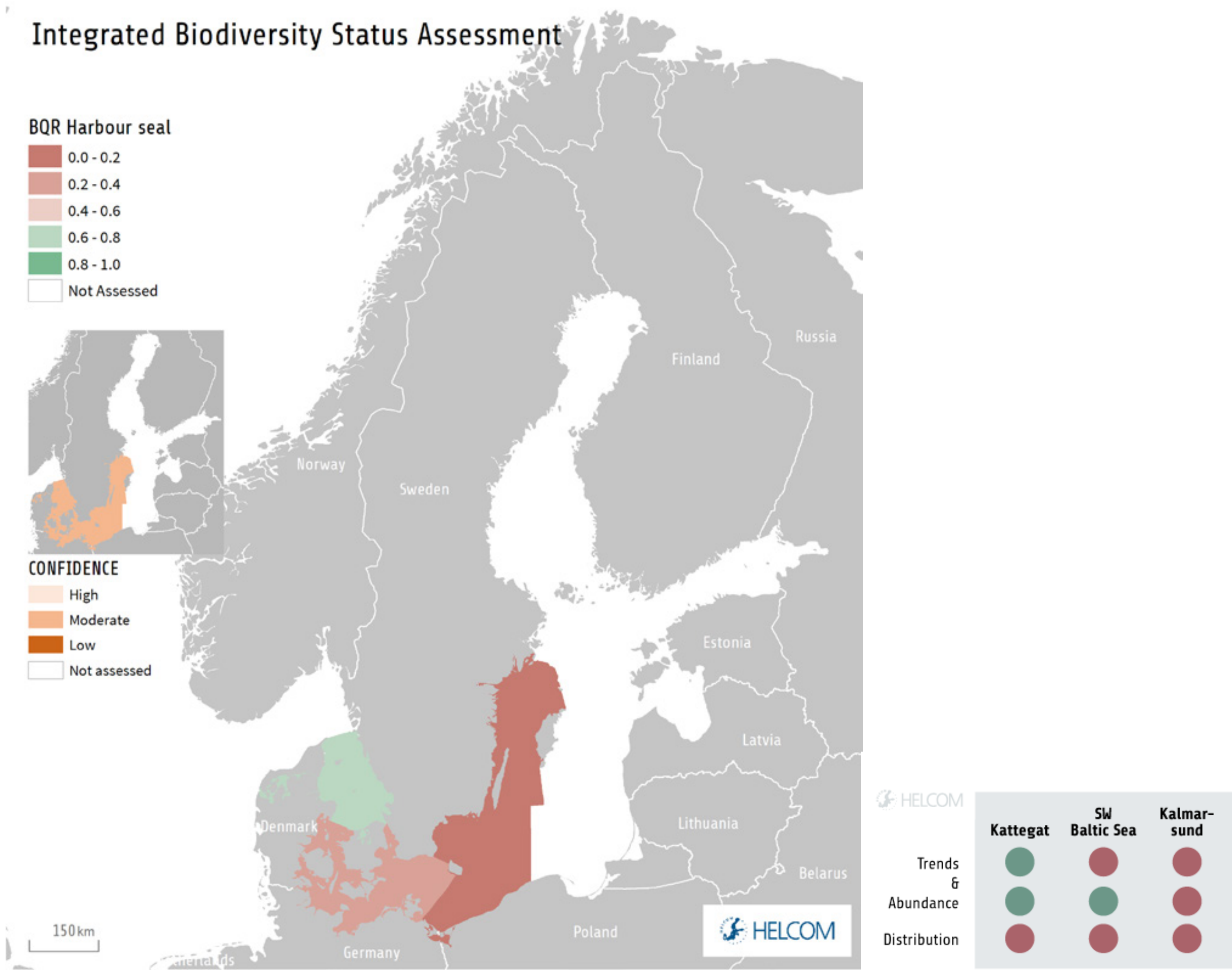

Figure 25.
Integrated status of harbour seals. Status is shown in five categories based on the integrated biological quality ratios (BQR). Values of at least 0.6 correspond to good status. The assessment is based on the one-out-all-out approach, which means that the indicator reflecting the worst status determines the status of the species. The map reflects the BQR for the indicator furthest away from good status in each assessment unit. The integrated confidence assessment result is shown in the smaller map, with darker shaded areas indicating lower confidence. The table (right) shows corresponding assessment results for the core indicators, with green denoting 'good' and red 'not good' statuses. The indicator 'Trends and abundance' consists of two parameters, and results for these are shown separately. However, 'good status' for the indicator requires that the threshold value is achieved for both parameters. The harbour seals in the Baltic Sea are separated into three management units; the Kattegat, the southwestern Baltic Sea, and the small Kalmarsund population which resides in the Western Gotland Basin and Bornholm Basin. The assessment is not applicable in the white areas of the map.

[17] For details on the Limit Reference Level for the metapopulation, see HELCOM (2016).

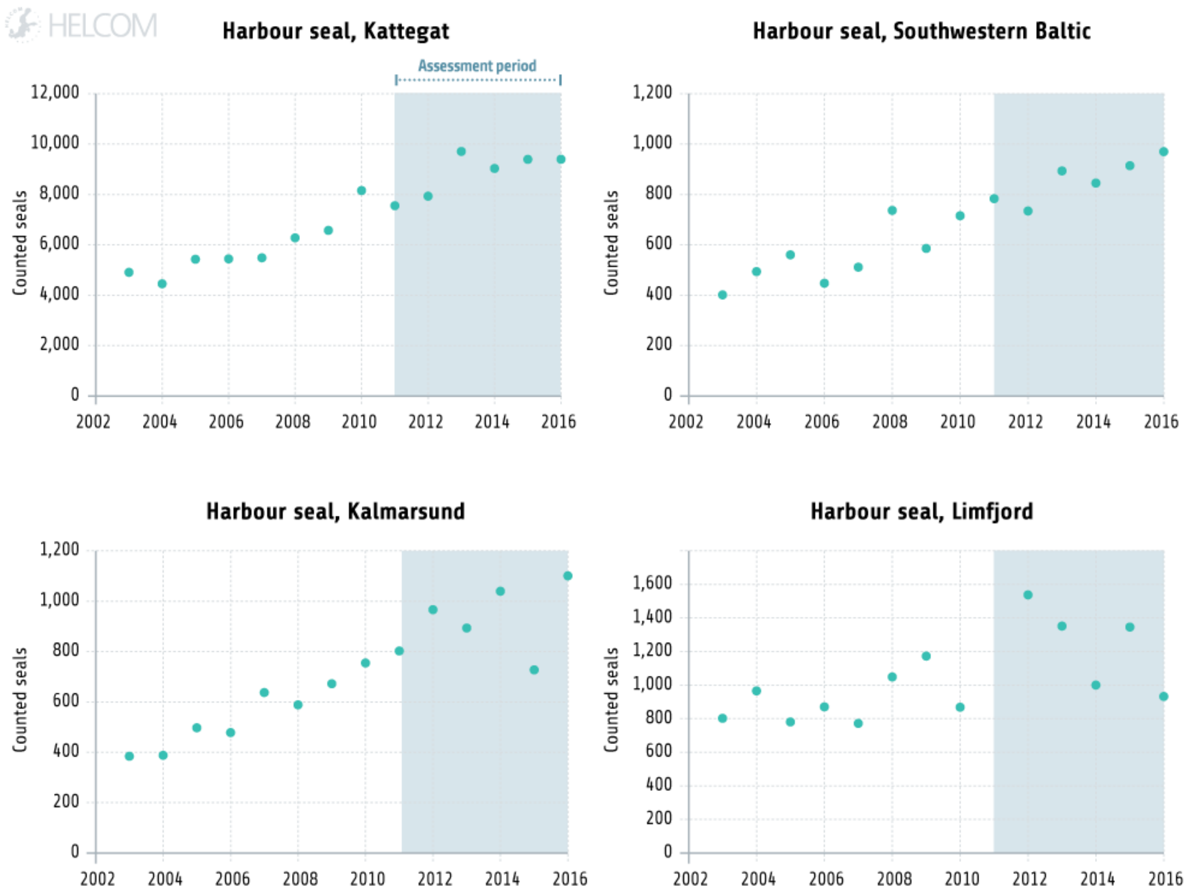

Figure 26.
Counted number of harbour seals during 2000–2016, based on monitoring at haul-outs during moulting time. The growth rate of the Kattegat population (top left) is levelling off, which is a sign of that it is approaching its carrying capacity. This management unit is currently assessed against so called second criteria (HELCOM 2018m), according to which the 'trends' parameter is considered to be in good status even though the specific growth rate is not achieved in recent years. For the Southwestern Baltic population (top right), the annual growth rate is positive but still below the threshold value. The Kalmarsund population (bottom left) is close to but does not reach the threshold value for growth rate, and the number of individuals is clearly below the limit reference level. Although the population development can be followed reliably in the graphs, it should be noted that not all individuals are encountered in the monitoring.

Table 19.
BEAT output from the integrated assessment of harbour seal. BQR= biological quality ratio. The two last columns show the corresponding integrated assessment results at indicator level. The integrated assessment result (column 2) gives the result for the indicator showing poorest status out of these. In the final results, a penalty was applied to the confidence in areas marked *, as no indicators on population condition were available for harbour seal. The table shows results for all assessment units were the assessment is applicable.

Spatial assessment unit	BQR	Integrated Confidence	Distribution	Population trends and abundance
Kattegat	0.80	High*	0.80	0.84
Great Belt	0.30	High*	0.30	0.58
The Sound	0.30	High*	0.30	0.58
Kiel Bay	0.30	High*	0.30	0.58
Bay of Mecklenburg	0.30	High*	0.30	0.58
Arkona Basin	0.30	High*	0.30	0.58
Bornholm Basin	0.06	High*	0.80	0.06
Western Gotland Basin	0.06	High*	0.80	0.06

Assessment results for ringed seal *(Pusa hispida)*

The status of the ringed seal is assessed as not good (Figure 27). Ringed seals in the Gulf of Bothnia management unit are at a population size above the Limit Reference Level of 10,000 seals, but the threshold values for growth rate or distribution are not achieved (See also Figure 28). In the southern management unit, the status of ringed seal is critical. In this area, covering the Archipelago Sea, Gulf of Finland, Gulf of Riga and Estonian coastal waters, the population is decreasing. The eastern part of the Gulf of Finland has only around 100 animals.

Despite the weak results (Figure 27; Table 20), the status of ringed seal in the integrated assessment is likely overestimated for the southern management unit. Due to a lack of estimates for population size, this parameter was included qualitatively in the assessment tool, which likely gave a stronger result than if quantitative estimates had been available.

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

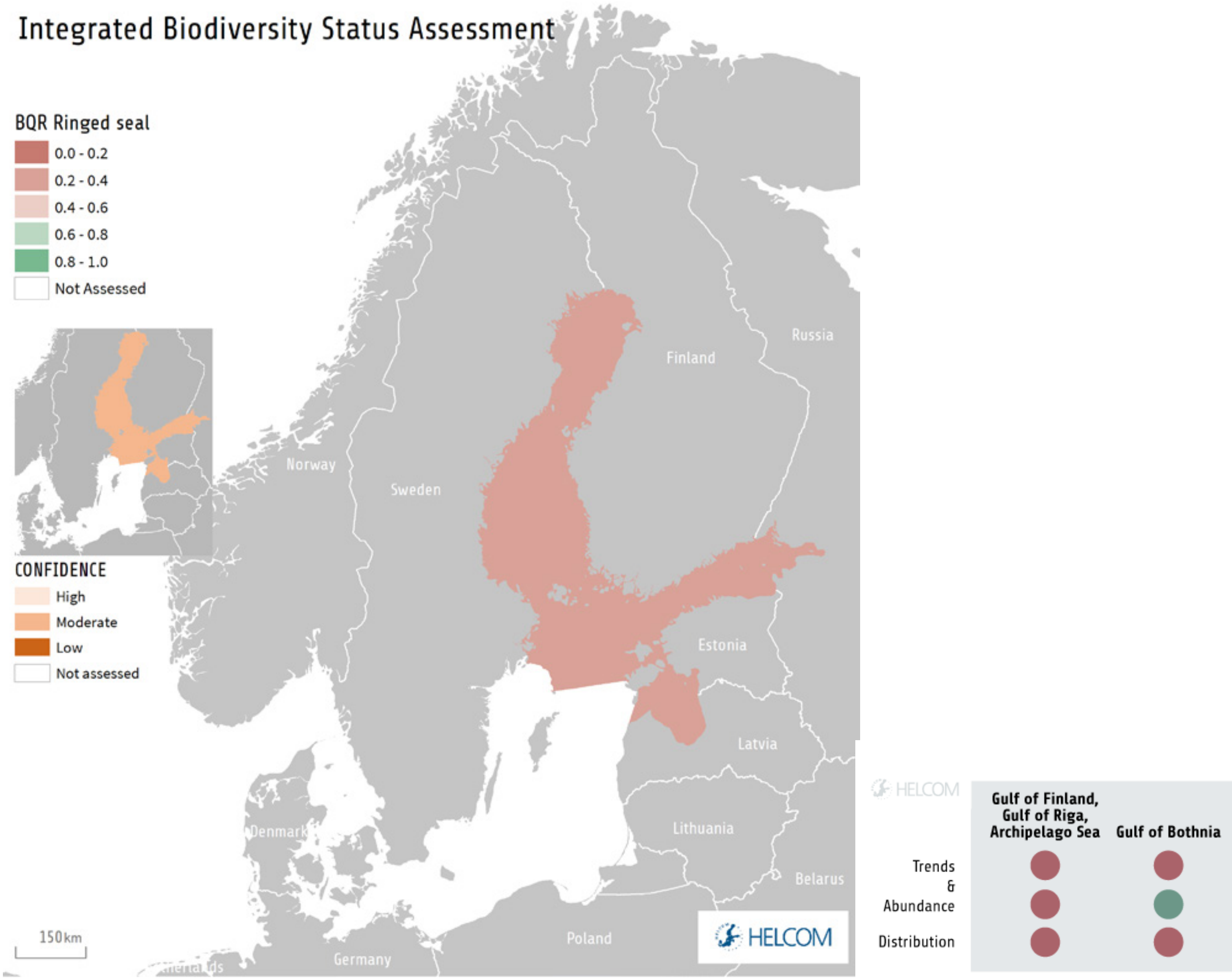

Figure 27.
Integrated status of ringed seals. Status is shown in five categories based on the integrated biological quality ratios (BQR). Values of at least 0.6 correspond to good status. The assessment is based on the one-out-all-out approach, which means that the indicator reflecting the worst status determines the status of the species. The map reflects the BQR for the indicator furthest away from good status in each assessment unit. The integrated confidence assessment result is shown in the smaller map, with darker shaded areas indicating lower confidence. The table (right) shows corresponding assessment results for the core indicators, with green denoting 'good' and red 'not good' statuses. The indicator 'Trends and abundance' consists of two parameters, and results for these are shown separately. However, 'good status' requires that the threshold value is achieved for both parameters. The ringed seals belong to two different management units; Gulf of Bothnia and an assessment unit covering the Gulf of Finland, Gulf of Riga, Estonian coastal waters and the Archipelago Sea. The assessment is not applicable in the white areas of the map.

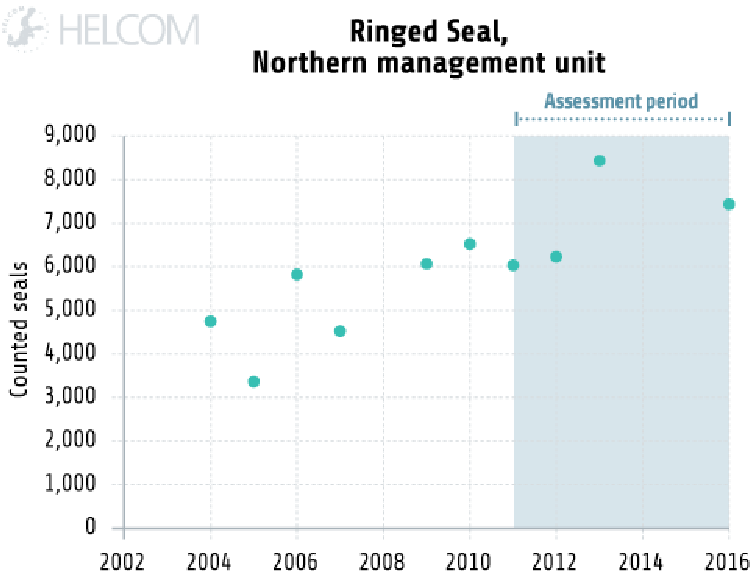

Figure 28.
Counted number of ringed seals during 2000–2016, based on monitoring at haul-outs during moulting time. The annual growth rate is positive but it is below the species specific threshold value (HELCOM 2018m). Although the population development can be followed reliably, it should be noted that not all individuals are encountered in monitoring. The total number of ringed seals in the Bothnian Bay is estimated at more than 20,000.

Table 20.
Output from the integrated assessment of ringed seal. BQR= biological quality ratio. The two last columns show the corresponding integrated assessment results at indicator level. The integrated assessment result (column 2) gives the result for the indicator showing poorest status out of these. In the final results, a penalty was applied to the confidence in areas marked*, as no indicators on population condition were available for ringed seal. The table shows results for all assessment units were the assessment is applicable.

Spatial assessment unit	BQR	Confidence	Distribution	Population trends and abundance
Gulf of Riga	0.30	High*	0.30	0.08
Northern Baltic Proper	0.30	High*	0.30	0.08
Gulf of Finland	0.30	High*	0.30	0.08
Åland Sea	0.30	High*	0.30	0.08
Bothnian Sea	0.30	High*	0.30	0.58
The Quark	0.30	High*	0.30	0.58
Bothnian Bay	0.30	High*	0.30	0.58

Harbour porpoise *(Phocoena phocoena)*

A major study conducted in 2011–2013 using passive acoustic recorders supports the presence of two sub-populations of harbour porpoise in the Baltic Sea; one mainly occurring east of Bornholm in the Baltic Proper and the other one occurring in southern Kattegat, the Belt Sea, and the southwestern parts of the Baltic Sea (Anonymous 2016; Figure 29). A recent population genomics approach also emphasised notable differences between the Kattegat, Belt Sea, Western Baltic and the Baltic Proper (Lah *et al.* 2016).

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

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

By comparing the age structure with the average age at sexual maturity, it has been estimated that only about 28 % of the female harbour porpoises found dead along the German Baltic coast of Schleswig-Holstein had lived long enough to reach sexual maturity. In comparison, about 45 % of the females from the North Sea had reached sexual maturity. About 30 % of the animals were suspected to be by-caught, based on pathological findings. The low proportion of harbour porpoises reaching sexual maturity in the Baltic Sea supports the need to reduce the magnitude of by-catches (Kesselring *et al.* 2017, see also Box 2).

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

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

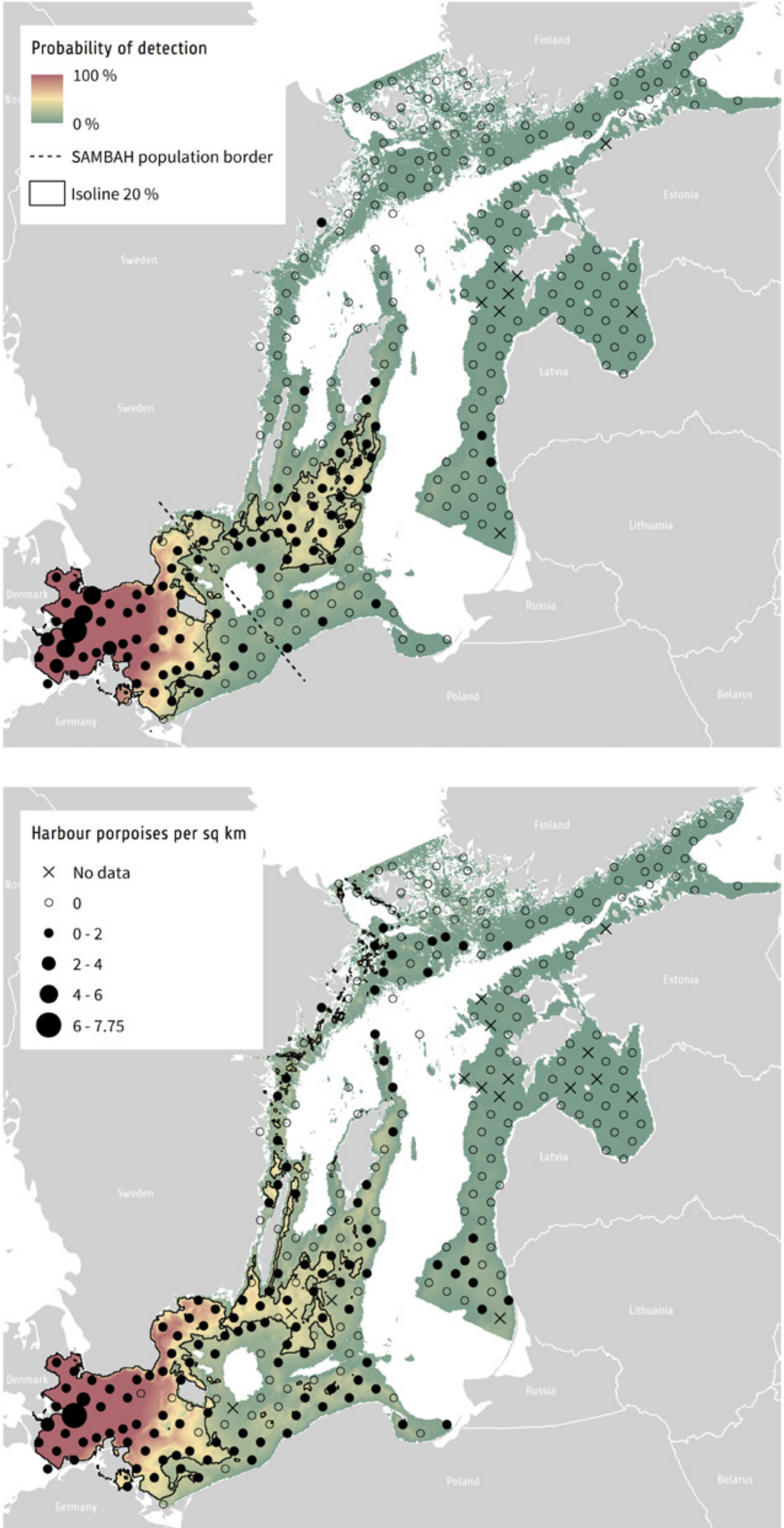

Figure 29.
Harbour porpoise in the Baltic Proper. Predicted probability of detecting harbour porpoise per month between May and October (upper graph) and between November and April (lower graph). The black line delineates areas with 20 % probability of detection (Denoted 'Isoline 20 %' in the legend). These areas correspond approximately to the area which encompasses 30 % of the population, and the limit is often used to define high-density areas. In the upper figure, the hatched line indicates the spatial separation between the Belt Sea and Baltic harbour porpoise populations during May to October. White colour denotes areas that were not surveyed. Source: SAMBAH project (Anonymous 2016).

Box 2.

Incidental by-catch of mammals in fishing gear

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

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

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

Future perspectives

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

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

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

4.5. Integrated assessment results for waterbirds

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

At the smaller assessment scale, encompassing aggregated sub-basins, the core indicators reflect good status in the breeding season for waterbirds in the Belt group (Great Belt and the Sound) and the Bothnian group (Bothnian Bay, the Quark and the Bothnian Sea). Good status in the wintering season is seen in most of the region, excluding the Kattegat, Belt group and Åland group (Northern Baltic Proper and Åland Sea; Table 21; HELCOM 2018q-r).

With respect to different groups of bird species, surface feeding and pelagic feeding birds have good status during both the breeding and wintering seasons at the whole Baltic Sea scale. Wading feeders do not achieve good status in the breeding season, and benthic feeders and grazing feeders not in the wintering season (Table 21; first column, Tables 22–23; Figures 30–32).

When assessed at the smaller scale, the status evaluation differed regionally (Table 21). In addition to defining the abundances of the involved species more clearly, assessments of waterbirds at smaller scales alters the number of species assessed within a feeding group in each case. In cases where a species has locally high abundance and/or where few species make up the feeding group, it is possible for all assessments at smaller scales to fail the assessment while the whole Baltic assessment achieves the respective threshold value, as seen for example benthic feeders in the breeding season (Table 21; see the Core indicator reports: HELCOM 2018q-r for details).

Table 21.
Status of waterbirds by species groups at the whole Baltic Sea scale and aggregated assessment unit scale, based on results within the core indicators on abundance of waterbirds during the breeding and the wintering season. Status is evaluated based on the trends over time in the abundance of species within each of the groups. The assessment result for the entire Baltic Sea is shown in the first column. The following columns show the corresponding assessment results for different areas of the Baltic Sea. Green denotes that the species group passed the threshold value, and red that it failed. Since harmonised offshore monitoring was not possible to carry out for this assessment period waterbirds are assessed based predominantly on land-based surveys. Offshore species are thus not adequately assessed.

		Entire Baltic Sea	By assessment areas						
			Kattegat	Great Belt, Little Belt, The Sound	Kiel Bay, Bay of Mecklenburg, Bornholm Basin, Arkona Basin	Eastern Gotland Basin, Western Gotland Basins, Gulf of Riga, Gdansk Basin	Northern Baltic Proper, Åland Sea	Gulf of Finland	Bothnian Sea, Quark, Bothnian Bay
Breeding season	Grazing feeders								
	Benthic feeders								
	Pelagic feeders								
	Surface feeders								
	Wading feeders								
Wintering season	Grazing feeders								
	Benthic feeders								
	Pelagic feeders								
	Surface feeders								
	Wading feeders								

Among waterbirds breeding in the Baltic Sea, species with declining abundance belong to the group of benthic feeders (common eider and velvet scooter), surface feeders (great black-backed gull and common gull), grazing feeders (mute swan), pelagic feeders (goosander), and wading feeders (dunlin, pied avocet, and turnstone, when assessed at the whole Baltic Sea scale and during the period 1991-2016. Among waterbirds wintering in the Baltic Sea declining abundances are seen in species belonging to grazing feeders (Eurasian coot), pelagic feeders (goosander), and benthic feeders (common pochard, Steller´s eider; see Tables 22-23 for detail, and scientific names).

Table 22.
List of species included at the entire Baltic Sea scale in the core indicator 'Abundance of waterbirds in the breeding season'. Species groups not achieving good status according to the definition of the core indicators when applied at species group level, are highlighted in red. Species listed in Annex 1 of the Birds Directive are marked with an asterisk*. The column to the right shows the status of the same species according to the HELCOM Red List, which includes additionally thirteen species not included in the core indicators (HELCOM 2013a).

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

Table 23.
List of species included at Baltic Sea Scale in the core indicator 'Abundance of waterbirds in the wintering season'. Species groups not achieving good status according to the definition of the core indicators when applied at species group level, are highlighted in red. Species listed in Annex 1 of the Birds directive are marked with an asterisk*. The column to the right shows the status of the same species according to the HELCOM Red List, which includes additionally thirteen species not included in the core indicators (HELCOM 2013a).

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

Waterbird species with relatively high abundance during the assessment years compared to the baseline are the Arctic tern *(Sterna paradisaea)*, common tern *(Sterna hirundo)*, sandwich tern *(Thalasseus sandvicensis)*, great crested grebe *(Podiceps cristatus)*, common guillemot *(Uria aalge)* and black guillemot *(Cepphus grylle)*, assessed during the breeding season, and the Eurasian teal *(Anas crecca)*, black-headed gull *(Larus fuscus)*, great cormorant *(Phalacrocorax carbo)*, common goldeneye *(Bucephala clangula)* and smew *(Mergellus albellus)*, assessed during the wintering season. Low abundances relative to the baseline are observed in great black-backed gull *(Larus marinus)*, velvet scoter *(Melanitta fusca)*, pied avocet *(Recurvirostra avosetta)*, dunlin *(Calidris alpina)* and turnstone *(Arenaria interpres)*, assessed during the breeding season. Among the wintering birds, low abundances are seen in common pochard *(Aythya ferina)*, Bewick's swan *(Cygnus bewickii)*, Eurasian coot *(Fulica atra)* and clearly so in Steller's eider *(Polysticta stelleri)*.

It must be noted that important bird species have been omitted from the evaluation because they are not appropriately represented in the assessment data. Several species which spend the winter mainly in open sea areas have not been assessed, such as long-tailed duck *(Clangula hyemalis)*, common scoter *(Melanitta nigra)*, velvet scoter *(Melanitta fusca)*, common eider *(Somateria mollissima)*, red-throated diver *(Gavia stellata)*, black-throated diver *(Gavia arctica)*, red-necked grebe *(Podiceps grisegena)*, razorbill *(Alca torda)*, black guillemot *(Cepphus grylle)*, common guillemot *(Uria aalge)* and Slavonian grebe *(Podiceps auritus)*. These are important representative species for the benthic and pelagic feeders. Hence, the core indicator results reflect only the status of wintering waterbirds located in more coastal areas.

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

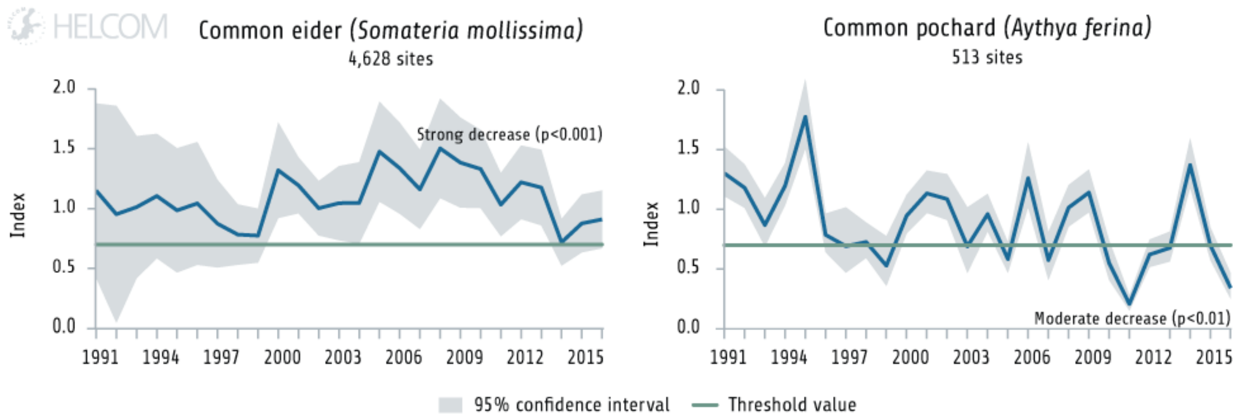

Figure 30.
Temporal development in the abundances of two benthic feeders; common eider (*Somateria mollissima*) in the breeding season and the common pochard (*Aythya ferina*) in the wintering season, at the whole Baltic Sea scale. Based on abundance index values during 1991–2016. Source: HELCOM (2018q–r).

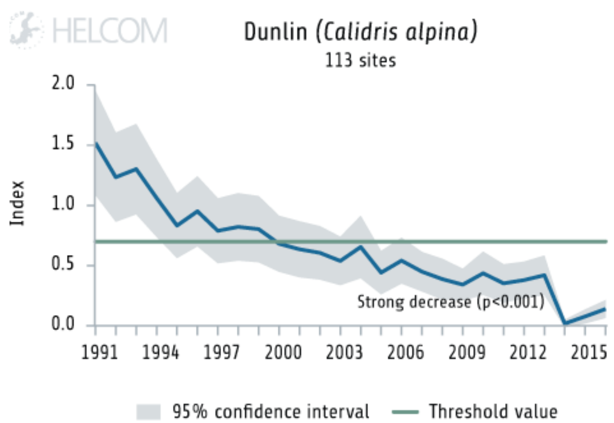

Figure 31.
Temporal development of the abundance of the wading feeder dunlin (*Calidris alpina*) in the breeding season at the whole Baltic Sea scale. Based on abundance index values during 1991–2016. Source: HELCOM (2018q).

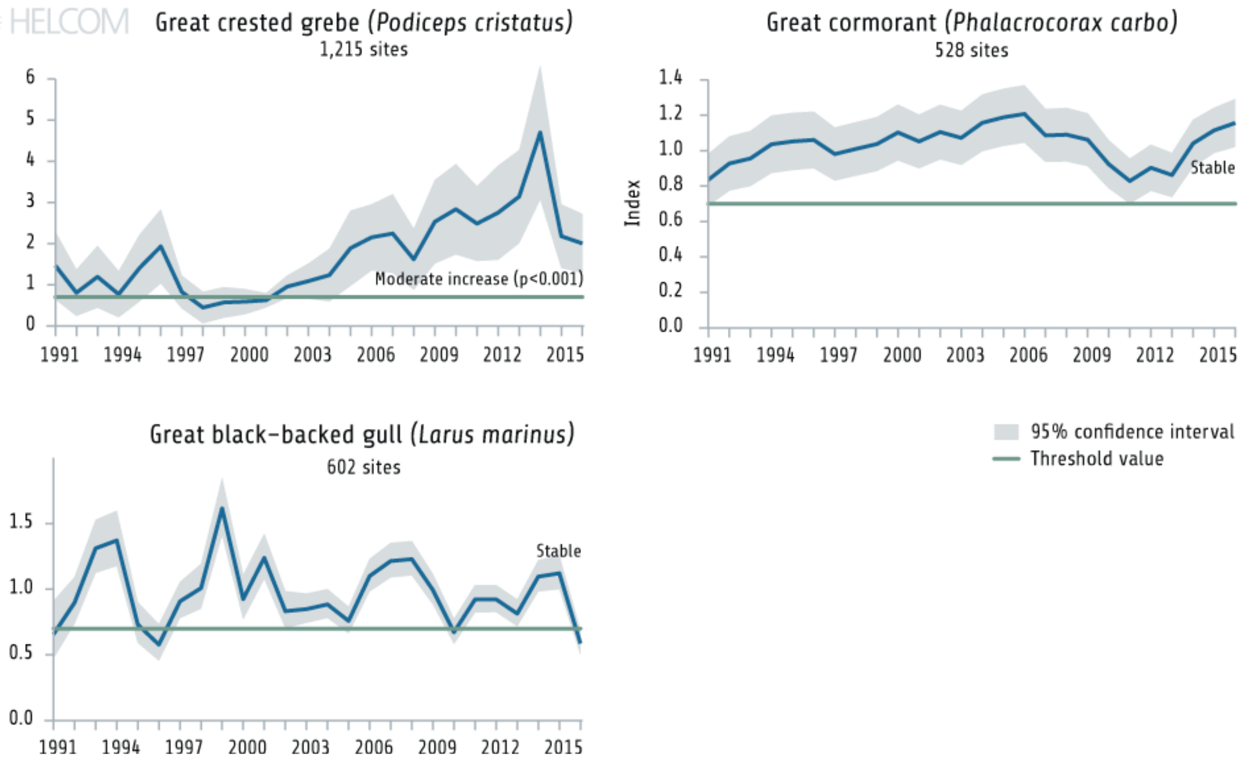

Figure 32.
Temporal development of the abundances of the pelagic feeders great crested grebe (*Podiceps cristatus*) and great cormorant (*Phalacrocorax carbo*) in the breeding season, and great black-backed gull (*Larus marinus*) in the wintering season, at the whole Baltic Sea scale. Based on abundance index values during 1991-2016. Source: HELCOM (2018q-r).

Box 3.

Incidental by-catch of waterbirds in fishing gear

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

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

Beside the assessment of incidental by-catch, hunting must also be taken into account (See Chapter 4.6 in HELCOM 2018a) because the total anthropogenic mortality has to be related to the population in order to assess its impact.

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

Red-listed species

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 2013a). 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 ae 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 ten species that are also included in the core indicator for breeding birds, and two species that are included in the core indicator for wintering birds. In some instances, the core indicator evaluations may show a good status for a red-listed species.

For example, the black guillemot *(Cepphus grylle)*, tufted duck *(Aythya fuligula)*, ringed plover *(Charadrius hiaticula)*, greater scaup *(Aythya marila)*, common eider *(Somateria mollissima)*, Caspian tern *(Hydroprogne caspia)*, and lesser black-backed gull *(Larus fuscus)* have a good status according to the core indicator for waterbirds during the breeding season, but are listed as 'vulnerable' by HELCOM (2013a) and this also applies for the red-breasted merganser *(Mergus serrator)* in the wintering season.

Differences in the methodological approaches should be considered when making such comparisons. The core indicators are evaluated against a modern baseline and do not address the potential recovery of the species or overall population stability. Bird species are also assessed in other contexts, such as national red lists, which may show different results. Such inconsistencies between assessments may occur due to differences in the applied assessment periods, but may also reflect different population trends in different parts of the Baltic Sea. For example, the lesser black-backed gull (subspecies *Larus fuscus fuscus*) has decreased by around 40 % in Finland in 1991–2013 (Hario and Rintala 2016), while the core indicator shows a rather stable Baltic Sea scale population due to the increase of subspecies Larus fuscus intermedius in the western Baltic.

Future perspectives

Waterbirds are widely dispersed and influenced by various human activities and pressures. Coastal developments, fishing, shipping, wind farms, recreation and hunting, are examples of human activities that may lead to disturbance, loss of habitat, alterations to the breeding and feeding environment, as well as mortality (Larsson and Tydén 2005, Žydelis *et al.* 2009, Petersen *et al.* 2011, Schwemmer *et al.* 2011). Many waterbird species are vulnerable to incidental by-catches in fishing gear (Box 3).

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

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

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

Summary for benthic and pelagic habitats

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

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

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

A HELCOM threat assessment for biotopes and biotope complexes identifies seventeen biotope complexes as threatened, and ‘aphotic muddy bottoms’ are categorised as critically endangered (HELCOM 2013d). The evaluation represents a minimum estimate, based on available data. Eight out of ten assessed biotope complexes (comparable to ‘habitats’ as defined in Annex 1 of the EU Habitats Directive), are categorised as threatened in the Baltic Sea.

Summary for benthic and pelagic habitats

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

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

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

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

Food web aspects

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

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

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

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

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

Habitat quality

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

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Annex 1. Threshold values for the biodiversity indicators in open waters

State of the soft-sediment macrofauna community

Assessment unit (Scale 3, open sea only)	Sensitivity value	Threshold value
Kiel Bay	Schiele *et al.* 2016	
	– subset 2	7.22
	– subset 3	5.44
	– subset 4	4.52
Bay of Mecklenburg	Schiele *et al.* 2016	
	– subset 2	7.22
	– subset 3	5.44
	– subset 4	4.52
Eastern Gotland Basin (interim)	Schiele *et al.* 2016	
	– subset 8	1.81
	– subset 9	2.1
Western Gotland Basin	Leonardsson *et al.* 2009	4.0
Gulf of Riga (interim)	Schiele *et al.* 2016	
	– subset 12	1.59
	– subset 13	1.07
Northern Baltic Proper	Leonardsson *et al.* 2009	4.0
Gulf of Finland (interim)	Schiele *et al.* 2016	
	– subset 11	0.93
	– subset 13	1.07
Åland Sea	Leonardsson *et al.* 2009	4.0
Bothnian Sea	Leonardsson *et al.* 2009	4.0
The Quark	Leonardsson *et al.* 2009	1.5
Bothnian Bay	Leonardsson *et al.* 2009	1.5

Zooplankton mean size and total stock

Assessment unit (scale 2)	Threshold value
Western Gotland Basin	5.1 mean size
	Gulf of Finland
Gulf of Finland	8.6 mean size
	Bothnian Sea
Åland Sea	10.3 mean size
	Gdansk Basin
Bothnian Sea	8.4 mean size
	23.7 total stock
Bothnian Bay	23.7 mean size
	161 total stock
Gdansk Basin	10.2 mean size
	103 total stock

Abundance of key coastal fish species

Assessment unit (scale 3, coastal only)	Threshold value	
All assessment units (assessed only when data is available, see core indicator report for details)	The threshold value is assessment unit specific however it is presented as a normalized value for all assessment units	0,6

Abundance of coastal fish key functional groups

Assessment unit (scale 3, coastal only)	Threshold value	
All assessment units (assessed only when data is available, see core indicator report for details)	The threshold value is assessment unit specific however it is presented as a normalized value for all assessment units	0,6

Abundance of salmon spawners and smolt

Assessment unit (scale 2)	Threshold value	
Bothnian Bay	75 % Potential Smolt Production Capacity	2313,16
Bothnian Bay/The Quark	75 % Potential Smolt Production Capacity	495,81
Bothnian Sea	75 % Potential Smolt Production Capacity	1,65
Western Gotland Basin	75 % Potential Smolt Production Capacity	65,34
Eastern Gotland Basin	75 % Potential Smolt Production Capacity	213,75
Gulf of Finland	75 % Potential Smolt Production Capacity	189,00

Distribution of Baltic seals[20]

Management unit	Threshold value
Grey seals	Pristine conditions. In cases where pristine sand banks have physically disappeared a "modern baseline" is used based on currently available haul out sites.
East and north of Bornholm	
Southwestern Baltic Sea	
Harbour seals	
Kalmarsund population	
Southwestern Baltic Sea	
Kattegat	
Ringed seals	
Gulf of Bothnia	
Archipelago Sea, Gulf of Finland, Estonian coastal waters	

[20] Note that the assessment of seals is carried out for the management units as defined in HELCOM Recommendation 27/28-2. The management units are associated to HELCOM assessment units on scale 2.

Population trends and abundance of seals[21]

<table>
<tr><th>Management unit</th><th>Threshold value</th></tr>
<tr><td colspan="2">Grey seals</td></tr>
<tr><td>Baltic Sea</td><td>Threshold value for grey seals: The number must exceed 10,000 seals. In addition the population growth rate must 1) exceed 7 % in the exponential phase of population growth, or 2) when close to carrying capacity, no decline greater that 10 % over a 10-year period. Currently the second criterion is used.</td></tr>
<tr><td colspan="2">Harbour seals</td></tr>
<tr><td>Kalmarsund population</td><td rowspan="3">Threshold value for harbour seals: The number must exceed 10,000 seals. In addition the population growth rate must 1) exceed 9 % in the exponential phase of population growth, or 2) when close to carrying capacity, no decline greater that 10 % over a 10-year period. In the assessment period 2011-2015, The first criterion is used for the Kalmarsund and Southwestern Baltic Sea management units while the second is used for the Kattegat population. Since the harbour seals in the Southwestern Baltic Sea are connected to those in the Kattegat, these populations are treated as a single metapopulation with respect to abundance but each sub-population is assessed separate with respect to growth rate.</td></tr>
<tr><td>Southwestern Baltic Sea</td></tr>
<tr><td>Kattegat</td></tr>
<tr><td colspan="2">Ringed seals</td></tr>
<tr><td>Archipelago Sea[22], Gulf of Finland, Estonian coastal waters</td><td rowspan="2">Threshold value for ringed seals: The number must exceed 10,000 seals. In addition the population growth rate must 1) exceed 7 % in the exponential phase of population growth, or 2) when close to carrying capacity, no decline greater that 10 % over a 10-year period. For ringed seals the first criterion is used.</td></tr>
<tr><td>Gulf of Bothnia</td></tr>
</table>

Nutritional status of seals

Management unit	Threshold value
Grey seals	
Baltic Sea	By-caught seals: 35 mm blubber thickness
Baltic Sea	Hunted seals: 49 mm blubber thickness

Reproductive status of seals

Management unit	Threshold value
Grey seals	
Baltic Sea	90 % pregnant grey seal females (>6 years old)

[21] Note that the assessment of seals is carried out for the management units as defined in HELCOM Recommendation 27/28-2. The management units are associated to HELCOM assessment units on scale 2.

[22] Gulf of Finland, Archipelago Sea and Estonian coastal waters are regarded as a single management unit, but sporadic survey data preclude an overall assessment.

Abundance of waterbirds in the breeding season

Assessment unit (scale 1)	Threshold value	
Baltic Sea	75% of populations deviate less than 30 % (20 % in species laying only one egg per year) below the abundance defined as a modern baseline during the reference period 1991-2000	0,75

Abundance of waterbirds in the wintering season

Assessment unit (scale 1)	Threshold value	
Baltic Sea	75 % of populations deviate less than 30 % (20 % in species laying only one egg per year) below the abundance defined as a modern baseline during the reference period 1991-2000	0,75

The fish stocks included are shown in Figure A.1.1 below, which corresponds to the results for the assessment of commercial fish and fisheries in Chapter 4.6 of the 'State of the Baltic Sea' report (HELCOM 2018a).

At the level of each stock, the indicator 'Fishing mortality' was assessed by comparison with the reference value 'FMSY', which is the level of fishing mortality estimated to deliver the long term maximum sustainable yield. The indicator 'Spawning stock biomass' was assessed in relation to the associated reference value 'MSY B-trigger'. No assessment results were available for the age and size distribution.

The results are assessed based on the average results for the years 2011 to 2016[23], using reference values from 2016 as presented in ICES (2017a-c), and are presented using the spatial delineation of subdivisions used by ICES (2017d; Figure A.2.2).

The results were evaluated against the condition that the average assessment ratios for all included years should achieve a threshold value of 1 for both fishing mortality and spawning stock biomass. Based on a compilation of available results, five of thirteen assessed stocks had too high a fishing mortality on average during 2011–2016, whereas eight stocks were fished at level consistent with maximum sustainable yield. Spawning stock biomass was below the biomass reference point for three out of nine assessed stocks, indicating not good status[24].

The overall stock status was evaluated with respect to stocks for which data on both fishing mortality and stock size was available, applying the condition both these indicators should achieve the threshold value. Based on this evaluation, three stocks show good status with respect to both fishing mortality and stocks size (plaice, central Baltic Sea herring and herring in the Gulf of Bothnia). Six out of nine stocks did not achieve good status (Eastern and western Baltic cod, dab, sole, spring spawning herring in the western Baltic Sea, Gulf of Riga herring and sprat).

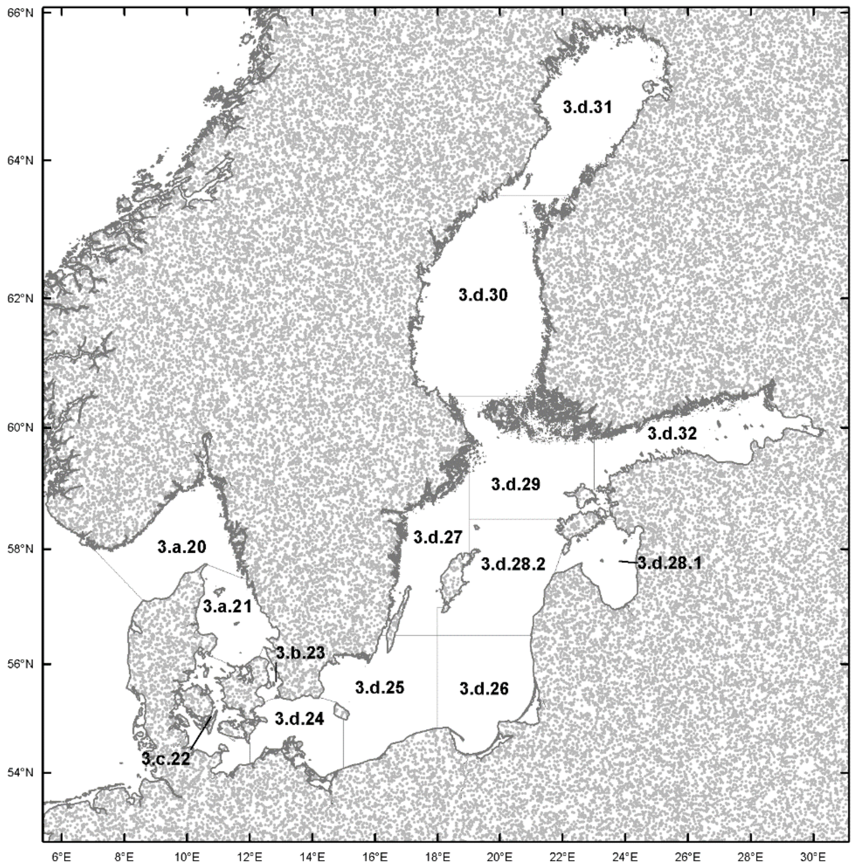
[23] Based on recommendations from the HELCOM SPICE Biodiv WS 1-2017, this is preferred over only using the results from the last year of assessment, since the reference points are not defined as a level to be exceeded with a high probability. For example for spawning stock biomass, the probability of being above this point in any single year varies from very high to approximately 50 % for some stocks. In contrast, the mean over prolonged periods should have a substantially higher probability of being above MSY B-trigger. The results for both F and SSB are included in order to have consistent results between the assessment of commercial fish and the biodiversity assessment.

[24] In the assessment, reference levels and estimates of stock size and fishing mortality in individual years change over time as new data become available. Hence, a fishing mortality above FMSY or a spawning stock biomass below the MSY B-trigger on average do not necessarily demonstrate that the advice from ICES on fishing opportunities was exceeded.

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

*Including recreational catches

Figure A.2.1.
Status of internationally managed fish stocks in the Baltic Sea during 2011-2016. Commercial fish species are assessed by stocks, which are named by their areal distribution. The numbers give the corresponding ICES assessment units (Subdivisions). The assessment is made in relation to reference points for fishing mortality (FMSY) and spawning stock biomass (MSY B-trigger), or their proxies (indicated close to the stock name in that case). The circle colours denote if the average indicator value during 2011-2016 achieves (green) or fails (red) the 2016 reference point (or proxy reference point, if indicated). Total status is assessed by the condition that both indicators should achieve their reference points, as shown in the last column. Salmon is assessed over many stocks, which show variable status. White circles denote that no status evaluation in relation to a threshold value is available. Source: ICES (2017a-c).



ure A.2.2.
S statistical areas with subdivisions in the
tic Sea. Source: ICES (2017d).

The results shown in Table Figure A.2.1 were applied in the integrated biodiversity assessment according to the rules shown in Table A.2.2, taking into variability between years during 2011-2016. The results for the indicator achieving the lowest value (comparing FMSY and SSB for each stock) was used as input data to the integrated assessment.

Confidence in the assessment was assessed as high for all stocks included in the integrated assessment.

Table A.2.2.
Principles for how the assessment results for commercial fish were entered into BEAT. The assessment results were transformed into four classes in order to provide a more nuanced assessment results as compared to the alternative of only giving information on under or below the reference point. The years assessed were 2011–2015.

Input value	Definition
0.125	Threshold value not achieved in any of the years
0.375	Threshold value not achieved for the average for 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

Table A.2.3.
Input of commercial fish data to the BEAT assessment, based on the approach outlined above. Green=Threshold value achieved by the average value for 2011–2015 for both indicators FMSY and SSB. Red= Threshold value not achieved by the average value for at least one of the indicators FMSY and SSB. NA= not applicable. White cells denote subdivisions not assessed due to lack of assessment result.

	Demersal				Pelagic	
ICES SD	Western Baltic Cod	Eastern Baltic cod	Plaice	Sole	Herring	Sprat
21	NA	NA	0.625	0.125	0.125	
22	0.125	NA	0.625	0.125	0.125	0.375
23	0.125	NA	0.625	0.125	0.125	0.375
24	0.125	0.125		0.125	0.125	0.375
25	NA	0.125		NA	0.825	0.375
26	NA	0.125		NA	0.825	0.375
27	NA	0.125		NA	0.825	0.375
28	NA	0.125		NA	0.825	0.375
28.1	NA	0.125		NA	0.375	0.375
29	NA	0.125		NA	0.825	0.375
30	NA	0.125		NA	0.675	0.375
31	NA	0.125		NA	0.675	0.375
32	NA	0.125		NA	0.825	0.375

R-script

BEAT 3.0 was coded as an R-script in order to provide a freely accessible and open tool. The script can be downloaded from: https://github.com/NIVA-Denmark/BalticBOOST.

The structure of the assessment is defined in input tables to the tool. The default spatial structure follows the HELCOM Monitoring and Assessment Strategy, whereas the ecosystem component structure follows the revised COM DEC. As a first step BEAT 3.0 reads the input tables, normalizes the indicators and assigns weight to them, as well as calculates the indicator confidence. In the normalization, the indicators are characterized as being either monotonic or unimodal. The monotonic (linear) response is the default. For unimodal indicators, which have both an upper and a lower threshold, the normalization is done in relation to the threshold value lying closer. Conditional indicators are assessed so that all parameters are considered, and the parameter with the lowest biological quality ratio (BQR) is used in the integration.

The following step is, following the defined structures, integrating the assessment results to the different ecosystem component and spatial assessment scales. In the last step, the results are summarized and exported as output tables, separately for the biodiversity assessment and the confidence assessment.

Input tables

Input tables to the tool are:

Spatial assessment units (SAU.txt file) – a hierarchical list of the assessment units with four levels (according to the HELCOM spatial assessment scales 1-4). The area (km2) of all spatial assessment units are specified here if applying the area-weighted spatial aggregation option.

Ecosystem components (EcosystemComponents.txt file) – a hierarchical list of the ecosystem components (birds, fish, mammals, pelagic habitats, benthic habitats) with four levels (1=Biodiversity, 2=Ecosystem component, 3=Species group/broad habitat type, 4=Species/habitat element). Each component is linked to the relevant higher level ecosystem component.

Descriptors (descriptors.txt file) – a list of the MSFD descriptors.

Criteria (criteria.txt file) – a list of the MSFD criteria. This list is updated to follow the revised European Commission Decision on GES criteria.

Indicator catalogue (IndicatorCatalogue.txt file) – a list where the indicators are assigned to relevant ecosystem component and MSFD criterion.

Indicators (indicators.txt file) – table of observed value, minimum and maximum values, threshold value and confidence evaluations for the indicators linked to the spatial assessment unit. One row is added for each assessment unit the indicator is used in. Instructions on how to define minimum and maximum values for the indicators can be found in the request sent to the indicator Lead and co-Lead country representatives (HOLAS II 5-2016 Document 4-1 Annex 1).

Indicator group (ooao.txt file) – a list grouping indicators/parameters used in conditional indicators and indicators to be treated with the OOAO approach, i.e. using the parameter with poorest status classification in further integration steps.

Of these input tables, the spatial assessment units, ecosystem components, descriptors and criteria can be used as they are in the HELCOM and MSFD context, but if new indicators are added to the tool one needs to follow the steps and update the input files as outlined in the ‘Step-wise description of the tool’ (section 7).

Step-wise manual to BEAT 3.0

1. Download the R script from https://github.com/NIVA-Denmark/BalticBOOST. Input files are found in the …/input folder.
2. Add the indicator to the indicator catalogue. Make sure to link the indicator with the correct ecosystem component ID and MSFD criteria. The ecosystem component ID is found in the EcosystemComponents.txt file
3. Insert the indicator results to the Indicators file. Add one row for each spatial unit the indicator has results for. If assessment is to be carried out on lower spatial assessment scale than the indicator is assessed at, the information needs to be downscaled. This is done by adding the (same) indicator result to all relevant spatial assessment units at that scale.
4. Specify the spatial assessment unit (ID is found in the SAU.txt file) and indicator ID (found in the IndicatorCatalogue.txt file).
5. Specify the indicator type (1: indicator value increasing/decreasing with improved/worsened environmental status, 2: indicator with an optimal range/interval).
6. Insert the minimum and maximum values of the indicator. Instructions on how to set the minimum and maximum values are found in HOLAS II 5-2016 Document 4-1 Annex 1. Make sure the minimum and maximum values are inserted correctly into the Bad and High columns, depending on if increasing value mean improved status (Minimum = Bad, Maximum =High) or decreasing value means improved status (Minimum = High, Maximum = Bad).
7. Insert the threshold value (ModGood column)
8. For type 2 indicators the optimal value is inserted in the High column. Minimum value is inserted in the Bad column, lower threshold value in the ModGood column, higher threshold value in ModGood2 column and maximum value in Bad2 column.
9. Insert the indicator result (Obs column).
10. Insert the standard error of the indicator result (if available)
11. Define and insert the confidence scores (High = 1, Intermediate = 0.5, Low = 0) for each of the four categories: confidence of classification (ConfA), temporal coverage (ConfT), spatial representation (ConfS) and methodological confidence (ConfM). The confidence can be inserted in numerical or text format. Instructions on how to assess the confidence in the different categories are found in HOLAS 5-2016 Document 4-1 Annex 1. If standard error has been provided ConfA can be left empty.
12. If the indicator uses a conditional approach, i.e. several parameters with threshold values, all parameters and their results are inserted as separate indicators following the instructions above. The parameters are grouped in the ooao.txt file, where the indicator ID's of the parameters used in the indicator are given the same group ID.
13. Run the R script BOOSTbiodiv.R (make sure to specify the work directory location of the include.R file).
14. Result files are found in the …/results folder.

Annex 4. Assessment results for coastal benthic habitats

Output table from BEAT 3.0 showing results from the integrated assessment of benthic habitats in coastal areas. The first column gives the codes for each of the applied spatial assessment unit (SAU). 'BQR'= Biological quality ratio. 'Confidence' shows the confidence at integrated indicator level, not including any overall penalty (NA= not applicable due to no indicators assessed). Columns 4–11 show the BQR scores applied at the level of each indicator and assessment unit in BEAT 3.0, after normalisation. In the first step, indicators were integrated within the groups; macrofauna and macrovegetation. In the second step, the integrated values for these two groups (not shown) were combined into the integrated into the BQR score shown in column 2, which is the average of values for the two first level groups.

SAU	BQR	Confidence	Second integration level							
			First integration level Macrofauna				First integration level Macrovegatation			
			Fauna			Oxygen	Vegetation			Secchi
			Indic. 1	Indic. 2	Indic. 3		Indic. 1	Indic. 2	Indic. 3	
EST-001	0.59	High	0.66	0.61	0.78		0.36	0.72	0.43	0.46
EST-002	0.74	High	0.63	0.62	0.77		0.90	0.91	0.78	0.59
EST-003	0.72	High	0.67	0.61	0.74		0.90	0.70	0.82	0.61
EST-004	0.68	High	0.66	0.63	0.82		0.69	0.63	0.65	0.62
EST-005	0.65	High	0.60	0.64	0.79		0.72	0.68	0.57	0.52
EST-006	0.60	High	0.55	0.71	0.75		0.46	0.67	0.50	0.49
EST-007	0.66	High	0.68	0.66	0.77		0.63	0.72	0.81	0.30
EST-008	0.54	High	0.60	0.75	0.65		0.53		0.59	0.15
EST-009	0.51	Intermediate	0.74	0.91	0.74				0.31	0.14
EST-010	0.68	High	0.65	0.66	0.78		0.65	0.92	0.53	0.52
EST-011	0.65	High	0.66	0.73	0.76		0.36	0.89	0.57	0.55
EST-012	0.67	High	0.60	0.69	0.76		0.73	0.74	0.74	0.40
EST-013	0.53	High	0.60	0.66	0.80			0.69	0.28	0.17
EST-014	0.71	Intermediate	0.64	0.69	0.73		0.65		1.00	0.55
EST-015	0.63	Intermediate	0.66	0.77	0.69		0.53		0.99	0.16
EST-016	0.63	Intermediate	0.62	0.70	0.79		0.47		0.80	0.43
FIN-001	0.45	Intermediate	0.58				0.38	0.24		0.33
FIN-002	0.53	Intermediate	0.66				0.36	0.42		0.42
FIN-003	0.44	Intermediate	0.59					0.49		0.38
FIN-004	0.44	Intermediate	0.40				0.49	0.47		0.49
FIN-005	0.47	Intermediate	0.69					0.16		0.34
FIN-006	0.60	Intermediate	0.62							0.57
FIN-007	0.72	Intermediate	0.61					1.00		0.65
FIN-008	0.54	Intermediate	0.67					0.35		0.44
FIN-009	0.68	Intermediate	0.75							0.61
FIN-010	0.54	Intermediate	0.57							0.51
FIN-011	0.58	Intermediate	0.54							0.61
FIN-012	0.44	Intermediate	0.45				0.56			0.30
FIN-013	0.57	Intermediate	0.62				0.62			0.43
FIN-014	0.58	Intermediate	0.62				0.61			0.47
GER-001	0.44	High	0.57							0.30

SAU	BQR	Confidence	Second integration level							
			First integration level Macrofauna				First integration level Macrovegatation			
			Fauna			Oxygen	Vegetation			Secchi
			Indic. 1	Indic. 2	Indic. 3		Indic. 1	Indic. 2	Indic. 3	
GER-002	0.51	High	0.61				0.52			0.30
GER-003	0.46	High	0.49				0.52			0.34
GER-004	0.44	High	0.52				0.37			0.37
GER-005	0.40	High	0.55				0.25			0.23
GER-006	0.38	High	0.41							0.35
GER-007	0.18	High	0.05				0.49			0.13
GER-008	0.40	High	0.43				0.54			0.20
GER-009	0.33	High	0.38				0.48			0.07
GER-010	0.44	High	0.63				0.20			0.28
GER-011	0.48	High	0.58				0.55			0.22
GER-012	0.40	High	0.51				0.40			0.17
GER-013	0.45	High	0.56				0.46			0.21
GER-014	0.21	High	0.19				0.41			0.05
GER-015	0.43	High	0.48				0.37			0.37
GER-016	0.11	High	0.00				0.20			0.25
GER-017	0.16	High	0.19				0.00			0.25
GER-018	0.43	High	0.55				0.34			0.26
GER-019	0.32	High	0.41							0.23
GER-020	0.26	High	0.23				0.30			0.27
GER-021	0.33	High	0.34				0.31			0.31
GER-022	0.48	High	0.51				0.50			0.42
GER-023	0.45	High	0.49							0.42
GER-024	0.53	High	0.53				0.67			0.41
GER-025	0.44	High	0.65				0.24			0.21
GER-026	0.40	High	0.70				0.10			0.12
GER-027	0.25	High	0.42				0.06			0.12
GER-028	0.49	High	0.55				0.44			0.41
GER-029	0.36	High	0.28							0.39
GER-030	0.50	High	0.52				0.51			0.48
GER-031	0.31	High	0.16							0.45
GER-032	0.43	High	0.52				0.35			0.31
GER-033	0.54	High	0.55				0.56			0.48
GER-034	0.50	High	0.55				0.48			0.40
GER-035	0.48	High	0.55							0.40
GER-036	0.45	High	0.50				0.41			0.37
GER-037	0.50	High	0.55				0.60			0.32
GER-038	0.51	High	0.48				0.60			0.46
GER-039	0.54	High	0.61							0.46
GER-040	0.40	High	0.50				0.18			0.43

SAU	BQR	Confidence	Second integration level							
			First integration level Macrofauna				First integration level Macrovegatation			
			Fauna			Oxygen	Vegetation			Secchi
			Indic. 1	Indic. 2	Indic. 3		Indic. 1	Indic. 2	Indic. 3	
GER-041	0.39	High	0.45				0.27			0.39
GER-042	0.25	Intermediate								0.25
GER-043	0.38	High	0.48				0.31			0.26
GER-044	0.10	Intermediate					0.00			0.21
GER-111	0.35	High	0.43				0.40			0.15
LAT-001	0.66	Intermediate					0.59	0.88		0.51
LAT-002	0.54	Intermediate								0.60
LAT-003	0.51	Intermediate	0.62							0.38
LAT-004	0.54	Intermediate	0.64				0.44			0.42
LAT-005	0.60	Intermediate	0.69							0.52
LIT-001	NA	NA								
LIT-002	0.66	High	0.66							0.48
LIT-003	0.26	High	0.19				0.32			0.40
LIT-004	0.39	High	0.39							
LIT-005	0.49	High	0.49							
LIT-006	0.52	High	0.69				0.36			
POL-001	0.28	Intermediate	0.21							0.35
POL-002	0.29	Intermediate	0.23							0.35
POL-003	0.30	Intermediate	0.12							0.48
POL-004	0.45	Intermediate	0.32				0.43			0.75
POL-005	0.46	Intermediate	0.38				0.52			0.56
POL-006	0.51	Intermediate	0.39							0.63
POL-007	0.30	Intermediate	0.35							0.25
POL-008	0.37	Intermediate	0.36							0.38
POL-009	0.29	Intermediate	0.30							0.27
POL-010	0.62	Intermediate	0.74							0.49
POL-011	0.54	Intermediate	0.31							0.77
POL-012	0.27	Intermediate	0.25							0.28
POL-013	0.26	Intermediate	0.17							0.35
POL-014	0.40	Intermediate	0.39							0.42
POL-015	0.47	Intermediate	0.43				0.56			0.47
POL-016	0.56	Intermediate	0.70							0.43
POL-017	0.56	Intermediate	0.60							0.51
POL-018	0.34	Intermediate	0.31							0.36
POL-019	0.26	Intermediate	0.15							0.36
RUS-001	NA	NA								
RUS-002	NA	NA								
RUS-003	NA	NA								
SWE-001	0.62	Intermediate	0.48			0.76	0.70			0.54

SAU	BQR	Confidence	Second integration level							
			First integration level Macrofauna				First integration level Macrovegatation			
			Fauna			Oxygen	Vegetation			Secchi
			Indic. 1	Indic. 2	Indic. 3		Indic. 1	Indic. 2	Indic. 3	
SWE-003	0.68	Intermediate	0.50			0.78	0.90			0.53
SWE-004	0.65	Intermediate	0.54			0.67	0.87			0.53
SWE-005	0.65	Intermediate	0.58			0.71	0.80			0.50
SWE-006	0.66	Intermediate	0.61			0.80	0.72			0.51
SWE-007	0.70	Intermediate	0.65			0.80	0.77			0.59
SWE-008	0.71	Intermediate	0.69			0.80	0.85			0.53
SWE-009	0.64	Intermediate	0.68			0.79	0.64			0.46
SWE-010	0.66	Intermediate	0.70			0.59	0.83			0.50
SWE-011	0.68	Intermediate	0.66			0.80	0.80			0.48
SWE-012	0.66	Intermediate	0.63			0.75	0.82			0.45
SWE-013	0.48	Intermediate	0.53			0.70	0.42			0.27
SWE-014	0.65	Intermediate	0.70			0.52	0.90			0.50
SWE-015	0.70	High	0.70				0.90			0.51
SWE-016	0.60	Intermediate	0.47			0.79	0.64			0.51
SWE-017	0.70	Intermediate	0.61			0.80	0.90			0.48
SWE-018	0.70	Intermediate	0.48			0.80	0.76			0.77
SWE-019	0.73	Intermediate	0.58			0.80	0.85			0.70
SWE-020	0.68	Intermediate	0.50			0.80				0.70
SWE-021	0.71	Intermediate	0.64			0.80				0.70
SWE-022	0.77	Intermediate	0.61			0.80				0.84
SWE-023	0.79	Intermediate	0.70			0.80				0.82
SWE-024	0.51	Intermediate	0.50							0.52
SWE-025	0.54	Intermediate	0.50			0.66				0.50

Annex 5. Assessment results for coastal pelagic habitats

Output table from BEAT 3.0 showing results from the integrated assessment of pelagic habitats in coastal areas. The first column gives the codes for each of the applied spatial assessment unit (SAU). 'BQR'= Biological quality ratio. 'Confidence' shows the confidence at integrated indicator level, not including any overall penalty (NA= not applicable due to no indicators assessed). Columns 4–5 show the BQR scores applied at the level of each indicator and assessment unit in BEAT 3.0, after normalisation.

SAU	BQR	Confidence	Chlorophyll-a	Biovolume
EST-001	0.57	High	0.56	0.58
EST-002	0.53	High	0.52	0.54
EST-003	0.70	High	0.62	0.77
EST-004	0.73	High	0.55	0.91
EST-005	0.50	High	0.51	0.50
EST-006	0.45	High	0.51	0.40
EST-007	0.54	Intermediate	0.52	0.55
EST-008	0.34	Intermediate	0.20	0.48
EST-009	0.54	Intermediate	0.56	0.51
EST-010	0.39	Intermediate	0.30	0.47
EST-011	0.70	Intermediate	0.50	0.91
EST-012	0.50	Intermediate	0.51	0.50
EST-013	0.51	Intermediate	0.51	
EST-014	0.57	Intermediate	0.59	0.55
EST-015	0.28	Intermediate	0.56	0.00
EST-016	0.57	Intermediate	0.59	0.55
FIN-001	0.49	High	0.59	
FIN-002	0.51	High	0.59	0.55
FIN-003	0.48	High	0.58	
FIN-004	0.51	High	0.56	0.59
FIN-005	0.50	High	0.57	0.55
FIN-006	0.56	High	0.56	
FIN-007	0.59	High	0.59	0.60
FIN-008	0.63	High	0.56	
FIN-009	0.63	High	0.58	0.59
FIN-010	0.59	High	0.57	
FIN-011	0.59	High	0.58	0.59
FIN-012	0.34	High	0.28	
FIN-013	0.48	High	0.57	
FIN-014	0.39	High		
GER-001	0.36	Intermediate	0.57	0.15
GER-002	0.49	Intermediate	0.57	0.41
GER-003	0.51	Intermediate	0.58	0.44
GER-004	0.61	Intermediate	0.67	0.55
GER-005	0.39	Intermediate	0.50	0.27
GER-006	0.59	Intermediate	0.60	0.57
GER-007	0.19	Intermediate	0.27	0.11
GER-008	0.28	Intermediate	0.36	0.21
GER-009	0.05	Intermediate	0.00	0.09
GER-010	0.67	Intermediate	0.75	0.59
GER-011	0.38	Intermediate	0.45	0.31
GER-012	0.34	Intermediate	0.39	0.28
GER-013	0.34	Intermediate	0.38	0.29

SAU	BQR	Confidence	Chlorophyll-a	Biovolume
GER-014	0.06	Intermediate	0.00	0.11
GER-015	0.50	Intermediate	0.59	0.41
GER-016	0.37	Intermediate	0.44	0.29
GER-017	0.34	Intermediate	0.38	0.29
GER-018	0.48	Intermediate	0.54	0.42
GER-019	0.38	Intermediate	0.44	0.31
GER-020	0.38	Intermediate	0.42	0.34
GER-021	0.51	Intermediate	0.51	
GER-022	0.59	Intermediate	0.59	
GER-023	0.59	Intermediate	0.59	
GER-024	0.60	Intermediate	0.60	
GER-025	0.22	Intermediate	0.22	
GER-026	0.00	Intermediate	0.00	
GER-027	0.00	Intermediate	0.00	
GER-028	0.60	Intermediate	0.60	
GER-029	0.59	Intermediate	0.59	
GER-030	0.67	Intermediate	0.67	
GER-031	0.59	Intermediate	0.59	
GER-032	0.47	Intermediate	0.47	
GER-033	0.67	Intermediate	0.67	
GER-034	0.67	Intermediate	0.67	
GER-035	0.67	Intermediate	0.67	
GER-036	1.00	Intermediate	1.00	
GER-037	1.00	Intermediate	1.00	
GER-038	0.65	Intermediate	0.65	
GER-039	0.67	Intermediate	0.67	
GER-040	0.60	Intermediate	0.60	
GER-041	0.59	Intermediate	0.59	
GER-042	0.42	Intermediate	0.42	
GER-043	0.36	Intermediate	0.36	
GER-044	0.29	Intermediate	0.29	
GER-111	0.12	Intermediate	0.12	0.13
LAT-001	0.42	Intermediate	0.41	0.42
LAT-002	0.71	Intermediate	0.41	1.00
LAT-003	0.32	Intermediate	0.38	0.26
LAT-004	0.50	Intermediate	0.38	0.62
LAT-005	0.31	Intermediate	0.38	0.24
LIT-001	0.38	High	0.38	
LIT-002	0.51	High	0.51	
LIT-003	0.29	High	0.29	
LIT-004	0.63	High	0.62	
LIT-005	0.66	High	0.66	
LIT-006	0.41	High	0.41	
POL-001	0.45	High	0.45	
POL-002	0.32	Intermediate	0.32	
POL-003	0.56	Intermediate	0.38	

SAU	BQR	Confidence	Chlorophyll-a	Biovolume
POL-004	0.43	Intermediate	0.13	
POL-005	0.67	Intermediate	0.61	
POL-006	0.64	Intermediate	0.55	
POL-007	0.05	Intermediate	0.05	
POL-008	0.57	Intermediate	0.41	
POL-009	0.52	Intermediate	0.52	
POL-010	0.54	Intermediate	0.35	
POL-011	0.45	Intermediate	0.17	
POL-012	0.37	Intermediate	0.00[26]	
POL-013	0.00	High	0.00	
POL-014	0.00	High	0.00	
POL-015	0.02	High	0.02	
POL-016	0.00	High	0.00	
POL-017	0.43	Intermediate	0.13	
POL-018	0.19	High	0.19	
POL-019	0.35	High	0.35	
RUS-001	0.39	High		
RUS-002	NA	NA		
RUS-003	NA	NA		
SWE-001	0.67	Intermediate	0.67	
SWE-003	0.87	Intermediate	0.86	0.88
SWE-004	0.79	Intermediate	0.70	0.87
SWE-005	0.65	Intermediate	0.65	
SWE-006	0.55	Intermediate	0.55	
SWE-007	0.52	Intermediate	0.63	
SWE-008	0.52	Intermediate	0.62	
SWE-009	0.39	Intermediate	0.39	
SWE-010	0.44	Intermediate	0.46	
SWE-011	0.46	Intermediate	0.40	0.52
SWE-012	0.45	Intermediate	0.50	0.44
SWE-013	0.36	Intermediate	0.22	0.43
SWE-014	0.44	Intermediate	0.48	0.43
SWE-015	0.44	Intermediate	0.46	0.43
SWE-016	0.64	High	0.48	0.73
SWE-017	0.60	High	0.50	0.60
SWE-018	0.62	High	0.58	0.59
SWE-019	0.70	High	0.69	
SWE-020	0.58	Intermediate	0.49	0.68
SWE-021	0.47	Intermediate	0.47	
SWE-022	0.66	High	0.61	0.76
SWE-023	0.58	High	0.54	
SWE-024	0.56	Intermediate	0.37	0.75
SWE-025	0.32	Intermediate	0.32	

[26] Value 0 means that the status of the observed value was above the limit for “worst” status