State of the Baltic Sea
Third HELCOM holistic assessment 2016–2021

Biodiversity
8. Foodweb

8. Results for the foodweb assessment

Assessment results in short

- Foodwebs are fundamental for ecosystem functioning and the delivery of ecosystem services, which highlights the relevance of foodweb status assessments.
- Unfortunately, the currently available data and knowledge can only support qualitative but not systematic quantitative assessments of Baltic Sea foodwebs. Achieving systematic, quantitative assessments of foodweb status should be a priority for future work in HELCOM.
- Available evidence suggests that major changes in the abundance and biomass of species, driven by human pressures, have been associated with corresponding changes in Baltic Sea foodwebs, and several examples of foodweb disruptions and putative tipping points give cause for concern.
- Foodweb knowledge is essential for informing sustainable and effective management of pressures and biodiversity components and should be more widely applied.

8.1. Introduction to foodwebs

Foodwebs represent feeding relationships within species communities (Hui 2012). Through the lens of foodwebs, aquatic species can be broadly represented by primary producers, which make energy and nutrients available to the ecosystem, primary consumers, which feed on the primary producers, and different levels of predators feeding on lower trophic levels in the foodweb. Species that feed on or utilize dead organic material contribute to the recycling of energy and nutrients, and some species function as parasites (Belgrano *et al.* 2019, Hui 2012, Thompson *et al.* 2012).

In contrast to this simplified description, however, natural foodwebs are often highly complex. A large number of links exist between species, reflecting the variety of feeding relationships. Further, many species migrate between different systems, depending on the season, or shift their preferred feeding type or habitat type during the course of their life cycle. Dividing the main groups into trophic guilds based on, for example, the habitat types, such as benthic or pelagic, and their principal feeding type such as grazing or filter-feeding is a way of simplifying the system, thus facilitating temporal comparisons within a foodweb and evaluations of foodweb status (Luczkovich *et al.* 2002, Thompson *et al.* 2020).

Knowledge of foodwebs is fundamental for understanding ecosystem functioning and its effects on the delivery of ecosystem services (Eero *et al.* 2021). Further, foodweb processes mediate many if not most of the existing pressures in the Baltic Sea, such as effects of eutrophication via bottom-up foodweb controls and contamination via bioaccumulation (Eero *et al.* 2021). Several changes of concern in Baltic Sea foodwebs have been identified over the past decades, which are also described in the current chapter.

Under the EU Marine Strategy Framework and the criteria under its Descriptor 4, foodweb status is primarily evaluated based on the diversity within and balance of abundance between trophic guilds, for example by addressing changes in biomass or species composition within different feeding guilds, and the balance of total abundance between trophic guilds (European Commission 2022). For a deeper and more holistic understanding, however, evaluating the status of foodwebs also requires considering trophic interactions and assess how foodwebs contribute to the performance of the ecosystem. Example of aspects that reflect foodweb functioning are productivity, energy flow and transfer efficiency, as well as ecosystem resilience and stability over time (Korpinen *et al.* 2022).

However, regionally agreed indicators or methods for evaluating the status of foodwebs are still not available for the Baltic Sea. Although many scientific publications provide relevant insights, their outputs are not aligned in a systematic way, and they do not have the coordinated spatial or temporal scope needed to support a comprehensive evaluation. Developing status assessments of foodweb is also challenging when it comes to defining boundaries for good status, due to the interconnectedness of different foodwebs within the same ecosystem, and possible conflicting perspectives on desired ecosystem properties. Given these challenges, the current evaluation of foodwebs is developed using a combined qualitative and quantitative approach, which aims to synthesize available information and support a way forward for future assessments. An evaluation based on selected data and methods is presented in Section 8.2, and this is followed by a synthesis of results from relevant scientific studies focusing on links between the status of foodwebs and key pressures in the Baltic Sea (Section 8.3). The last two sections give perspectives on the applied approach and suggest possible ways towards future, more quantitative assessments.

8.2. Summary of evaluation results for foodwebs

The quantitative evaluation of foodweb status in the Baltic Sea is at present not possible due to the lack of regionally agreed indicators. However, many research studies show that Baltic Sea foodwebs have changed over the past decades (Section 8.4); Major human-induced changes in the abundance and biomass of important species have been associated with corresponding changes in Baltic Sea foodwebs, including disruptions and the passing of tipping points. Changes that give cause for concern have been observed in both open sea and coastal systems.

Foodwebs experienced particularly strong changes during a period of environmental deterioration up to the early 1990s (Box 8.5). Eutrophication has been identified as a key driver of the changes in productivity and species composition of plankton (Section 8.4.1), while high fishing pressure strongly contributed to declines in predatory and some forage fish stocks, which also induced cascading effects throughout the foodweb (Section 8.4.2). These pressures have later stabilized to some extent as a result of improved management, and in some cases they have slightly decreased. However, impacts from eutrophication and high fishing pressure on Baltic Sea foodwebs are still evident. In addition, other prevailing pressures, such as non-indigenous species and contaminants have been associated with impacts on foodwebs (Sections 8.4.3-4). However, the extent of change varies among Baltic sub-basins and conclusions could be region-specific. In combination with climate-related changes, such as warming and increasing oxygen deficiency, continuing human pressures have recently been associated with worrying changes in the relative abundance of trophic guilds in some sub-basins (Section 8.4.5).

Current HELCOM indicators of other assessment grounds may to some extent indicate the status of key foodweb components, although they do not address changes in foodweb functionality, nor MSFD criteria under D4 (Section 8.3.1). Evaluation of selected biodiversity core indicators, potentially applicable to addressing foodweb status, indicates variable states across sub-basins for pelagic primary producers, zooplankton and coastal fish, although deteriorated states predominate (Table 8.1). Apex predators do not achieve good status, based on core indicators on the nutritional and reproductive statuses of grey seal that are evaluated at the scale of the whole Baltic Sea (See also Section 7.2).

Regional case studies can further illustrate the occurrence and nature of foodweb-related changes. A first such example is provided by the analysis of offshore foodweb dynamics in the Bothnian Sea over the last 30 years. This integrated trend analysis reveals shifts in the relative abundance of trophic guilds with breaking points in 2005 and 2016, coupled with decreases in herring biomass and changes in seal abundance (Section 8.3.2). The shifts were associated with changes in fishing mortality, nutrient availability and benthic species composition. Although overall abundances of benthic, zooplankton and phytoplankton trophic guilds were relatively stable over time, species composition shifted within all guilds. As another example, an ecosystem model of the Western Baltic Sea indicates that the collapse and lack of recovery of both western Baltic cod (*Gadus morhua*) and western Baltic spring-spawning herring (*Clupea harengus*) has had negative consequences for overall biodiversity, the integrity of trophic chains, carbon sequestration and foodweb resilience, during the ongoing assessment period (Section 8.3.3).

Taken together, available evidence from existing core indicators, the case studies and many scientific works highlights that maintaining the resilience and regulatory capacities of foodwebs requires management that accounts for multiple pressures and is conservative (Section 8.6.1). Examples include measures to adapt fish extraction quotas to ecological preconditions, and enhanced protection of biodiversity and habitats. Vice versa, considering the strong role of foodwebs in mediating prevalent pressures in the Baltic Sea, improved foodweb understanding has strong potential to inform and strengthen the management of pressures and biodiversity components in the Baltic Sea (Section 8.6.2).

To achieve future quantitative evaluations of foodweb status, improved and harmonised assessment methods are needed (Section 8.6.3). For example, the EU Marine Strategy Framework Directive requests assessments based on guild abundances or biomasses, and there is strong potential to use existing HELCOM data more effectively to address these features. However, data are currently not available for all relevant guilds, sub-basins or time-periods. Further, existing data do not support the evaluation of crucial functional properties of foodwebs, such as feeding interactions or energy flows. Future development of HELCOM foodweb assessments should aim to (1) use existing data more systematically, (2) close data gaps in existing assessment frameworks and (3) incorporate information on functional foodweb properties more explicitly. The latter could be supported for example via the collection of data on feeding interactions using dietary tracers, classical stomach content analysis or molecular approaches, and the integration of available information in ecosystem models.

8.3. Details on the assessment: Evaluation of changes over time in Baltic Sea foodwebs

The aim of this section is to provide the best possible qualitative evaluation of foodwebs using existing evidence. Aspects considered are 1) to what extent HELCOM indicators assessed under other themes also reflect changes in foodwebs, as well as how 2) integrated analyses of environmental monitoring data and 3) indices derived from ecosystem models could support the further development of foodweb assessments. The two latter aspects are explored by case studies for the Bothnian Sea and the Western Baltic Sea, respectively, to demonstrate methods that could support the future development of HELCOM foodweb indicators. More information on the assessment methodology and approach can be found in in Annex 1 (Methodology manuals).

8.3.1 Evaluation of core indicators of potential relevance for foodwebs

Table 8.1 summarizes evaluation results for selected HELCOM indicators developed under other assessment grounds that are also potentially relevant for indicating foodweb status. The selection identifies indicators that could directly reflect changes in foodweb functions or a clear foodweb-related mechanism (Box 8.1).

The overall results imply a degraded foodweb status in the Baltic Sea, based on biodiversity core indicators on primary producers, zooplankton, coastal fish and grey seal (*Halichoerus grypus*) during the current assessment period. Athough the evaluation results vary to some extent across the Baltic Sea, good status is only seen in a few assessment units and for few elements, such as pelagic habitats (phytoplankton and zooplankton, Chapter 3), and fish (Chapter 5).

Even within this limited selection, indicator evaluations are lacking for several sub-basins, further emphasizing the need to develop HELCOM indicators, and extend methods and monitoring to currently unassessed sub-basins (see section 5.3).

Box 8.1. HELCOM indicators potentially relevant for addressing the status of foodwebs

Most existing HELCOM biodiversity indicators reflect the status of structural components of the foodweb. There is a gap for indicators reflecting changes in foodweb functions and processes, such as productivity and energy transfer, or changes in diversity within trophic guilds or in the balance between trophic guilds, as requested in the MSFD (European Commission 2022).

However, several HELCOM biodiversity core indicators have been suggested to infer information on the status of foodwebs (Korpinen *et al.* 2022). Existing HELCOM indicators that at least partly address key foodweb aspects (Tam *et al.* 2017, ICES 2021) are mainly related to pelagic habitats, fish and marine mammals, whereas there is a lack of benthic and water bird indicators relevant for foodweb assessment. Indicators on fish are restricted to coastal areas, leaving out important foodweb components in open sea areas of the Baltic Sea such as herring (*Clupea harengus*), sprat (*Sprattus sprattus*) and cod (*Gadus morhua*), for which information is obtained from ICES (Chapter 5).

In the current evaluation, several HELCOM indicators reflecting changes in biomass or abundance of species groups (See Table 2.1 in Chapters 2) were not included as they do not represent full trophic guilds in an adequate way, as requested in the MSFD (European Commission 2022). Nevertheless, the abundance and biomass data of species groups supporting those indicators provide valuable information for future work to develop quantitative foodweb indicators, which could be used in future assessments (See section 8.6.3).

Table 8.1. Evaluation results for HELCOM biodiversity indicators that address foodweb aspects, by HELCOM sub-basins. Green cells indicate that the indicator achieves its threshold value, red cells that the threshold value is not achieved. Yellow cells indicate that the threshold value is achieved partly, either in coastal or open sea area, but not in the assessment unit as a whole. NA=not assessed. The spatial coverage of the sub-basins may vary, details are given in the Chapters 3, 5 and 7, for pelagic, fish and marine mammals assessment, respectively.

Indicator	Trophic guild	Criterion	Kattegat	Great Belt	The Sound	Kiel Bay	Bay of Mecklenburg	Arkona Basin	Bornholm Basin	Gdansk Basin	Eastern Gotland Basin	Western Gotland Basin	Gulf of Riga	Northern Baltic Proper	Gulf of Finland	Åland Sea	Bothnian Sea	The Quark	Bothnian Bay
Seasonal succession of functional phytoplankton groups	Primary producers - phytoplankton	D4C1, D4C2	**	NA	NA			** +	**		-	NA	+			*	**	*	
Diatom/ Dinoflagellate index *(test indicator)*	Primary producers - phytoplankton	D4C2	NA	NA	NA	**	**	NA	NA	NA	** +	NA	NA	NA	NA	NA	NA	NA	NA
Cyanobacterial bloom index	Primary producers - phytoplankton	D4C4	NA	NA	NA	NA	**	**	**	**	**	**	**	**	**	**	**	NA	NA
Zooplankton Mean Size and Total Stock	Secondary producers - Zooplankton	D4C1, D4C2, D4C3	NA	NA	NA	NA	NA	NA	**	**	**	**	**	**	**	** +	**		**
Abundance of coastal fish key functional groups	Planktivores/ Sub- apex predators - Fish	D4C2	NA	NA	NA	NA	NA	NA	*	*	*	*	*	*	*	*	* +	*	*
Nutritional status of seals	Apex predators - Mammals	D4C4	NA																
Reproduction status of seals	Apex predators - Mammals	D4C4																	

*= coastal areas only, **= open sea areas only, +/- = improved/ worsend from HOLAS II

Selected indicators and their relation to foodweb aspects

Phytoplankton are the main primary producers in marine ecosystems and constitute the foundation of marine foodwebs. Phytoplankton are only assessed for a part of the HELCOM region. The core indicator 'Seasonal succession of dominating phytoplankton groups' evaluates changes in the biomass of dominating phytoplankton groups during the seasonal cycle (Section 3.2.2) and may relate to MSFD criterion D4C1 Diversity within guilds for the guild of primary producers. Since the amounts and ratios of available nutrients change with alterations in species composition, the indicator may provide insight on quality of food for higher trophic levels. The test indicator 'Diatom -Dinoflagellate ratio' (Section 3.2.2) can give insights on energy pathways, with dinoflagellates mainly fuelling the pelagic system while the larger-sized diatoms enhance energy transport to the benthic system through higher sedimentation (Wasmund *et al.* 2017). The core indicator 'Cyanobacterial bloom index' (Section 3.2.2) reflects symptoms of eutrophication and potential changes in the phytoplankton community, as cyanobacteria commonly dominate during blooms. Extensive cyanobacterial blooms have negative impacts on the biodiversity and functioning of marine ecosystems (Suikkanen *et al.* 2005, Vahtera *et al.* 2007).

Zooplankton function as important mediators of energy in the foodweb, as they are a link between pelagic primary producers and larger species. The core indicator 'Zooplankton mean size and total stock' (Section 3.2.2) can give information about the functioning of the link between phytoplankton and fish. Higher abundances of large sized individuals indicate good foodweb functioning, as this provides high grazing potential on phytoplankton and offers favourable fish feeding conditions (Gorokhova *et al.* 2016). Zooplankton status is evaluated for the central and northern Baltic Sea. In the areas where the zooplankton indicator did not achieve good status, it was the size component that failed, indicating adverse bottom-up conditions in the foodweb, apart from in the Bothnian Bay.

Fish are central components of many foodwebs, where different fish species and trophic guilds contribute to different functions and ecosystem services. Fish is an important food resource for humans but also for other species in the ecosystem. Many fish species also have important regulatory functions through their feeding. Viable populations of top piscivores (fish that mainly feed on other fish) generally indicate a balanced foodweb structure, whereas increases in mesopredatory fish (carnivorous mid trophic-level species that hold the dual role of being both prey and predator, Manenti *et al.* 2020) could reflect more deteriorated conditions. The abundances of key predator species such as pike (*Esox lucius*) and perch (*Perca fluviatilis*) were assessed in the core indicator 'Abundance of key coastal fish species' whereas the core indicator 'Abundance of coastal fish key functional groups' in the current assessment addressed cyprinids and mesopredatory fish. Fish are affected by a variety of pressures, such as fishing, eutrophication, and habitat deterioration. In addition, climate changes influence for example their reproduction and growth rates.

Marine mammals are top predators in the marine ecosystem being exposed to changes both in the environment and variations in the foodweb. For grey seals, the core indicators 'Nutritional status of seals' and 'Reproductive status of seals' both signal changes in food supply. The reproduction rate of grey seal has been shown to indicate changes in the Baltic Sea foodweb spanning over three trophic levels (zooplankton biomass, clupeid fish quality and grey seal reproduction rate, Kauhala *et al.* 2017). Both indicators are assessed at the scale of the whole Baltic Sea, and none of them achieves their threshold value. Long-term trends show improved reproduction rates, whereas nutritional status is decreasing.

Table 8.1 does not include sea birds or benthic habitats, as it is limited to indicators that can be directly linked to changes in foodweb processes, or to a clear foodweb related mechanism (Box 8.2). For benthic fauna, it should, however, be noted that information on reproductive status of amphipods is available in the supplementary indicator 'Reproductive disorders: malformed embryos of amphipods'. This supplementary indicator implies good status in the Quark and Western Gotland Basin, but fails the threshold value in the Bothnian Sea, Northern Baltic Proper and the Gulf of Finland.

Birds respond strongly to food availability and can potentially be efficient indicators of changes in different prey compartments, regarding both changes in abundance and changes in prey composition. Locations with high bird abundance can often reflect ecological key areas where energy flow through marine foodwebs is maximized. For sea birds (marine birds including

Box 8.2. Understanding of trophic cascades is needed to link changes in structure to foodweb status

Changes in the abundance of breeding common guillemots are connected to fisheries on cod (*Gadus morhua*) and sprat (*Sprattus sprattus*) in the Baltic Sea, but the effects differ depending on the fishery management strategy. Studies have shown effects of changes in abundance and biomass of sprat, and of lower bycatch rates following a ban of salmon drift nets, on the breeding success (Österblom *et al.* 2006) and survival (Kadin *et al.* 2019) of common guillemots (*Uria aalge*). Large-scale and long-term ecosystem changes resulted in a decrease of cod, which is the main fish predator of sprat. As the sprat stock subsequently increased, leading to lower energy content of fish, the body mass of guillemot chicks at fledging decreased. Their fledging body mass recovered later as the sprat stock diminished, which brought about corresponding increases in sprat weight-at-age and energy content (Österblom *et al.* 2006). Extraordinary high breeding success of guillemots was also shown in the indicator ' breeding success of waterbirds' (HELCOM 2023u). One of the first quantitative assessments of six management alternatives in the Baltic Sea was based on direct coupling of the demographics of the birds and food-web models. The results showed that negative impacts on the survival and population growth rates of Baltic Sea guillemots were likely if the scenarios mirrored successful implementation of current management initiatives, that is, precautionary fishing to restore the cod stock and reductions of nutrient inputs to combat eutrophication, is successfully implemented. As follows from this case study, a decline of forage fish consumers such as seabirds is not necessarily a sign of an ecosystem in poor health, as it may signal development toward an oligotrophic ecosystem with abundant predatory fish (Kadin *et al.* 2019). Such effects of trophic cascades may similarly occur for the other guilds in a food web and thus need to be considered when evaluating foodweb status.

coastal water birds) the HELCOM water bird indicators address changes in species abundances within species groups defined in MSFD D1, such as pelagic-feeding or benthic-feeding birds, for example. In the current status assessment of seabirds (see Chapter 6) stable or increasing trends in pelagic feeders (represented by piscivorous birds) could reflect increasing prey fish abundance, while decreasing trends of benthic feeders could reflect decreases in the abundance and body condition of benthic fauna. While bird abundance can be linked to changes in prey abundances, it does not necessarily indicate a positive or negative response with respect to foodweb status, or explain the ultimate reason for the changes, for which an understanding of the full foodweb dynamics is needed (Box 8.2).

The HELCOM indicators that can reflect foodweb aspects do not provide a complete picture, however, and do not cover several aspects requested for assessment in relation to the MSFD (European Commission 2022). For a more representative evaluation of Baltic Sea foodweb status, including trophic cascade effects, it is necessary to cover a range of relevant trophic guilds and sub-guilds, and to identify fluxes between them for resolving foodweb functioning.

8.3.2 Examples on integrated trend analysis of foodwebs in selected sub-basins: Bothnian Sea

Integrated analyses of trends in monitoring data could support an evaluation of foodweb status by addressing changes in the relative abundance/biomass of species within and across functional guilds (Box 8.3), as tested here in a case study of the Bothnian Sea, developed specifically for HOLAS III.

Box 8.3 The ITA method in short

Integrated trend analysis can support foodweb assessments, as different measures of abundance can be compared directly between and within trophic guilds, and temporal shifts can be identified. To compare relative abundances between and within trophic guilds (MSFD criteria D4C1 and D4C2, respectively, ref to MSFD) in the Bothnian Sea case study, constrained principal components analyses (PCO) with Chord distances were used. These were combined with chronological clustering and minimum-maximum factor (MAFA) analysis to identify shifts in community composition over time and the underlying common patterns in the data. The integrated trend analysis can address several elements of a marine foodweb simultaneously, and relate the trends to a selection of drivers. Here, drivers encompassed explanatory variables related to changes in nutrient enrichment, climate change, and herring fishing mortality. Main uncertainties lie in that only linear relationships are examined and the lack of long-term data available for some pressures. When using correlative methods, correlation does not always imply causation and interpretation of the results should reflect this. A method description is provided in Annex 1.

The Bothnian Sea was chosen as the focus area as there are long data time series (1979-2021) available for many open sea taxa. Changes in relative abundances between and within trophic guilds, in alignment with MSFD criteria D4C1 and D4C2, were addressed to compare foodweb configurations for primary producers (phytoplankton), secondary producers (zooplankton), deposit feeders (benthic animals), planktivores (herring) and apex predators (grey seal). Comparing relative abundances of all trophic guilds show how foodweb configurations for the offshore area of the Bothnian Sea have changed over the last 30 years (Figure 8.1). An initial shift occurred in 2005 towards a foodweb with lower herring biomass and increasing numbers of seals and a high biomass of benthic deposit feeders. Zooplankton biomass had also been increasing up to 2004 but levelled off at this point. Within the current assessment period, a second shift occurred in 2016, which was characterised by steep declines in herring biomass and a decline in seal abundance.

The shift in 2005 coincided with increased herring mortality and increasing concentrations of phosphorus at sea (Figure 8.1a). The increase in phosphorus was not attributed to inflows from land into the Bothnian Sea, which have been decreasing or remained stable over the last 20 years (Räike *et al.* 2020). Total plankton biomasses increased until 1999 for phytoplankton and 2004 for zooplankton and have been relatively constant over the last 17-21 years in comparison to seals and herring (Figure 8.1a). The results can be compared to the HELCOM zooplankton indicator, which showed a significant increase in zooplankton biomass in the Bothnian Sea up to 2004-2005, after which it stabilized (Section 3.2.2 in Chapter 3). Care should be taken interpreting these results, as only linear relationships are investigated, and the explanatory variables account for 44% of the total variation in Figure 8.1a. Further analysis has revealed this is due to some of the relationships between variables being non-linear, and drivers being differently important for the trophic guilds.

Although the total biomass of lower trophic levels appeared relatively stable over the last 17-21 years, major shifts occurred for the phytoplankton and benthic trophic guilds. Changes within trophic guilds (D4C1) were compared over the same time period and drivers, with respect to species composition and relative abundances. Example results are shown for phytoplankton and benthic species. For phytoplankton (Figure 8.1b), a shift occurred in 1999 when the relative abundance of cyanobacteria and diatoms began to increase while dinophytes and euglenoids decreased. The changes were associated with decreasing salinity and increasing phosphorus concentrations. For benthic species (Figure 8.1c), a major shift in community composition occurred with the introduction of the invasive species complex *Marenzellaria* spp., which was first recorded in 2004 and rapidly increased to a peak in 2010, after which it declined. A decline in *Monoporeia* spp. had begun before the increase of *Marenzellaria*, potentially due to changes in primary production and foodweb efficiency (Wiklund *et al.* 2008), but it is notable that salinity and oxygen had also declined at this time. Other studies that have reported changes over time in aquatic communities in support of food web assessments in the Bothnian Sea include Lehtinen *et al.* (2016), who evaluated long-term changes in functional traits of phytoplankton taxa, and Kuosa *et al.* (2017), observing changes in the food web structure in relation to changes in climate, hydrography and nutrients.

State of the Baltic Sea
Third HELCOM holistic assessment 2016–2021

Biodiversity
8. Foodweb

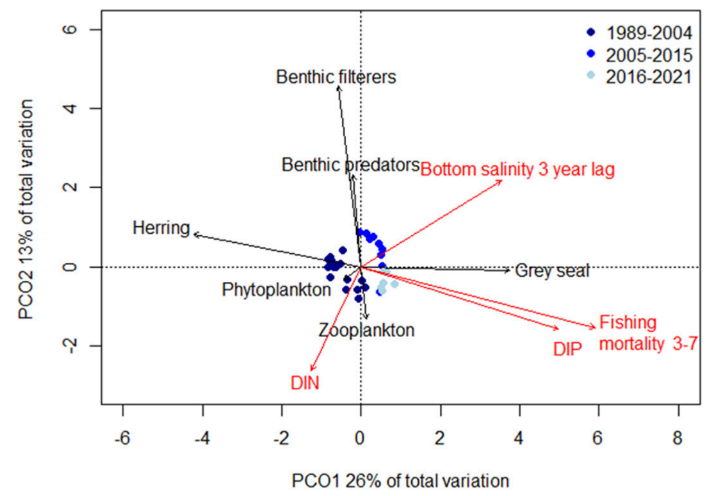


Figure 8.1a. Overarching results from the integrated trend analyses for the Bothnian Sea, using a constrained principal components ordination (PCO) with ln+1 and normalized data. Chronological clusters of years are represented by points of different colours with the year periods shown in the legend, with shifts present at 2004–2005 and 2015–2016. The biplot for first two PCO axes is shown, with the direction of the arrows representing linear relationships between the variables and the length of arrows representing the strength of the relationship. Black arrows indicate biotic variables and red arrows indicate variables classified as drivers (explanatory variables). Only explanatory variables remaining after model simplification are shown; dissolved inorganic phosphorus (DIP) and nitrogen (DIN), bottom salinity with a 3-year lag, and herring fishing mortality. For example, fishing mortality on 3 to 7 year-old herring is negatively correlated with herring along PCO axis 1, which explains 26% of the variation of all the variables. Along PCO axis 2, benthic filters and benthic predators show a negative relationship with dissolved inorganic nitrogen (DIN), although only 13% of the variation is explained by this axis.

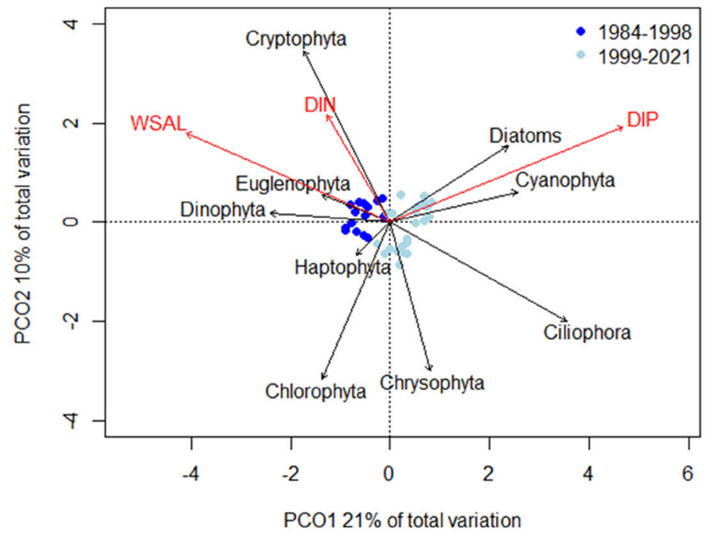


Figure 8.1b Constrained PCO showing variation over time in the primary producer guild, for the Bothnian Sea ITA case study. Chronological clusters of years are represented by points of different colours with the year periods shown in the legend, with a shift at 1998–1999. The biplot for first two PCO axes is shown, with the direction of the arrows representing linear relationships between the variables and the length of arrows representing the strength of the relationship. Black arrows indicate biotic variables and red arrows indicate variables classified as drivers (explanatory variables). Only significant explanatory variables are shown, with dissolved inorganic nitrogen (DIN) and phosphorus (DIP), and winter salinity (WSAL) explaining 33% of the variation in the diagram. Diatoms and Cyanophytes are correlated with DIP and have increased over time, being close to the samples from later years (1999–2021).

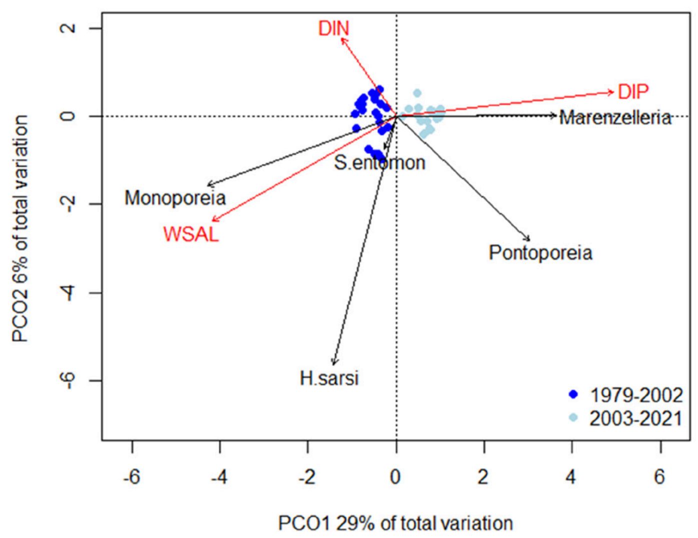


Figure 8.1c Constrained ordination for all benthic taxa included in the Bothnian Sea ITA case study. Three chronological clusters of years are represented by points of different colours with the year periods shown in the legend, with a shift at 2002–2003. The biplot for first two PCO axes is shown, with the direction of the arrows representing linear relationships between the variables and the length of arrows representing the strength of the relationship. Black arrows indicate biotic variables and red arrows indicate variables classified as drivers (explanatory variables). Significant explanatory variables were DIP, DIN and winter salinity, which accounted for 38% of the variation of the benthic taxa. *Monoporeia* was related to salinity and *Marenzelleria* associated with more recent samples (2003 onwards) and the increase in DIP concentration.

8.3.3 Example on foodweb assessment based on a Western Baltic Sea ecosystem model

Indices derived from ecosystem models may signal changes in functional properties of the foodweb. Hence, they could also detect early signs of stress, prior to the onset of any major events such as the collapse of species and the occurrence of regime shifts (Longo *et al.* 2015). The use of an Ecopath with Ecosim (EwE) model to evaluate changes in foodwebs was exemplified for the Western Baltic Sea (Box 8.4). Outcomes show a decline of fish biomass, which has consequences at ecosystem level, as reflected in reduced biodiversity. Decline of cod and herring resulted in a diminished range of pathways available for energy circulation, by decreasing the weight of the pelagic grazing chain and lowering foodweb resilience.

The Ecopath with Ecosim model of the Western Baltic Sea (Scotti *et al.* 2022a) was applied to calculate the trends displayed by whole-ecosystem indices during the period 1994-2021 (Figure 8.4). The model area was delineated by ICES subdivisions 22 and 24, which is homogeneous and distinctive from neighboring areas in ecological characteristics. Further, variations in the potential for carbon sequestration due to main fish groups (i.e., western Baltic cod, western Baltic spring-spawning herring, sprat and flatfish) and top consumers such as harbor porpoise (*Phocoena phocoena*) and seals were quantified by accounting for the trends in the amount of feces egested, as well as natural mortality towards the sea bottom (Bianchi *et al.* 2021).

Box 8.4 The ecosystem model-based indicator approach in short

The use of ecosystem models to compute whole-system indicators responding to management requirements for environmental and fisheries aspects has been subject to various research (Lassen *et al.* 2013, Raoux *et al.* 2019, Safi *et al.* 2019). These contributions add to the search of ideal foodweb indicators, based on their sensitivity to disturbance and capability of detecting responses to multiple stressors (Tam *et al.* 2017, Halouani *et al.* 2019).

The Ecopath with Ecosim model is composed of two modules. In the presented model for the Western Baltic Sea (Figure 8.2), the Ecopath module provides a static snapshot of carbon exchanges between compartments and fisheries in 1994, which is the first year for which reliable data on main fish stocks and other trophic groups are available (Figure 8.3). The Ecopath model is the starting point to perform dynamic simulations through the second component, Ecosim. The quality of simulations was evaluated based on the capacity of the model to reproduce real stock biomass and catch trends, assessed here for main fish groups over the period 1994-2019 (see Annex 1). After model validation, Ecosim was then applied to calculate whole-ecosystem indices, with emphasis on those capable of accounting for changes in the structure of carbon circulation, and thereby indicative of ecosystem functionining (Figure 8.4). A time series of static trophic networks (Ulanowicz 2004) was extracted using Ecosim, by generating 25 mass-balanced snapshots of carbon circulation in the Western Baltic Sea ecosystem through simulations and using these for calculating network analysis indicators (Safi *et al.* 2019).

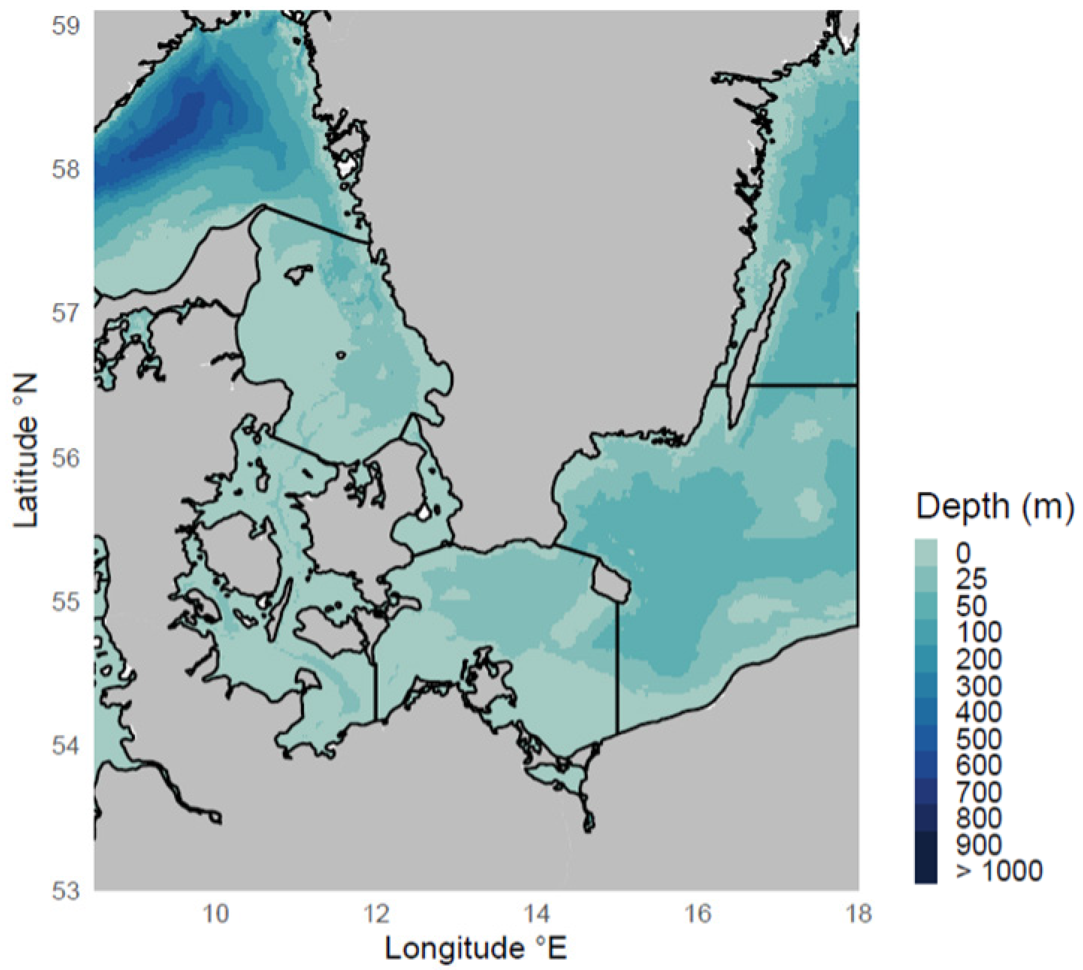


Figure 8.2. Study site is the Western Baltic Sea, which corresponds to ICES subdivisions 22 and 24. Such a choice ensures data availability, homogeneous ecological conditions, and correspondence with management units. Figure modified from Scotti *et al.* (2022a).

The foodweb derived indices may reflect variations at the level of the entire ecosystem, beyond the changes characterizing species or trophic guilds. Figure 8.4 illustrates the diversity of indicators obtained from an ecosystem model, and how models can be used to evaluate changes in for example foodweb functioning, environmental status, and impacts on blue carbon. In the here applied case study, the Shannon's index of diversity (H) shows a substantial decrease in the evenness of biomass distribution from 1994 to the early 2000s, after which the index attains a stationary state with lowest biodiversity in 2009 (Figure 8.4a). For the mean trophic level of catches (MTLC), a monotonic decline is found (Figure 8.4b). The Finn cycling index (FCI) quantifies the fraction of recycling out of the total amount of carbon circulating in the ecosystem. This index displays relatively high values compared to those of other marine systems (Pizzol *et al.* 2013) and increases to reach its maximum in 2010 (Figure 8.4c). The FCI shows the relative importance of benthic food chains in the Western Baltic Sea, with their relevance most likely raised by two factors: (1) increasing relevance of benthic invertebrates in the diet of cod, following the decline of herring stock biomass, and (2) the increase of flatfish biomass, favored by the excessive harvest of cod (Scotti *et al.* 2022a). Overall, a reduced internal pathway redundancy (R) at disposal of carbon circulation reflects diminished foodweb resilience (Figure 8.4e). The decreased resilience agrees with the increase of relative constraints to carbon circulation (A/DC), attributed to a lower importance of the pelagic food chains following declines in herring, cod and harbor porpoise (Figure 8.4d). Finally, smaller size of main commercial fish stocks and consequent decline of top consumers reduces the potential for carbon sequestration (i.e., carbon flows, CF) as it results in lower natural mortality and smaller feces production (Figure 8.4f). Further, changes of the guilds' relative contribution to H and total productivity can reveal restructuring with the foodweb. The ecosystem model of the Western Baltic Sea, which was applied to derive the indices shown in Figure 8.4, has high resolution at the level of fish communities and is particularly centered on fisheries. This has effects on the patterns shown. The modelling framework provides uncertainty assessments, which can support giving advice for environmental management and planning (Heymans *et al.* 2016).

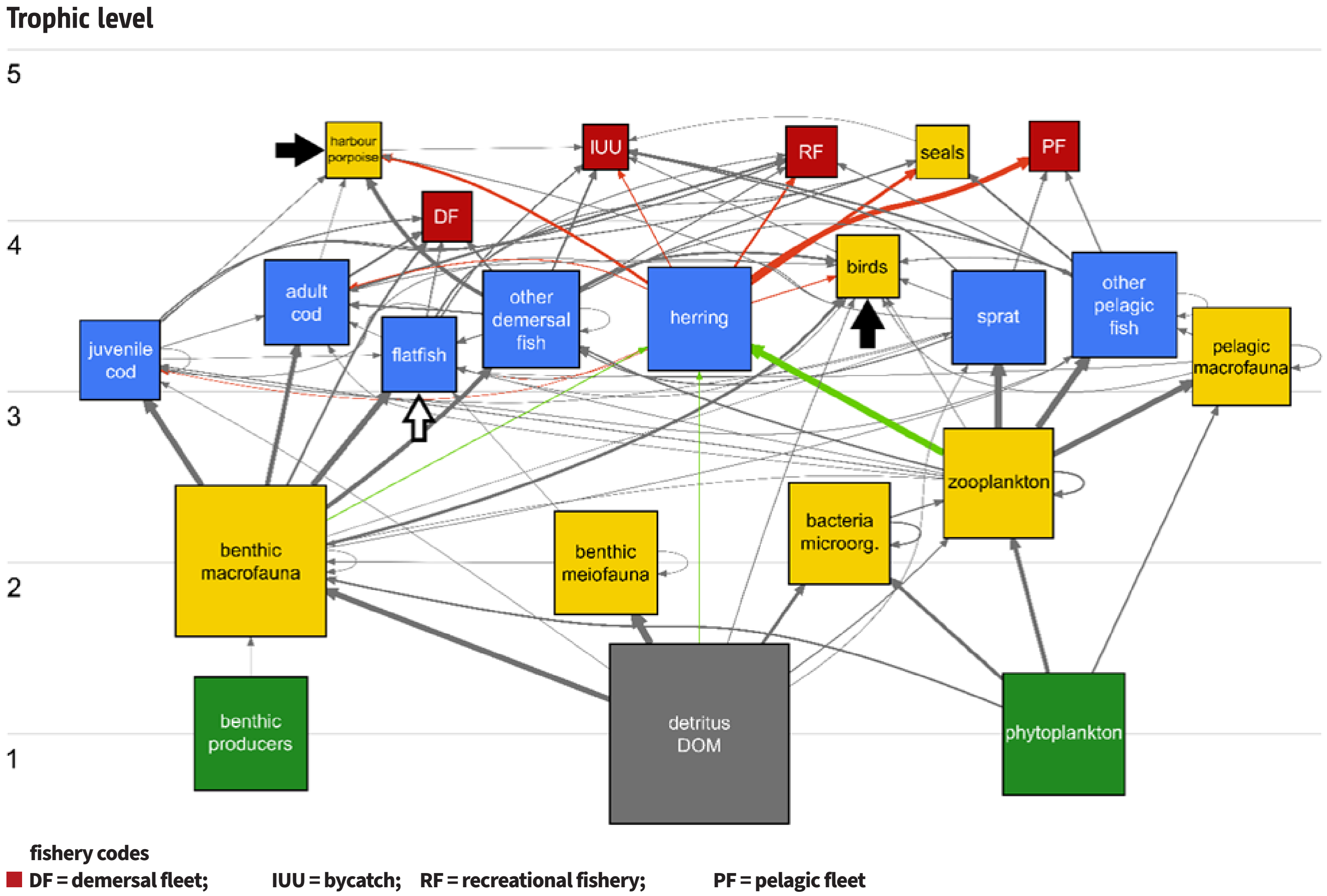


Figure 8.3. Steady-state trophic network illustrating carbon exchanges in the Western Baltic Sea during 1994. Thickness of links is proportional to consumers' feeding preferences and arrows define the directions of energy transfer. The ordering on the y-axis informs on trophic levels, and compartments are distributed from the pelagic to benthic domain along the x-axis. The mass-balanced network highlights the key position of herring. This forage fish represents a bottleneck to transfer energy from the planktonic foodweb to higher-trophic level consumers and fisheries, being the key to deliver carbon from lower trophic levels (green links; see the relevance of zooplankton) to predators and fisheries (red links). Figure modified from Scotti et al. (2022a).

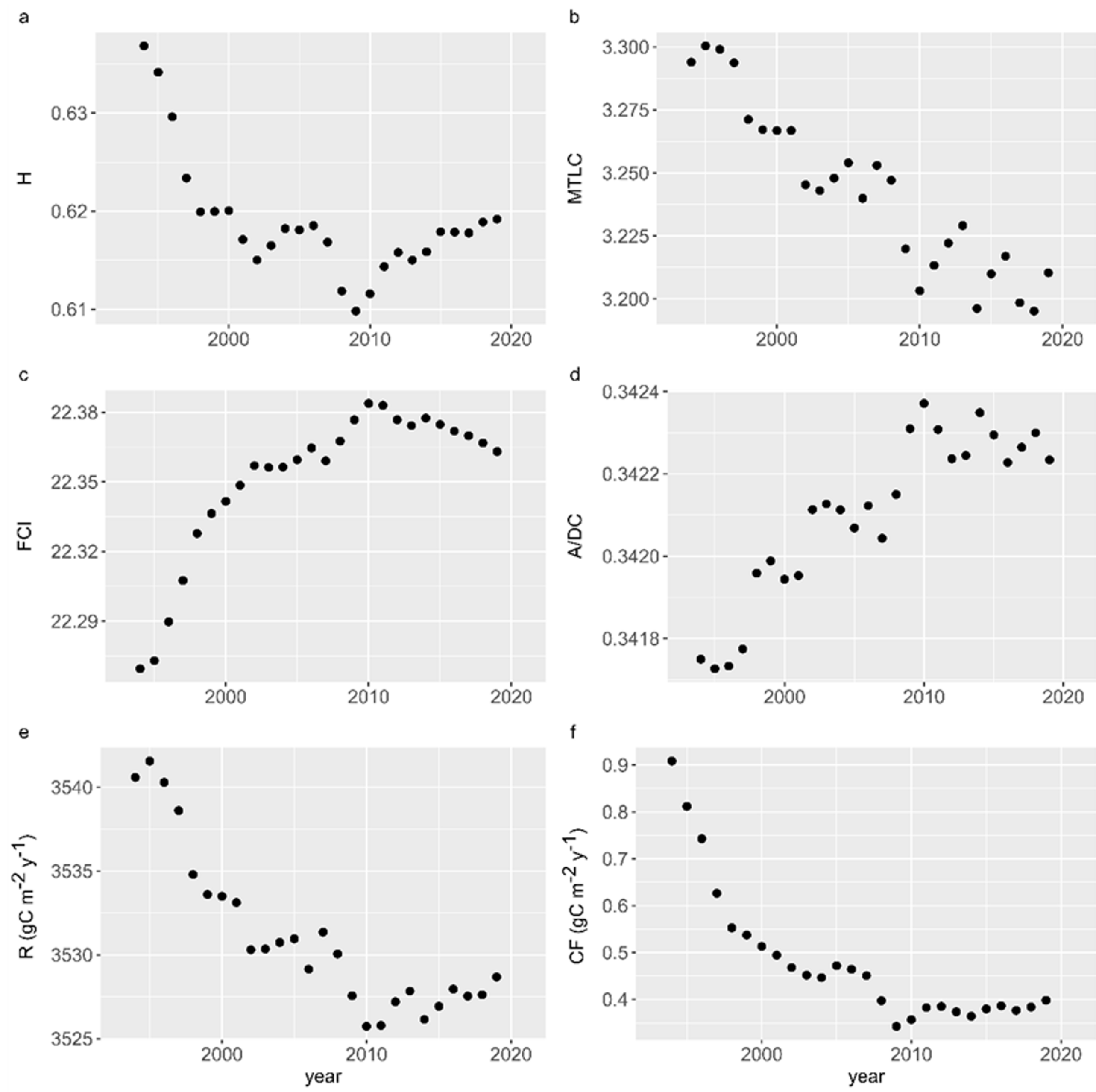


Figure 8.4. Indicators from ecosystem models could complement foodweb assessments for trends in both "traditional" metrics (Shannon's index of diversity, H and mean trophic level of the catch, MTLC), indicators reflecting the amount of cycling (Finn cycling index, FCI), the stability and resilience (internal redundancy, R and ascendency/development capacity, A/DC), or on blue carbon (carbon flows from fish stocks and top predators to detritus, CF). The example presented here does not intend to provide a definitive set of indicators. Rather, it shows the diversity of indicators obtained from an ecosystem model, and it describes how they can be used to quantify foodweb functioning, environmental status, and impacts on blue carbon. Charts a–d visualize dimensionless indices while internal redundancy, R (e) and net carbon flows to detritus, CF (f) are expressed as gC m^{-2} y^{-1}.

The presented results refer to a specific region. However, other existing Ecopath with Ecosim models (e.g., Bauer *et al.* 2019, Box 8.5) could be applied to implement the same approach over a larger geographical area in the Baltic Sea. The approach can be applied to express outcomes with respect to trophic guilds (Scotti *et al.* 2022a), as required by the MSFD (European Commission 2022). Foodweb derived indices may thus contribute to assess foodweb status as required by MSFD criteria. In particular, the Shannon Index H across guilds, internal pathway redundancy and A/DC are reflect aspects of D4C2 Abundance across guilds, while FCI, guild productivity and the potential for carbon sequestration relate to D4C4 Productivity of guilds. The MTLC indicator may be compared with the FW4 indicator applied in OSPAR, and the indicators derived from ecological network analysis may be connected to candidate OSPAR indicators to assess foodwebs (Safi *et al.* 2019,), potentially supporting coherent assessments across sea regions (Piroddi *et al.* 2021). Testing the robustness of findings through ensemble modelling is advisable to ensure the robustness of the results (Pethybridge *et al.* 2019).

Box 8.5 Ecosystem models demonstrate large scale changes in the temporal dynamics of foodwebs

The current case study illustrates results for the Western Baltic Sea, but the use of model-derived foodweb indices could potentially apply to a larger geographical area in the Baltic Sea.

Large-scale changes in the temporal dynamics of foodwebs have previously been demonstrated in ecosystem models for the Central Baltic Sea. Tomczak *et al.* (2013) found that the regime shift that occurred in the Central Baltic Sea in the late 1980s is well reflected by the environmental network analysis indices, and that two different ecosystem regimes could be distinguished within years 1974-2005. The first regime between 1974 and 1988 exhibited a more balanced ecosystem, with a more diverse flow structure and higher resilience. This was also characterized by high primary production and high fishing pressure at relatively high trophic levels. The second regime, between 1994 and 2006, was less resilient, with high primary production and high fishing pressure on lower trophic level species, indicating a more productive and linearized foodweb. The authors hypothesized that the regime shift in structure was caused by the interplay of multiple drivers including climate, eutrophication and fishing.

Further studies (Tomczak *et al.* 2021) showed a regime shift from a benthic- to a pelagic-dominated state in the Baltic Sea on an even longer time scale, over the years 1925-2005. Benthic components were seen to have played a significant role in trophic transfer historically, whereas pelagic–benthic coupling was weak during the more recent period, and pelagic components dominated. Changes in productivity, climate, and hydrography mainly affected the functioning of the foodweb over time, whereas fishing became important more recently. Eutrophication was connected to far-reaching direct and indirect impacts, changing not only the trophic state of the system but also affecting higher trophic levels. The study by Tomczak *et al.* (2021) also suggested a switch in regulatory drivers from salinity to oxygen during the last century.

8.4. Relationship of foodwebs to drivers and pressures

Pressures impact on foodwebs through their component species, as the effects are mediated through the foodweb to other species and trophic guilds, and subsequently to ecosystem functions (Eero *et al.* 2021). Further, impacts can be altered if a pressure affects many parts of the foodweb simultaneously, or by cumulative effects of many pressures (See also Box 8.6). Pressures could also have differential effects along natural environmental gradients, or as a result of synergies with climate-related factors (Nordström *et al.* 2020, Reusch *et al.* 2018).

Although environmental pressures are recognised as important for foodweb status, they are challenging to identify in a systematic way due to the presence of synergies and combinations of direct and indirect links between species. Further, time lags and non-linear relationships contribute to that responses may not be easily detectable in statistical analyses.

This section summarizes examples from research on how key environmental pressures in the Baltic Sea have impacted on, or could affect, foodwebs over time. The evaluation focuses on a few widely impacting pressures, namely eutrophication, contamination, fishing and the introduction of non-indigenous species (HELCOM 2023ag), as well as climate effects, even though other pressures which are not directly addressed here, can also be of importance in certain areas. Although the pressures are addressed in separate, one general conclusion from the examples is the relevance of carrying out overall assessments to address the interactive effects across pressures, foodweb components and processes.

8.4.1 Eutrophication effects on foodwebs

Although primary production is a key process in the foodweb to provide energy for all organisms, excessive primary production leads to eutrophication symptoms and impairs the function of the foodweb in many cases (HELCOM 2023d). The increased intensity and frequency of phytoplankton blooms leads to increased sedimentation and microbial degradation of organic matter, which initiates excessive oxygen consumption. These processes cause poor oxygen conditions at the seabed as well as in parts of the water column, affecting benthic organisms as well as their predators (Carstensen *et al.* 2014). Oxygen depletion in the Baltic Sea continues to spread and worsen (Rolff *et al.* 2022). Increased production of phytoplankton also reduces water clarity, limiting the distribution of submerged vegetation and impairing habitat quality in coastal areas, with effect on trophic interactions. Eutrophication is associated with changes in species composition within several key trophic groups in the Baltic Sea, such as pelagic primary producers, benthic fauna, coastal fish, and sea birds (see Chapers 3, 4, 5 and 6 in this report).

Analyses at ecosystem level show that eutrophication has had far-reaching direct and indirect impacts on Baltic Sea foodwebs, changing not only the trophic state of the ecosystem but also affecting higher trophic levels (Tomczak *et al.* 2022). Since the 1920s, the Baltic Sea has transferred from a typical low productive aquatic system to a high productive system where the presence of insufficient oxygen conditions is a main regulatory driver (Figure 8.5).

Interactions with climate change is expected to worsen negative impacts on foodwebs from eutrophication, through for example increased algal blooms and oxygen consumption (see section below).

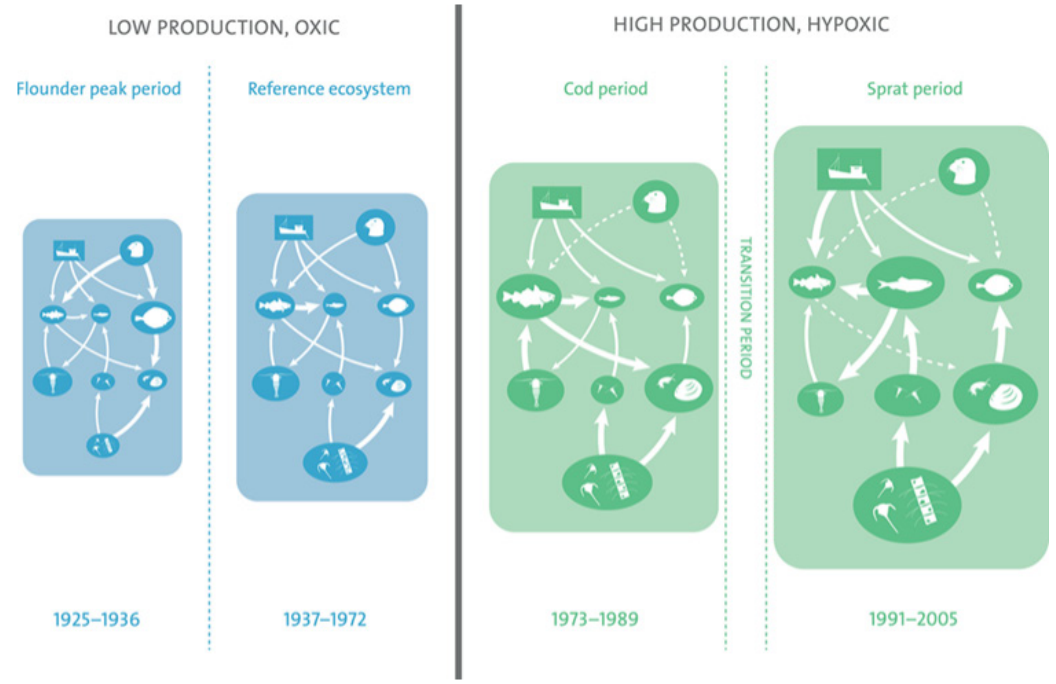


Figure 8.5. Illustration of changes in the Baltic Sea ecosystem between 1925 and 2005, with potential regime shifts. Circles and ellipsoids represent the natural elements of the foodweb, squares stand for fisheries. Blue and green boxes indicate low and high productive systems, respectively. Arrows represent the direction and strength of controlling links in the foodweb. The width of each arrow indicates the strength of relationships. Dashed lines represent a weakened or lost trophic control (Tomczak *et al.* 2021).

8.4.2 Effects of the extraction of fish on the foodweb

Several examples are evident of where fishing has played a key role in driving changes in the foodwebs of the Baltic Sea. In addition, bycatches of non-targeted fish species such as birds and mammals can have an impact on biodiversity and hence potentially affect the foodweb (see Chapter 9 for information on bycatch). Cascading effects attributed to rapid declines and collapses of the Baltic cod stocks are among the most substantial changes in Baltic Sea foodwebs connected to overfishing. More recently, ongoing regime shifts are observed in coastal areas, relating to enhanced dominance of stickleback (Eklöf *et al.* 2020), and the role of herring in regulating zooplankton abundances (*Limnocalanus macrurus* in the Gulf of Riga, Einberg *et al.* 2019).

The most notorious example is the collapse of the eastern Baltic cod stock in the late 1980s and early 1990s, which led to a chain of cascading effects on the structure and function of the offshore foodweb in the Baltic Proper (Casini *et al.* 2008, Tomczak *et al.* 2012, Blenckner *et al.* 2015). The change was mediated by fishing on cod, climate change, and eutrophication (Möllmann *et al.* 2009). Similar effects have also been seen elsewhere, including the Gulf of Riga, where a decline in cod biomass induced by overfishing, climate changes and eutrophication resulted in increases in clupeid biomass, which in turn affected lower trophic levels (Casini *et al.* 2012). Examples of foodweb impacts attributed to effects of fishing are also shown in section 8.3.3 for the Western Baltic Sea. During the current assessment period, evaluations for the Western Baltic Sea show a collapse of western Baltic cod and decline of herring, indicating a further deterioration, and the Baltic cod stock is not recovered (see Chapter 5). The decline of herring has negative consequences on the harbour porpoise because a smaller stock size of the forage fish reduces the energy available for sustaining the population of this top predator (Scotti *et al.* 2022a). Cod stocks have not recovered yet (see Chapter 5), and the resulting impacts on Baltic Sea foodwebs are present and persistent, indicating that for a recovery of the foodweb several currently ongoing pressures need to be addressed as well.

Since coastal and open sea areas are connected, impacts in the open sea also have implications on coastal areas, and vice versa. Rapid declines in cod have shown to propagate cascading effects in coastal areas (Eriksson *et al.* 2011, Olsson *et al.* 2015, Tomczak *et al.* 2016). Fishing, including recreational fishing, is not the only factor affecting coastal predatory fish (Olsson 2019), but is likely a significant driver behind currently observed shifts (Bergström *et al.* 2022, Olin *et al.* 2022). In coastal foodwebs, declining populations of piscivorous fish have been attributed to increased abundances and ecological dominance of mesopredatory fish, such as stickleback (*Gasterosteus aculeatus)* in the Baltic Proper, wrasses and gobies in the Kattegat, and also with enhanced ephemeral algae (Eriksson *et al.* 2009, 2011, Donadi *et al.* 2017, Eklöf *et al.* 2020, Olin *et al.* 2022).

8.4.3 Contaminant effects of the foodweb

Contaminants with potential to accumulate in the foodweb, by biomagnification, have a capacity to affect the health and abundance of species through trophic dynamics. For example, evidence is accumulating for biomagnification and health effects of MeHg (Vainio *et al.* 2022), population declines related to POP exposure (Sonne *et al.* 2020), and transgenerational effects in Baltic biota (Mauritsson *et al.* 2022).

Some contaminants are associated with specific consumers and show strongly different biomagnification potential between pelagic and benthic systems. Hence, the same contaminant could have differential effect in different foodwebs and its biomagnification could also be affected by the extent of benthic-pelagic coupling (Vainio *et al.* 2022). However, whereas many data are available on concentrations of contaminants in biota, as well as biomagnification factors, there is a lack of empirical and modelling studies estimating how environmental contaminants contribute to foodweb changes. Development of biological effect indicators would be important to accompany current concentration-based indicators (see HELCOM 2023c for information on the status of hazardous substances).

Top predators can serve as sentinels for persistent harmful substances in the ecosystem. Because persistent chemicals accumulate in the foodweb, new emerging pollutants that are below detection limits in other biota could be detected in top predators. The white-tailed eagle (*Haliaeetus albicilla*) is the ultimate top predator of the Baltic ecosystem, feeding mainly on fish and sea birds, and is hence strongly exposed to any persistent chemicals that accumulate in the food chain. In the past, widely used insecticides (DDTs) and possibly polychlorinated biphenyls were major causes of impacts and declines of white-tailed eagle in the Baltic Sea (Helander *et al.* 2008). Bans on the use of these substances have thereafter led to a positive development, since the 1980s (HELCOM 2023ah), although other factors such as habitat availability are also decisive.

Contaminants enter the marine environment through multiple pathways (HELCOM 2023c), and marine litter ingested by feeding is another emerging source of potential foodweb effects (HELCOM 2023c). Measuring and projecting biological effects across different levels of biological organization would allow to attribute chemical pollution to the actual contributing pressures on the foodwebs to inform future regulations, policies, and assessments (HELCOM 2023c).

8.4.4 Impact of NIS on different trophic guilds and on natural foodwebs

Impacts of non-indigenous species (NIS) on foodwebs are not quantitatively investigated or monitored. As neither the number of new introductions (HELCOM 2023ag) nor the distribution and spread of NIS can be taken as proxies of impact, it is not possible to evaluate the impact of NIS relative to the pre-assessment period. However, quantitative evidence on the impacts of NIS on benthos and birds, for example, may provide valuable contribution to the evaluations of benthos and birds core indicators. Several non-indigenous species have been attributed to impacts on biotic properties in the Baltic Sea (Ojaveer *et al.* 2021).

The predatory cladoceran *Cercopagis pengoi* has been attributed to the highest foodweb impact, closely followed by the zebra mussel (*Dreissena polymorpha*), according to a meta-analysis of widespread NIS, while the relatively lowest effect was attributed to the bay barnacle *Amphibalanus improvisus* (Ojaveer *et al.* 2021). Based on biotic properties affected, the largest impact was attributed to NIS that are a prey for native species. Effects on the facilitation of native species, consumption, bioturbation and competition yielded very similar effect sizes. With respect to effects by trophic guilds, the biggest effect size was documented for planktivores, followed by sub-apex demersal predators and pelagic primary producers, but all investigated trophic guilds were affected by at least one NIS. However, only a few NIS (polychaete *Marenzelleria* spp., the mud crab *Rhithropanopeus harrisii*, the round goby *Neogobius melanostomus* and *D. polymorpha*) had major roles in the foodweb, contributing to processes at multiple trophic levels and affecting multiple habitats, which stresses the high relevance of species identity. Of special importance, evidence is present that NIS (*R. harrisii*) can also induce regime shifts in the Baltic Sea, through a combination of foodweb and abiotic effects (Kotta *et al.* 2018). Consumption and competition for habitat or food were the best studied processes, both involving a large number of NIS (Ojaveer *et al.* 2021). In some cases, effects on foodweb processes were due to only one or two NIS taxa, for example effects on bioturbation triggered by *Marenzelleria* spp. and partly *R. harrisii*.

8.4.5 Climate change effects on foodwebs

Climate change is likely to influence on several processes that are fundamental for ecosystem functioning in the Baltic Sea, related to foodweb interactions, nutrient recycling, and ecosystem properties (HELCOM/Baltic Earth 2021). Climate-related factors, for example changes in temperature, oxygen, seasonality or ice cover, can impact on the structure of the foodweb by direct effects on organisms, but also through bottom-up and top-down cascading effects, such as effects on predation or biomass production (Casini *et al.* 2009, Hjerne *et al.* 2019, Kahru *et al.* 2014, 2016, 2020).

Further, climate change is very prone to interacting with other pressures. HELCOM/Baltic Earth (2021) stressed the importance to estimate the magnitude and interactive effects of climate change relative to other human pressures. In the Baltic Sea, changes in climatic conditions in combination with fishing and eutrophication have been attributed to shifts from larger to smaller zooplankton, stronger impacts of nutrients on ecosystem structure (bottom-up control) and reduced regulatory capacity of predators on ecosystem structure (top-down control, HELCOM and Baltic Earth 2021). These effects have been observed in both pelagic and coastal Baltic Sea foodwebs (for example Casini *et al.* 2009, Eklöf *et al.* 2012, Lindegren *et al.* 2012, Möllmann *et al.* 2009, Niiranen *et al.* 2013, Eriksson *et al.* 2009, 2011, Pekcan-Hekim *et al.* 2016, Suikkanen *et al.* 2013, Östman *et al.* 2016).

One example encompasses the effects of climate change on primary and secondary production, where increased pelagic primary productivity is mainly attributed to eutrophication (Saraiva *et al.* 2019, Ref to HOLAS report on Eutrophication). However, warmer water may increase pelagic and benthic primary production (Kahru *et al.* 2016, Karlson *et al.* 2015, Lindegren *et al.* 2012, Hjerne *et al.* 2019, Suikkanen *et al.* 2013), and algal blooms have been observed more frequently during warmer years during the last decades (HELCOM/Baltic Earth 2021). The algal blooms, in turn, may cause increased decomposition and the depletion of oxygen in bottom sediments, with subsequent worsened conditions for benthic species and lowered productivity of important prey species (Carstensen *et al.* 2014, Hjerne *et al.* 2019, Kahru *et al.* 2014, 2016, 2020, Lindegren *et al.* 2012, Saraiva *et al.* 2019, Suikkanen *et al.* 2013). Further, changes in the timing of algal blooms, due to changes in ice cover, cloudiness, or wind condition in spring, can have subsequent effects on zooplankton as well as benthic productivity (Kahru *et al.* 2014, 2016), and lead to temporal mismatches in predator-prey relationships and effects on fish recruitment. Changes in temperature could also have effects on the physiology of species and on nutrient cycling, where a faster recycling at higher temperatures could affect the quality of primary production.

Due to the complex interactions, the effects of climate change on higher trophic levels are expected to differ among different organism groups (Helenius *et al.* 2017, Lindegren *et al.* 2012, Olsson *et al.* 2012, Niiranen *et al.* 2013, Svensson *et al.* 2017, Pecuchet *et al.* 2013). Further, current knowledge is limited to what can be observed or deduced for future conditions under existing climatic conditions, while there are knowledge gaps on how the foodweb structure, functioning and resilience may change under expected future environmental conditions (HELCOM/Baltic Earth 2021).

Another knowledge gap concerns responses to extreme events, such as heat waves (Humborg *et al.* 2019, HELCOM/Baltic Earth 2021). For instance, a mesocosm experiment showed that consecutive heatwaves may have differential effects on benthic invertebrates inhabiting coastal ecosystems of the Western Baltic Sea, showing positive effects on some species (amphipods) and negative effects on others (tellinid bivalve), thus highlighting how the same stress factor yields diverse responses that contribute to the reshaping of the foodweb (Pansch *et al.* 2018).

Box 8.6 Can a combination of pressures lead to non-additive effects?

Changes observed in the foodweb dynamics are very often associated with the combined effect of more than one pressure or process, acting directly or indirectly. Hence, impacts from one pressure is seldom decoupled from other stressors (Möllmann *et al.* 2009, Reusch *et al.* 2018), as shown in several examples provided in this section. Synergistic or antagonistic effects occur when the combined effects of many pressures cannot be explained only by additive mechanisms. Such interactive effects are very difficult to single out in analyses based on field data.

As one example, severely decreasing energy reserves of the western Baltic cod (*Gadus morhua*) have been explained by an environmentally driven decreased availability of suitable habitats in terms of both metabolic needs and food supply. Changes in these factors were attributed to a decrease in the hepato-somatic index and muscle weight of cod by 50% and 10%, respectively, between 1977 and 2020. Specifically, an increase in bottom water temperature, expansion of hypoxic areas and changes in diet composition (less herring (*Clupea harengus*)) was observed, as a result of both climate change and eutrophication (Receveur *et al.* 2022). These changes can then be aggravated by pressure from fisheries (Section 8.4.2).

Another example is provided by variability in the abundance of the energy rich large-bodied copepod *Limnocalanus macrurus* in the Gulf of Riga during 1958-2016. Fluctuations in abundance were connected to changes in herring spawning stock biomass, winter severity, and bottom water temperature (Einberg *et al.* 2019), highlighting the key roles of climate change and fisheries as main drivers of pressure.

8.5. Challenges to evaluating the status of foodwebs and how they were met

Several challenges to describing and assessing complex foodwebs are apparent. To support management, a key aspect is that methods are needed to represent and, where applicable, reduce the inherent complexity of foodwebs and extract meaningful patterns and trends. A wide variety of tools and approaches are used in foodweb research (Dierking *et al.* 2020, in prep.), and offer valuable information. However, research studies are usually focused on specific areas and time periods, and they do therefore not have the spatial and temporal scope and resolution that is required to support Baltic-wide periodical assessments.

In the current assessment of foodwebs, the present challenges were met by using a variety of approaches and drawing qualitative conclusions to the extent that was considered possible. The aim of the HELCOM indicator evaluation was to apply a coherent approach to the largest possible spatial area of the Baltic Sea (Section 8.3.1), whereas the aim of the case studies (Sections 8.3.2-3) was to show examples of methodological approaches that could be developed and applied to various sub-basins to support future evaluations of foodweb status. These results were complemented by published research output supporting the qualitative evaluation of changes in foodwebs in the Baltic Sea.

A more specific challenge is the identification of ecologically relevant assessment units (European Commission 2022), especially as several foodwebs are typically linked and interconnected in the ecosystem. Existing HELCOM assessment units may not automatically be suitable for assessing foodwebs, although they may be reasonable in some cases. In other cases, combinations of assessment units with similar characteristic properties might be more relevant. The case studies presented here, as examples, were delineated based on ecological characteristics, where the Bothnian Sea ITA study (Section 8.3.2) represented one HELCOM sub-basin under assessment scale 3 and was also assumed relevant for ICES subdivision 30. The EwE model of the Western Baltic Sea (Section 8.3.3) matches ICES subdivisions 22 and 24, also representing one ecologically uniform area.

A central remaining challenge is the setting of meaningful threshold values. Ideally, operational indicators should respond to manageable pressures and have defined threshold values. However, separating effects of multiple pressures and evaluating pressure-specific responses on foodweb-indicators is complex. Here, foodweb models could support the identification of threshold values for quantitative status assessment, by exploring different pressure scenarios (Korpinen *et al.* 2022). In addition, it is conceptually not straightforward to define the characteristics of foodwebs in good status. The undertaking could also be societally complex due to the presence of potential trade-offs, why effects on multiple objectives would need to be considered in the process.

Finally, applying an assessment period of six years could be a challenge as some foodweb changes are only detectable, or relevant, at longer time scales, and as differences in the life history of constituting species could affect how soon responses to a change in pressure could be seen for different trophic guilds. Trends over time can more conveniently be addressed in a systematic way across guilds and sub-basins.

Suggestions for how these methods could be developed further to move towards quantitative assessments and to include the functional aspects of foodwebs more explicitly are presented in Section 8.6.

8.6. Follow up and needs for the future with regards to foodwebs

8.6.1 How are issues with Baltic Sea foodwebs dealt with in management

Foodwebs are not managed directly, but the status of foodweb benefits from the management of pressures that affect them and each of their individual components, including eutrophication, fishing pressure, non-indigenous species, contaminants, as well as measures to reduce climate change, and by achieving a good status of key species constituting the foodwebs. As pressures are manifold, the establishment of strictly protected areas is an important tool to ensure a functioning foodweb now and in the future. Vice versa, foodweb processes mediate most of the prevalent pressures in the Baltic Sea, as seen in for example the bioaccumulation of contaminants along food chains, and the structure and function of foodwebs determines interdependencies among species in the ecosystem. Foodweb information is therefore key to improving and strengthening environmental and marine management, and the development of ecosystem-based management (Eero *et al.* 2021, Nordström *et al.* 2021).

8.6.2 What does the foodweb evaluation tell us?

Inference from existing HELCOM biodiversity indicators shows that key components of Baltic Sea foodwebs are not in good status. Pressures affecting individual components indirectly affect other parts of the foodweb as well as its functioning. Several research studies show that Baltic Sea foodwebs in many cases have undergone changes over the past decades. The observations include strong and therefore worrying changes in the relative abundance of trophic guilds, attributed to pressures from eutrophication and fishing in combination with climate-related changes. Effects on foodweb from non-indigenous species and chemical pollution have also been noted in some sub-basins. Further, widespread oxygen deficiency has affected foodweb structure and productivity. Negative changes triggered by oxygen depletion have included a lower productivity of benthic fauna, and subsequent effects on fish, birds, and mammals, leading to reduced stability and resilience of foodwebs against future pressures, which are likely to be enhanced under future climate change.

8.6.3 Needs for future assessments

Current HELCOM indicators focus on single trophic guilds and only rarely address the trophic interactions, energy flow and functioning of foodwebs, making it apparent that specific foodweb indicators and assessment approaches need to be developed. The evaluations above showed examples on how approaches to evaluate foodwebs could be applied today. Potential directions for further development are presented below, structured around the same aspects: the further development of HELCOM indicators based on available monitoring data, integrated trend analyses, and applying ecosystem models to derive indicators of function. The examples presented in Section 8.2 were applied as separate cases in terms of approaches as well as geographically, but their further integration across areas could be possible in the future. Finally, we discuss how existing tools and methods in foodweb research could be used to fill gaps in foodweb knowledge in the Baltic Sea, and thus benefit future assessments.

Data and indicator development

Although HELCOM data and indicators exist for most trophic guilds, few explicitly address foodweb-relevant aspects. For example, the EU MSFD requests that the status of foodwebs is assessed through a comparison of changes in biomasses between and across guilds (European Commission 2022). Such an evaluation was not achievable at this time, although it could be feasible in future assessments provided indicator and method development. One existing gap is that most HELCOM indicators focus on certain species or taxonomic groups, but do not cover diversity, size distribution or production at the level of the whole trophic guild. However, existing HELCOM monitoring data could support the dedicated development of foodweb indicators in line with European Commission (2022), as many trophic guilds are included.

Another limitation is potentially that monitoring programs are typically designed by taxonomic groups, whereas foodweb indicators would need to combine data from several programs, which are not necessarily spatially or temporally compatible. Enhancing the use of existing monitoring data to support foodweb assessments may require further harmonization of monitoring programs to ensure their spatial and temporal relevance for this purpose. In addition, expanding the spatial coverage of the HELCOM monitoring programs should be supported to enable evaluation of more assessment units, as several parts of the Baltic Sea could not be addressed this time. In developing data to support foodweb assessments, the provision of additional types of data to support indicator development and feed into foodweb models should also be kept in mind, as outlined in the next two sections.

Further model development

Ecosystem models have great potential to support foodweb assessments (Piroddi *et al.* 2015, Korpinen *et al.* 2022). Available foodweb-related models encompass multiple trophic levels and allow runs of different scenarios. Especially, Ecopath with Ecosim, Atlantis and Dynamic Bayesian networks models could support indicator-based assessments and are available for some Baltic Sea sub-basins (Korpinen *et al.* 2022).

The ecosystem models can guide ecosystem-based management, as they address multiple impacts of human activities on ecosystems. In indicator method development, models could be applied to explore suitable threshold values and assess possible stable states under different pressure scenarios. They could also be used to obtain indicators that are not available from guild biomasses alone. For example, transfer efficiency throughout the foodweb has been proposed as "actual" foodweb indicator (Kortsch *et al.* 2021, Maureaud *et al.* 2017), and some of the whole-system indices presented in the EwE test case match FW9 - Ecological Network Analysis (ENA) indicators proposed in OSPAR (Niquil *et al.* 2014, Safi *et al.* 2019). Models could also help fill data gaps if monitoring data are insufficient in temporal or spatial coverage, as an ecologically more justified alternative to simple interpolation of data. As the modelling approach considers ecological interactions, this could be achieved by addressing for example aspects of diversity, biomass or size/age distribution of a trophic guild or taxon.

Integration of indicators and modelling outputs may give a more robust assessment result, if implemented within a coherent framework (Borja *et al.* 2016, HELCOM 2018). Models supporting management or assessment frameworks need to be robust and accredited (ICES WKGMSFDD4-II 2015, ICES 2019b), meaning that they capture the relevant foodweb components and their trophic interactions (see also next section), are published and peer-reviewed, benchmarked against quality criteria, and evaluated for indicator robustness. In the case of the Baltic Sea, intercalibration would be required for existing foodweb models. Ensemble modelling drawing upon results by different approaches could be preferential (Gårdmark *et al.* 2013, Pethybridge *et al.* 2019).

Potential additional and supporting methods

A key aspect for improving future Baltic Sea foodweb evaluations is integrating functional aspects, such as information on trophic interactions, trophic niches of key species, foodweb connections and structure, as well as energy flows, in the assessment approach. Several powerful methods have emerged over the past decades and are used routinely in foodweb research, but only rarely in foodweb assessments. This includes DNA metabarcoding, which can complement classical stomach content analysis to obtain diet information, and stable isotope and fatty acid analyses, as broadly applicable, time-integrated dietary tracers (Nielsen *et al.* 2018). Further, the combination of data from different methods, such as stable isotopes and molecular analyses, can be used to address complex questions, such as the quantification of diazotropic nitrogen from cyanobacteria entering pelagic foodwebs (Motwani *et al.* 2018). Output from these methods has strong potential to improve the parameterization of foodweb models (see previous section), trait-based approaches and ecological network analysis.

A wealth of published information on for example foodweb baselines, foodweb structure and trophic interactions is already available for the Baltic Sea, as exemplified by a recent systematic review of the stable isotope ecology field (Eglite *et al.* 2022). Many of these existing stable isotope studies demonstrate the potential applicability to foodweb assessments, including the use of blue mussel time-series data to identify baseline changes in foodwebs (Karlson and Faxneld 2021), or fish trophic level data to assess bioaccumulation of contaminants along food chains. However, to date, the routine use of stable isotope data in assessments is prevented a limited spatial or temporal scope of individual research studies.

The routine use of additional or supporting methods in foodweb assessments requires that their outputs fit the temporal and spatial scope of the assessment, which is also strongly linked to the availability of data fit for this purpose. Considering the limitations of individual research studies, further development will depend on whether future monitoring programmes can support the collection of the necessary samples and data. As an example, stable isotope analysis of key species, for example top consumers, could serve to detect foodweb changes by indicating shifts in trophic level, length of trophic chains, shifts in benthic versus pelagic diet, or shifts in primary sources of organic matter at the base of the foodweb (that is, autochthonous versus allochthonous). To achieve this would require spatially and temporally resolved systematic collection and preservation of samples, integrated in existing monitoring schemes. The re-assessment of current monitoring programs "through the lens of foodweb assessments" should therefore be a future priority.

Another key aspect is that the usefulness of existing and new data for assessments is directly linked to accessibility, as only easily accessible and usable data has a chance of entering assessments. Eglite *et al.* (2022) highlighted the urgent need to implement openly accessible databases for stable isotope data[1], combining existing and future data from scientific studies as well as monitoring.

1 See Global Isobank effort https://isobank.tacc.utexas.edu/

9. Results for the bycatch assessment

Assessment results in short

- Fisheries bycatches have an impact on pelagic- and benthic-feeding waterbirds in the Baltic Sea and these impacts occur widely, though can differ between species groups (for example those with different feeding modes). The results of the integrated assessment indicates that impacts from bycatch on benthic feeding waterbirds occur widely, with the assessment indicating high impacts in the Great Belt and the Sound as well as in Bornhom Basin and Arkona Basins. It is worth noting that the bycatch assessment was spatially restricted and there might be high impact elswewhere, where no bycatch data was available.
- For pelagic feeders, the areas Kattegat, Belt Sea, The Sound, Kiel Bay, Bay of Mecklenburg, Arkona Basin, Bornholm Basin and Eastern Gotland Basin failed the threshold value for good status with regards to bycatches, which is to be compared to the integrated assessment results for waterbirds (Chapter 6), where bycatch is not considered.
- All assessed marine mammal populations failed the threshold value for good status when bycatch is considered in the status assessment. For most marine mammal populations and assessment areas, this implies no changes in assessment results compared to the integrated assessment results for marine mammals (Chapter 7), where bycatch is not considered. One exception is harbour seal in Bornholm and Western Gotland Basin, for which the inclusion of bycatch in the status assessment results in a deteriorated status.
- The widespread lack of adequate data on both bycatch rates and fishing effort has hampered a comprehensive assessment of bycatch in both marine mammals and waterbirds.

9.1. Introduction to bycatch

Bycatch of marine mammals and waterbirds in gillnets has been documented in many fisheries worldwide and bycatch is regarded as one of the most significant source of premature mortality in a large number of marine mammal and bird species (Read *et al.* 2006, Lewison *et al.*, 2014, Dias *et al.*, 2019). In the Baltic Sea there are five species of indigenous mammals present in the marine environment. The harbour porpoise (*Phocoena phocoena*) is the only resident cetacean, while three species of seals are present year round: the grey seal (*Halichoerus grypus*), the harbour seal (*Phoca vitulina*) and the ringed seal (*Pusa hispda*). In addition, the Eurasian otter (*Lutra lutra*) occurs in the Baltic Sea. The Baltic Sea is also a major migratory route for millions of Palearctic birds and an essential breeding and wintering ground for numerous waterbird species. All five species of marine mammals in the Baltic Sea, as well as dozens of species of seabirds have been reported as bycatch in gillnets within Baltic fisheries (Vinther, 1999, Žydelis *et al.*, 2009, Degel *et al.*, 2010, Kindt-Larsen *et al.*, 2012, Sonntag *et al.*, 2012, Bellebaum *et al.*, 2013, Žydelis, Small and French, 2013, HELCOM, 2018a, 2018b, Field *et al.*, 2019, ICES, 2019, Glemarec *et al.*, 2020, Marchowski *et al.*, 2020, Morkūnas *at al.* 2022).

The assessment presented in this chapter targets mammals and waterbirds, which are prone to become entangled in various types of fishing gear and subsequently die by drowning. It provides an overview regarding the link between conservation status of the relevant species and the loss of individuals from populations due to bycatch in fishing gear. This, in turn, has implications for efficient measures to be taken in order to achieve a good status of biodiversity in the Baltic Sea. While bycatch of non-target fish species is also a recognised pressure, this is not covered by the HOLAS 3 assessment. Due to lack of data, otter could not be taken into account for the assessment.

9.1.1 Effects of bycatch on the ecosystem and ecosystem health

Waterbirds

Waterbirds are an integral part of the Baltic marine ecosystem. They are predators of fish and macroinvertebrates, scavengers of carcasses and fishery discards and herbivores of littoral vegetation (Chapter 6). Many of the species included in the bycatch assessment are in the top of the foodweb.

Drowning due to bycatch in fishing gear is a significant pressure on waterbirds, particularly benthic and pelagic feeders, e.g. long tailed-duck, and velvet scooter, with the potential to affect their population trends and demography (Marchowski *et al*. 2020, Morkūnas *et al.* 2022). In vulnerable waterbird species, many of which are included in this assessment, the numbers of drowned birds may represent a relatively large proportion of the total population size (Morkūnas *et al.* 2022).

Waterbirds diving during foraging in order to catch demersal or pelagic fish (divers, grebes, cormorants, mergansers, alcids) and benthic invertebrates (ducks), respectively, are prone to become entangled in various types of static nets or caught in traps and to die by drowning. In addition to hunting (Mooij 2005) and oiling (Larsson & Tydén 2005, Žydelis *et al.* 2006), drowning in fishing gear is a quantitatively important source of mortality for waterbirds living in the Baltic. Scientific studies show that the number of waterbirds by-caught is very high and differs significantly from the much lower numbers reported in official reports (Morkūnas *et al.* 2022). Due to their population dynamics, waterbirds are especially vulnerable to additive mortality (Bernotat & Dierschke 2021). Additional anthropogenic mortality that exceeds the potential rate of increase will eventually drive a population to extinction. It is thus necessary to keep the sum of all anthropogenic mortality, including bycatch, below a critical value.

High longevity is typical for the waterbirds found in the Baltic Sea. The mismatch between the loss of individuals and the effort to replace them is most pronounced in alcids which have a late sexual maturity and only low numbers of offspring, whereas ducks may compensate more easily owing to higher reproductive rates and lower ages of first breeding. However, other factors promoting or impeding population growth rates may override or possibly add to this pattern. For example, fluctuations in population sizes are at least partly caused by favourable supply of prey fish (increase of alcids; Österblom *et al.* 2006), reduced mussel stocks (common eider (*Somateria mollissima*); Laursen & Møller 2014) or low reproductive success (long-tailed duck (*Clangula hyemalis*); Hario *et al.* 2009).

Bycatch of waterbirds is typically occurring also in longline-fishing (Anderson *et al.* 2011) and the risk varying between species groups, but due to the very low overall effort of long-line fisheries in the Baltic Sea, and in the quasi-absence of data for these gears in the region, it is not considered further for HOLAS 3.

Recreational fisheries using static nets, traps and long-lines also contribute to bycatch of mammals and waterbirds. Their effort and spatiotemporal distribution as well as bycatch rates are largely unknown.

Seals

The three seal species all represent top predators in the Baltic Sea marine foodweb (see Chapter 7). They are also species with a high longevity and low reproductive rates. Their populations are therefore vulnerable to the loss of individual, especially of adults, as it takes a relatively long time to compensate for such losses. Due to their population dynamics, they are especially vulnerable to additive mortality (Bernotat & Dierschke 2021).

Seals in general have a higher maximum reproductive rate compared to cetaceans (Wade 1998). In contrast to harbour porpoises, they are still hunted in the Baltic Sea and, while the hunting quotas are set so that they do not affect the population increase, mortality from hunting represent a source of direct takes from the populations which needs to be considered together with mortality from bycatch when comparing anthropogenic mortality against a threshold value which still would allow reaching conservation objectives. Bycatch numbers of seals in static nets, traps and fyke nets are in the thousands (Vanhatalo *et al.* 2014) although reported numbers are orders of magnitude lower. The majority of seal population numbers are increasing, indicating that anthropogenic pressures, including bycatch, is not causing depletion (see section 7.4). However, all seal populations fail the threshold values for the respective indicators for population size and abundance (see section 7.3.2 as well as HELCOM 2023v, HELCOM 2023w and HELCOM 2023x) as all three species have population growth rates lower than the threshold value. This in turn indicate that pressures are impacting the population.

Harbour porpoise

Similar to the seal species, harbour porpoises are also a top predator in the Baltic Sea marine foodweb and a species with a high longevity and low reproductive rates (Chapter 7). Harbour porpoise populations are therefore vulnerable to the loss of individuals, especially of adults, as it takes a relatively long time to compensate for such losses. Due to their population dynamics, they are especially vulnerable to additive mortality (Bernotat & Dierschke 2021). Furthermore, harbour porpoises are also exposed to a number of other pressures, such as contaminants, that can cause immune function impairment or reproductive failure (e.g. Siebert *et al.* 1999, Beineke *et al.* 2005, 2007a, 2007b, Ciesielski *et al.* 2006, Murphy *et al.*2015). It is thus important to consider these additional effects when estimating threshold value limits for takes. Harbour porpoises in the Baltic Sea show a marked reduction in lifespan when compared to individuals in the North Sea, with the average age at death in animals stranded along the German Baltic Sea coast being only 3.67 (±0.30) years, significantly less than in North Sea animals.

Otters

During the 1970s, Eurasian otters had disappeared along the coasts of the Baltic Sea. Environmental contaminants such as PCBs, DDT, dieldrin and mercury have shown to be among the leading causes of the decrease in the population. In the 1980s, otters were only found in small, scattered areas in Sweden and they were absent from the Baltic coast. Since then the population started to recover and otters have been re-established in many coastal habitats (Norrgren & Levengood 2012). The Eurasian otter is recognised as another mammal species which is sensitive to bycatch and otters are known to be by-caught in static nets and traps (Hauer *et al.* 2020). They often use coastal areas and are mainly territorial whereas juveniles disperse over wider areas. Due to their coastal distribution otters may be especially vulnerable to specific gear such as static nets, fyke nets and traps, both commercial and recreational, and may need more attention in future assessments. However, the otter abundance in the Baltic Sea is not monitored and also bycatch is rarely reported. Hence, no evaluation can be made for HOLAS 3 due to lack of data. In Norway it has been shown that bycatch in local fisheries disrupts the natural re-establishment in otter habitats (Landa & Guidos 2020).

9.1.2 Bycatch in environmental management

Understanding the magnitude, impact and spatiotemporal variability of bycatch is important in order to implement adequate mitigation measures that reduce bycatch. Incorporating bycatch into the status assessment of waterbirds and mammals is an important tool for detecting the effect of additional mortality from bycatch on the overall status of key populations of these highly mobile species. The populations of marine mammals (cetaceans and seals) and diving waterbirds assessed represent species which are sensitive to additive mortality caused by various métiers of fishing gear due to their characteristic slow reproduction rate. The distribution and abundance of piscivorous species are closely linked to abundant fish stocks as is the distribution of fishing activities.

Drowning and asphyxia due to by-catch in fishing gear is a significant pressure on waterbirds (Tasker *et al.* 2000, Žydelis *et al*. 2009, Žydelis *et al.* 2013, Lewison *et al*. 2014, Northridge *et al*. 2017). In vulnerable waterbird species, many of which are included in this assessment (e.g. long-tailed duck, velvet scoter (*Melanitta fusca*), and greater scaup (*Aythya marila*)), the numbers of drowned birds have been found to be caught in large numbers and in similar propotions across several Baltic Sea countries and may represent a relatively large proportion of the total population size (Stempniewicz 1994, Urtans and Priednieks 2000, Žydelis 2002, Larsson and Tydén 2005, Bellebaum *et al.* 2013, Morkūnas *at al.* 2022). Bycatch is an additional source of human induced mortality for waterbirds as in some Baltic Sea countries selected waterbird species are also hunted (see Chapter 6, section 6.5.1. for information on mortality of seabirds from hunting during the assessment period), and oiling of birds can have an additional impact on waterbird populations (Larsson & Tydén 2005; Žydelis *et al.* 2006). This implies that the loss of individuals due to all human-induced mortality can impact the populations and needs to be taken into account.

For seals, bycatch in static nets or traps, especially for those without mitigation devices, has been shown to be an anthropogenic cause of death (Oksanen *et al.* 2015), with estimated mortality from bycatch for grey seal significantly exceed that of hunting (Vanhatalo *et al.* 2014, see section 7.5.1. for number of hunted seals during the assessment period).

For harbour porpoises, bycatch has been identified as the main known cause of human-related mortality and it is likely to inhibit population recovery towards conservation targets. For harbour porpoises, the bycatch risk is highest in various types of static nets, including gill nets and semi-driftnets (gear type: GNS) and entangling nets (trammel nets, GTR) (ICES 2016, MASTS 2016). Driftnets are banned in the Baltic Sea, but some hybrid nets such as ‘semi-driftnets’ which are fixed on one end of the net with the other end drifting around this anchor which are locally used in Poland are of special concern (Skóra & Kuklik 2003). Harbour porpoises are also facing a number of other human-induced pressures which affect their health, condition and longevity, including high levels of environmental contaminants. With a mean age at sexual maturity of 4.95 years, porpoise populations are especially vulnerable to factors that shorten the reproductive lifespan such as additional direct mortality (Kesselring *et al.* 2017) or pollution which has an impact on the reproductive success such as heavy metals and PCBs. Pollution load can result in impaired immune function (e.g. Siebert *et al.* 1999, Beineke *et al.* 2005, 2007a,b, Ciesielski *et al.* 2006) and reproductive failure (Murphy *et al.* 2015). A precautionary setting of the maximum reproductive rate, an important input value in population models used for assessments (in RLA and mPBR methods), is required from a conservation point of view.

The harbour porpoise population in the Baltic Proper requires special attention. Due to its very low population size, the additional mortality of each individual has the potential for a strong negative population consequences.

9.2. Assessment results for bycatch

The assessment shows that bycatches of marine mammals and waterbirds are generally too high, regarding additive mortality from bycatch in fishing gear and given the existing hunting mortality for some assessment units (Figure 9.1). This applies to all evaluated HELCOM subdivisions. Therefore, bycatch mortality is to be considered an ongoing and widespread threat for these populations.

When including bycatch in the integrated assessment using BEAT tool results the low number of species for which bycatch could be assessed results in a BQR which is considered to underestimate the effect of bycatch. This is due to the methodology of integrating from indicator to species status first which includes bycatch for only a small number of species of a group. The overall status is considered good if 75% of the species are in good status, regardless whether or not bycatch was assessed. The integrated results presented in figures 9.1 to 9.3 are thus biased towards the results of the abundance indicator evaluations underpinning the integrated assessment results.

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

9.2.1 Waterbirds

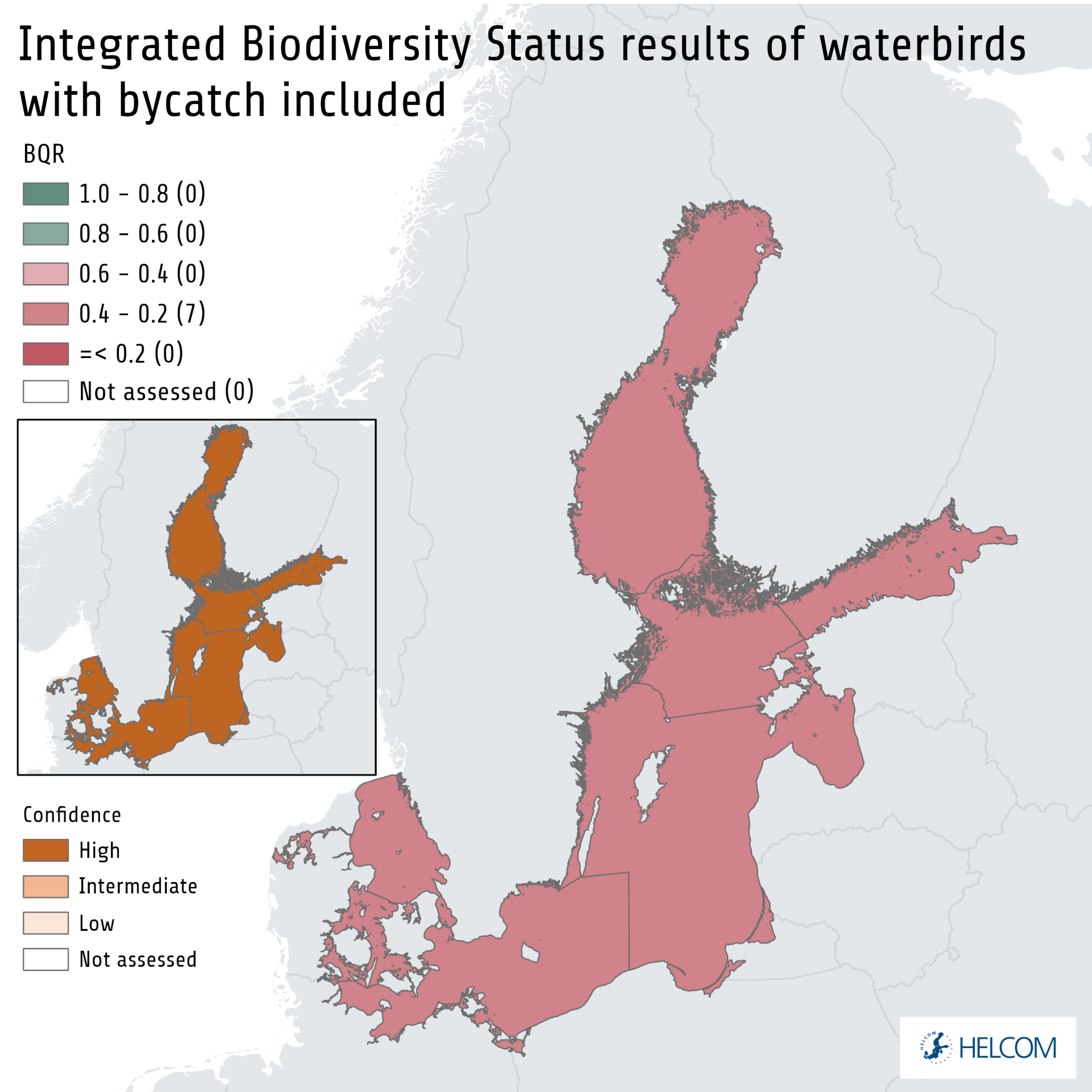


Figure 9.1. Integrated biodiversity status assessment results for waterbirds with bycatch, abundance (breeding and wintering seasons) and breeding success included in the assessment, as generated by the BEAT tool. A bycatch assessment was included for 11 out of 59 species assessments. Values >0.6 represent good status. Confidence is presented in the map insert.

It should be noted when utilising these results that bycatch of waterbirds is only evaluated for a small number of the overall species due to data availability. Thus, when the integrated assessment approach is applied the overall relevance of bycatch may be underestimated. This potential underestimation occurs both due to the lackof available information on all species in the assessment but also due to the structure of the integration approach that is based on species level information initially and then applies an assessment of a percentage of species within a given group.

Table 9.1. BEAT output from the integrated assessment of waterbirds with bycatch, abundance (breeding and wintering seasons) and breeding success included. The column "Sub-division" referes to the agreed name of each individual assessment area. "Spatial assessment unit level" indicates at what spatial resolution the assessment was conducted (see Section 2.3.2 or the HELCOM Monitoring and Assessment Strategy for more information on the assessment units used for HELCOM assessments). "Biological Quality Ration" represents the quantitative results of the integrated assessment for waterbirds, when bycatch is included in the assessment, with results >0.6 constituting Good Status (see Section 2.1.1 for more information on the BEAT tool). The following column indicates the proportion of the species included in the integrated assessment for this area which achieve the threshold of 75% of species being in good condition in order to indicate good status. The column "Status" indicates whether the quantitative assessment results achieve of fail the threshold for good status. The columns "Confidence" and "Confidence Class", respectively, provides a quantified value for confidence in the assessment and translates this value into a discreet confidence class, in line with the methodology outlined in Section 2.1.1. The results of the integrated assessment of waterbirds without bycatch included is presented to the right for comparison, as also presented in Chapter 6. The confidence values in the table refer to the confidence in the integrated assessment including bycatch. For confidence in the integrated assessment results for waterbirds, not including bycatch, please see Chapter 6. The assessment includes the entire Baltic Sea populations of the species indicated in table 9.4.

Sub-division	Spatial assessment unit level	Waterbirds integrated Biological Quality Ratio including bycatch	Proportion of species in good status, when bycatch is included	Status, including bycatch	Confidence	Confidence Class	Waterbirds integrated assessment Biological Quality Ratio excluding bycatch	Proportion of species in good status, when bycatch is included	Status, excluding bycatch
A: Kattegat (Kattegat)	2	0.3	0.0	Not good	0.87	High	0.3	0.2	not good
B: Belt Group (Great Belt, The Sound)	2	0.3	0.0	Not good	0.84	High	0.3	0.5	not good
C: Bornholm Group (Kiel Bay, Bay of Mecklenburg, Arkona Basin, Bornholm Basin)	2	0.3	0.3	Not good	0.92	High	0.3	0.5	not good
D: Gotland Group (Gdansk Basin, Eastern Gotland Basin, Western Gotland Basin, Gulf of Riga)	2	0.3	0.4	Not good	0.94	High	0.3	0.5	not good
E: Åland Group (Northern Baltic Proper, Åland Sea)	2	0.3	0.7	Not good	0.98	High	0.3	0.7	not good
F: Gulf of Finland (Gulf of Finland)	2	0.3	0.6	Not good	0.96	High	0.3	0.6	not good
G: Bothnian Group (Bothnian Sea, The Quark, Bothnian Bay).	2	0.3	0.3	Not good	1.00	High	0.3	0.3	not good

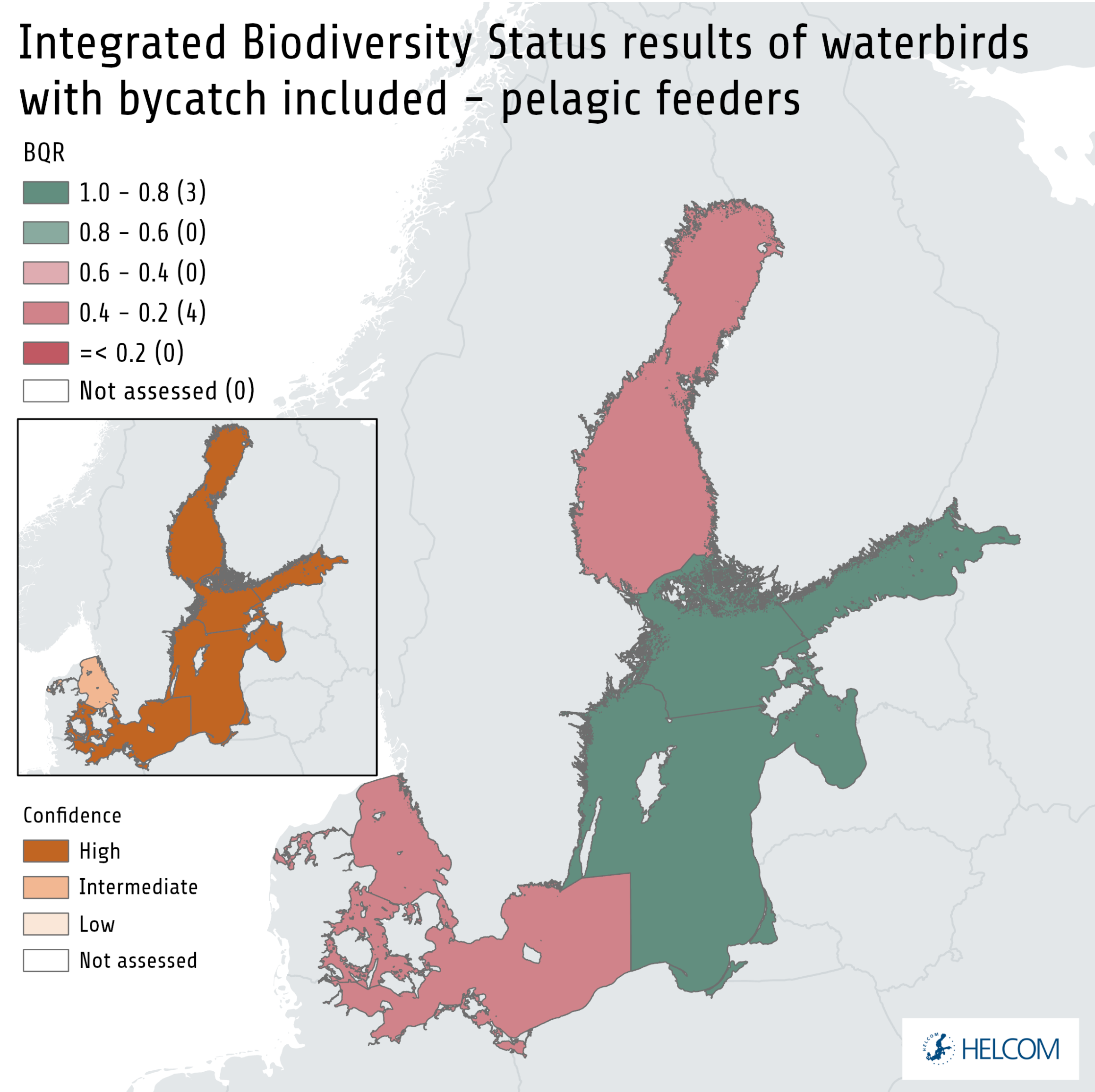


Figure 9.2. Integrated biodiversity status assessment results for pelagic-feeding waterbirds with bycatch, abudnace (breeding and wintering seasons) and breeding success included in the assessment, as generated by the BEAT tool. A bycatch assessment was included for 6 out of 16 species assessments. Values >0.6 represent good status. Confidence is presented in the map insert.

Table 9.2. BEAT output from the integrated assessment of pelagic-feeding waterbirds with bycatch, abundance (breeding and wintering seasons) and breeding success included. The column "Sub-division" referes to the agreed name of each individual assessment area. "Spatial assessment unit level" indicates at what spatial resolution the assessment was conducted (see Section 2.3.2 or the HELCOM Monitoring and Assessment Strategy for more information on the assessment units used for HELCOM assessments). "Biological Quality Ration" represents the quantitative results of the integrated assessment for waterbirds, when bycatch is included in the assessment, with results >0.6 constituting Good Status (see Section 2.1.1 for more information on the BEAT tool). The following column indicates the proportion of the species included in the integrated assessment for this area which achieve the threshold of 75% of species being in good condition in order to indicate good status. The column "Status" indicates whether the quantitative assessment results achieve of fail the threshold for good status. The columns "Confidence" and "Confidence Class", respectively, provides a quantified value for confidence in the assessment and translates this value into a discreet confidence class, in line with the methodology outlined in Section 2.1.1. The results of the integrated assessment of waterbirds without bycatch included is presented to the right for comparison, as also presented in Chapter 6. The confidence values in the table refer to the confidence in the integrated assessment including bycatch. For confidence in the integrated assessment results for waterbirds, not including bycatch, please see Chapter 6. The assessment includes the entire Baltic Sea populations of the species indicated in table 9.4.

Sub-division	AU level	Pelagic-feeding waterbirds Biological Quality Ratio including bycatch	Proportion of species in good status, when bycatch is included	Status, including bycatch	Confidence	Confidence Class	Pelagic-feeding waterbirds Biological Quality Ratio, excluding bycatch	Proportion of species in good status in this feeding group, excluding bycatch	Status, excluding bycatch
A: Kattegat (Kattegat)	2	0.3	0.5	not good	0.75	Intermediate	0.3	0.5	not good
B: Belt Group (Great Belt, The Sound)	2	0.3	0.3	not good	0.83	High	0.3	0.5	not good
C: Bornholm Group (Kiel Bay, Bay of Mecklenburg, Arkona Basin, Bornholm Basin)	2	0.3	0.6	not good	0.82	High	0.8	0.8	good
D: Gotland Group (Gdansk Basin, Eastern Gotland Basin, Western Gotland Basin, Gulf of Riga)	2	0.8	0.8	good	0.90	High	0.8	0.9	good
E: Åland Group (Northern Baltic Proper, Åland Sea)	2	0.8	0.9	good	1.00	High	0.8	0.9	good
F: Gulf of Finland (Gulf of Finland)	2	0.8	0.8	good	0.96	High	0.8	0.8	good
G: Bothnian Group (Bothnian Sea, The Quark, Bothnian Bay).	2	0.3	0.7	not good	1.00	High	0.3	0.7	not good

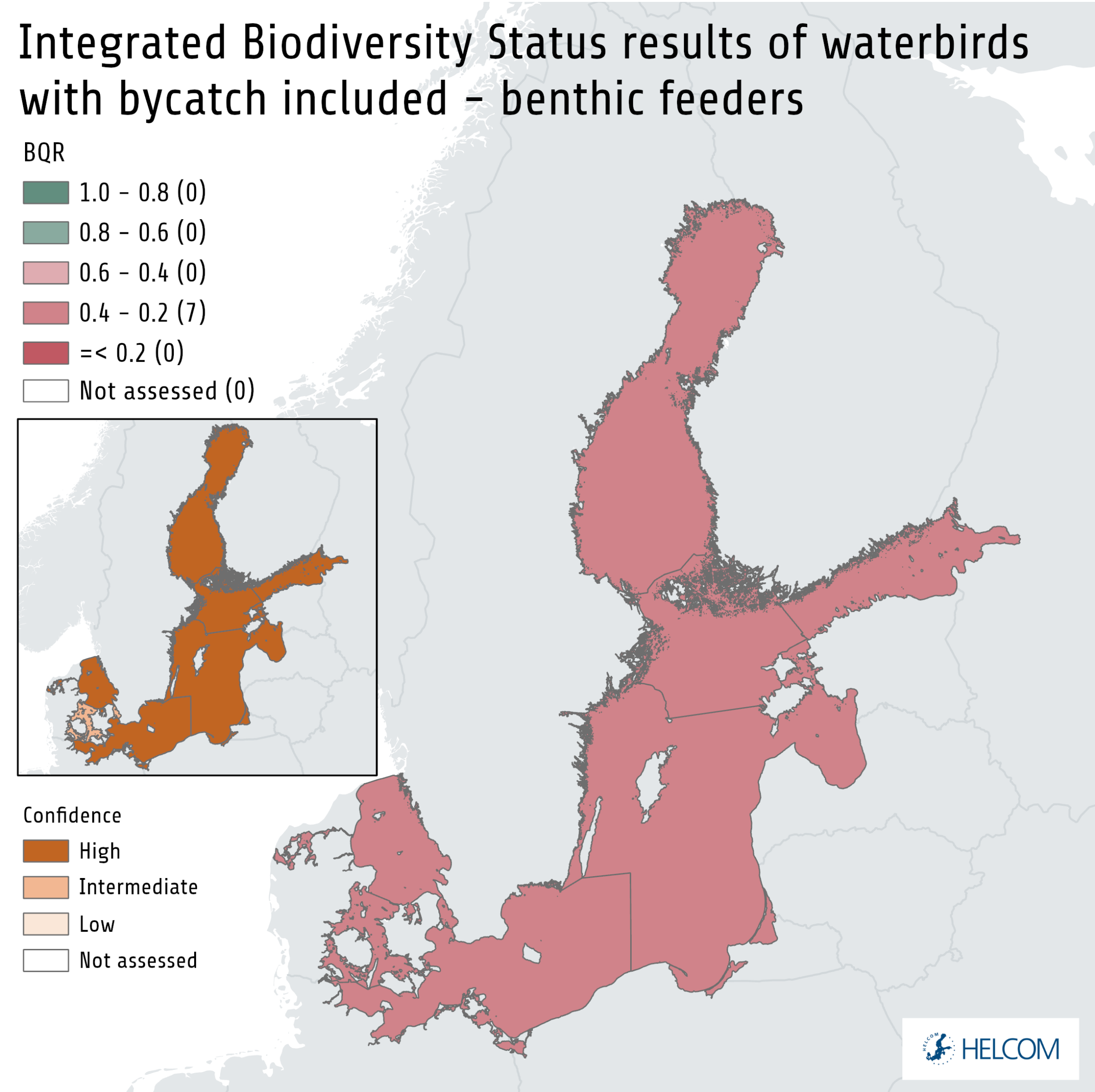


Figure 9.3. Integrated biodiversity status assessment results for benthic-feeding waterbirds with bycatch and abundance (breeding and wintering seasons) included in the assessment, as generated by the BEAT tool. A bycatch assessment was included for 5 out of 13 species assessments. Values >0.6 represent good status. Confidence is presented in the map insert.

Table 9.3. BEAT output from the integrated assessment of benthic-feeding waterbirds with bycatch, abundance (breeding and wintering seasons) and breeding success included. The column "Sub-division" referes to the agreed name of each individual assessment area. "Spatial assessment unit level" indicates at what spatial resolution the assessment was conducted (see Section 2.3.2 or the HELCOM Monitoring and Assessment Strategy for more information on the assessment units used for HELCOM assessments). "Biological Quality Ration" represents the quantitative results of the integrated assessment for waterbirds, when bycatch is included in the assessment, with results >0.6 constituting Good Status (see Section 2.1.1 for more information on the BEAT tool). The following column indicates the proportion of the species included in the integrated assessment for this area which achieve the threshold of 75% of species being in good condition in order to indicate good status. The column "Status" indicates whether the quantitative assessment results achieve of fail the threshold for good status. The columns "Confidence" and "Confidence Class", respectively, provides a quantified value for confidence in the assessment and translates this value into a discreet confidence class, in line with the methodology outlined in Section 2.1.1. The results of the integrated assessment of waterbirds without bycatch included is presented to the right for comparison, as also presented in Chapter 6. The confidence values in the table refer to the confidence in the integrated assessment including bycatch. For confidence in the integrated assessment results for waterbirds, not including bycatch, please see Chapter 6. The assessment includes the entire Baltic Sea populations of the species indicated in table 9.4.

Sub-division	AU level	Benthic-feeding waterbirds Biological Quality Ratio, including bycatch (BQR)	Proportion of species in good status when bycatch is included	Status, including bycatch	Confidence	Confidence Class	Benthic-feeding waterbirds Biological Quality Ratio, excluding bycatch (BQR)	Proportion of species in good status in this feeding group, excluding bycatch	Status, excluding bycatch
A: Kattegat (Kattegat)	2	0.3	0.0	not good	0.77	High	0.3	0.2	not good
B: Belt Group (Great Belt, The Sound)	2	0.3	0.0	not good	0.54	Intermediate	0.3	0.6	not good
C: Bornholm Group (Kiel Bay, Bay of Mecklenburg, Arkona Basin, Bornholm Basin)	2	0.3	0.3	not good	0.88	High	0.3	0.6	not good
D: Gotland Group (Gdansk Basin, Eastern Gotland Basin, Western Gotland Basin, Gulf of Riga)	2	0.3	0.4	not good	0.86	High	0.3	0.5	not good
E: Åland Group (Northern Baltic Proper, Åland Sea)	2	0.3	0.7	not good	0.91	High	0.3	0.7	not good
F: Gulf of Finland (Gulf of Finland)	2	0.3	0.6	not good	0.93	High	0.3	0.6	not good
G: Bothnian Group (Bothnian Sea, The Quark, Bothnian Bay).	2	0.3	0.3	not good	1.00	High	0.3	0.3	not good

The results of the integrated assessment indicate that bycatch impacts pelagic- and benthic-feeding waterbirds, as might be deduced based on the feeding behaviour and -areas of these species, making them more prone to come in contact with fishing gear compared to surface-feeders, waders or grazers for which bycatch was not assessed. This is in line with studies which show that both piscivorous birds (divers, grebes, mergansers, auks, cormorants) and benthophagic ducks are susceptible to entanglement and drowning in fishing gear (for an overview see HELCOM 2013c, Morkūnas *et al.* 2022). Table 9.4 shows an overview of what pelagic and benthic feeding species are included in the assessment.

When including by-catch information to the assessment of status, compared to what has been done for the integrated assessment results presented in chapter 6, the proportions of species evaluated to be in good status decreases in the species groups benthic-feeding birds and pelagic-feeding birds for almost all sub-basins (Tables 9.2 and 9.3) across both the assessment for all birds and the assessments for functional groups. Inclduing bycatch in the assessment changes the status for pelagic feeding birds in Kiel Bay, Bay of Mecklenburg, Arkona Basin and Bornholm Basin, where the inclusion of bycatch into the assessments shifts the integrated status for this functional group and areas from good to not good (Figure 9.2). Bycatch of surface feeding birds, wading birds and grazing birds was not assessed, and no bycatch information is presented for the areas Northern Baltic Proper, Gulf of Finland, Åland Sea, Bothnian Sea, The Quark, Bothnian Bay.

The results indicate that bycatch has a clear impact on pelagic and benthic feeders (Figures 9.2 and 9.3), based on the proportion of assessed species having good status within each of these groups otherwise (Table 5.3). The effect is most pronounced in the Great Belt and the Sound, where the number of species which achieve threshold values for good status is more than halfed when bycatch is included in the integration. This result may, however, reflect better data quality and higher data availability for these sub-basins due to the use of onboard video monitoring for bycatch, showing the importance of high quality data to ensure reliable assessment results for this pressure.

Table 9.4. Overview of species included in the functional groups pelagic and benthic feeders included in the integrated assessment. The species for which a bycatch evaluation within each group was done are presented in bold lettering.

pelagic feeders	smew	Wintering
	goosander	Breeding/wintering
	red-breasted merganser	Breeding/wintering
	great crested grebe	Breeding/wintering
	Slavonian grebe	Wintering
	red-necked grebe	Wintering
	red-throated diver	Wintering
	black-throated diver	Wintering
	great cormorant	Breeding/wintering
	razorbill	Breeding
	common guillemot	Breeding
	black guillemot	Breeding
benthic feeders	common pochard	Wintering
	tufted duck	Breeding/wintering
	greater scaup	Breeding/wintering
	common eider	Breeding/wintering
	Steller's eider	Wintering
	long-tailed duck	Wintering
	common scoter	Wintering
	velvet scoter	Breeding/wintering
	common goldeneye	Wintering

9.2.2 Seals

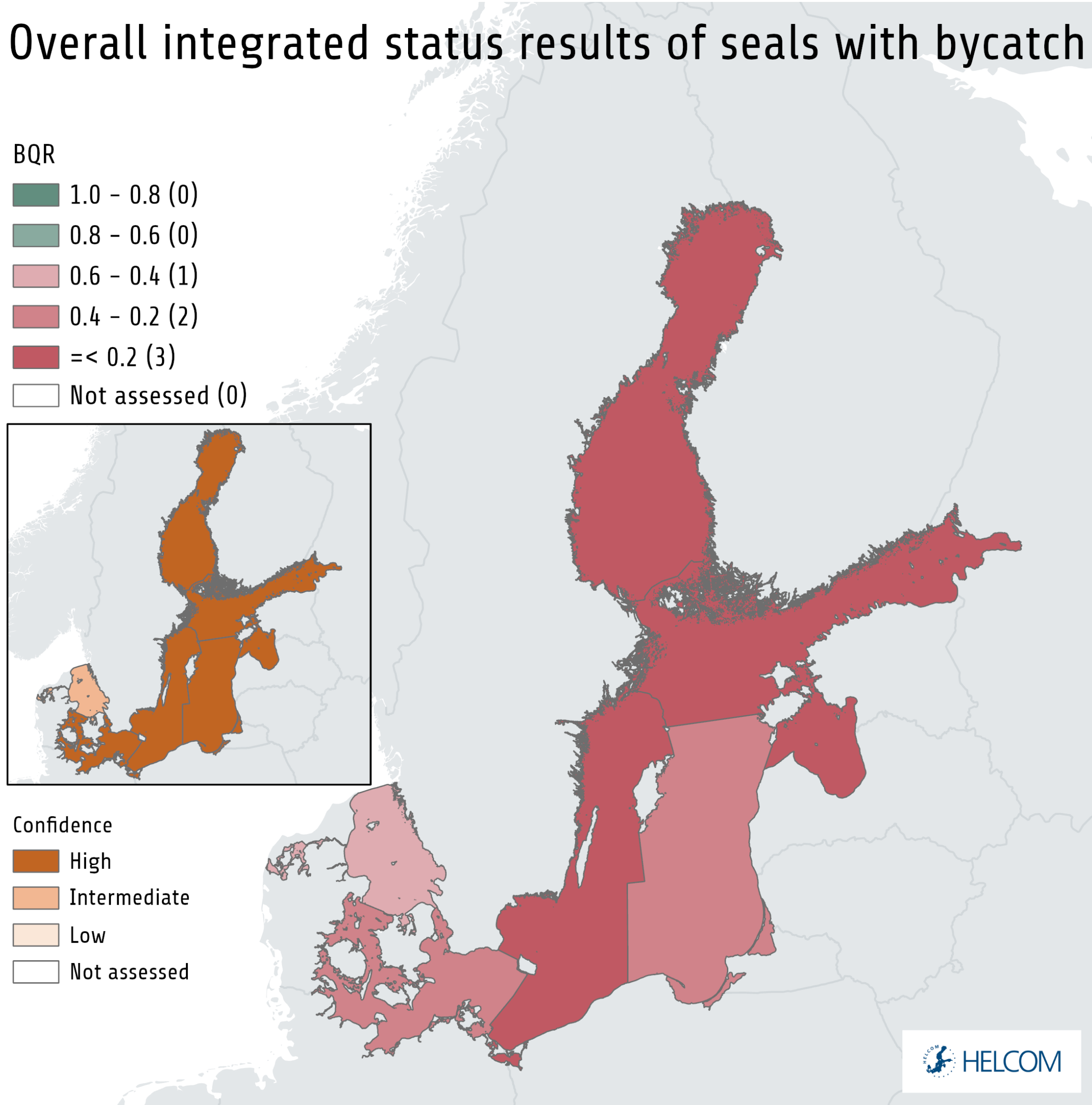


Figure 9.4. Integrated biodiversity status assessment results for seal with bycatch included in the assessment, as generated by the BEAT tool. Values >0.6 represent good status. Confidence is presented in the map insert.

Table 9.5. BEAT output from the integrated assessment of seals with bycatch included. The column "Sub-division" referes to the agreed name of each individual assessment area. "Spatial assessment unit level" indicates at what spatial resolution the assessment was conducted (see Section 2.3.2 or the HELCOM Monitoring and Assessment Strategy for more information on the assessment units used for HELCOM assessments). "Biological Quality Ration" represents the quantitative results of the integrated assessment for waterbirds, when bycatch is included in the assessment, with results >0.6 constituting Good Status (see Section 2.1.1 for more information on the BEAT tool). The column "Status" indicates whether the quantitative assessment results achieve of fail the threshold for good status. The columns "Confidence" and "Confidence Class", respectively, provides a quantified value for confidence in the assessment and translates this value into a discreet confidence class, in line with the methodology outlined in Section 2.1.1. presented in Chapter 7. The confidence values in the table refer to the confidence in the integrated assessment including bycatch. For confidence in the integrated assessment results for grey seal excluding bycatch, please see Chapter 7. The assessment includes the entire Baltic Sea populations of the species.

Sub-division	Spatial assessment unit level	Seal Biological Quality Ratio, including bycatch	Status including bycatch	Confidence	Confidence Class	Seal Biological Quality Ratio, excluding bycatch	Status excluding bycatch
Kattegat	13	0.6	not good	0.56	Moderate	0.6	not good
South-Western Baltic (Arkona basin, Kiel Bay, Bay of Mecklenburg, The Sound and Belt Sea)	13	0.3	not good	0.82	Good	0.3	not good
Remaining areas (Eastern Gotland Basin and Gdansk Basin)	13	0.3	not good	0.86	Good	0.3	not good
Kalmarsund area (Western Gotland Basin + Bornholm Basin)	13	0.2	not good	0.78	High	0.2	not good
outh-Western Archipelago sea (Northern Baltic Proper, Åland Sea, Gulf of Finland and Gulf of Riga)	13	0.1	not good	0.85	High	0.1	not good
Gulf of Bothnia (Bothnian Bay, Bothnian Sea and The Quark)	13	0.2	not good	0.84	High	0.2	not good

Table 9.6. BEAT output from the integrated assessment of grey seals with bycatch included. The column "Sub-division" referes to the agreed name of each individual assessment area. "Spatial assessment unit level" indicates at what spatial resolution the assessment was conducted (see Section 2.3.2 or the HELCOM Monitoring and Assessment Strategy for more information on the assessment units used for HELCOM assessments). "Biological Quality Ration" represents the quantitative results of the integrated assessment for seals, when bycatch is included in the assessment, with results >0.6 constituting Good Status (see Section 2.1.1 for more information on the BEAT tool). The column "Status" indicates whether the quantitative assessment results achieve of fail the threshold for good status. The columns "Confidence" and "Confidence Class", respectively, provides a quantified value for confidence in the assessment and translates this value into a discreet confidence class, in line with the methodology outlined in Section 2.1.1. presented in Chapter 7. The confidence values in the table refer to the confidence in the integrated assessment including bycatch. For confidence in the integrated assessment results for grey seal excluding bycatch, please see Chapter 7. The assessment includes the entire Baltic Sea populations of the species.

Sub-division	Spatila assessment unit level	Grey seal Biological Quality Ratio, including bycatch	Status including bycatch	Confidence	Confidence Class	Grey seal Biological Quality Ratio, excluding bycatch	Status excluding bycatch
South-Western Baltic (Arkona basin, Kiel Bay, Bay of Mecklenburg, The Sound and Belt Sea)	2	0.3	not good	0.86	High	0.3	not good
Remaining areas (Eastern Gotland Basin and Gdansk Basin)	2	0.3	not good	0.86	High	0.3	not good
Kalmarsund area (Western Gotland Basin + Bornholm Basin)	2	0.3	not good	0.86	High	0.3	not good
South-Western Archipelago sea (Northern Baltic Proper, Åland Sea, Gulf of Finland and Gulf of Riga)	2	0.3	not good	0.86	High	0.3	not good
Gulf of Bothnia (Bothnian Bay, Bothnian Sea and The Quark)	2	0.3	not good	0.96	High	0.3	not good

Grey seal

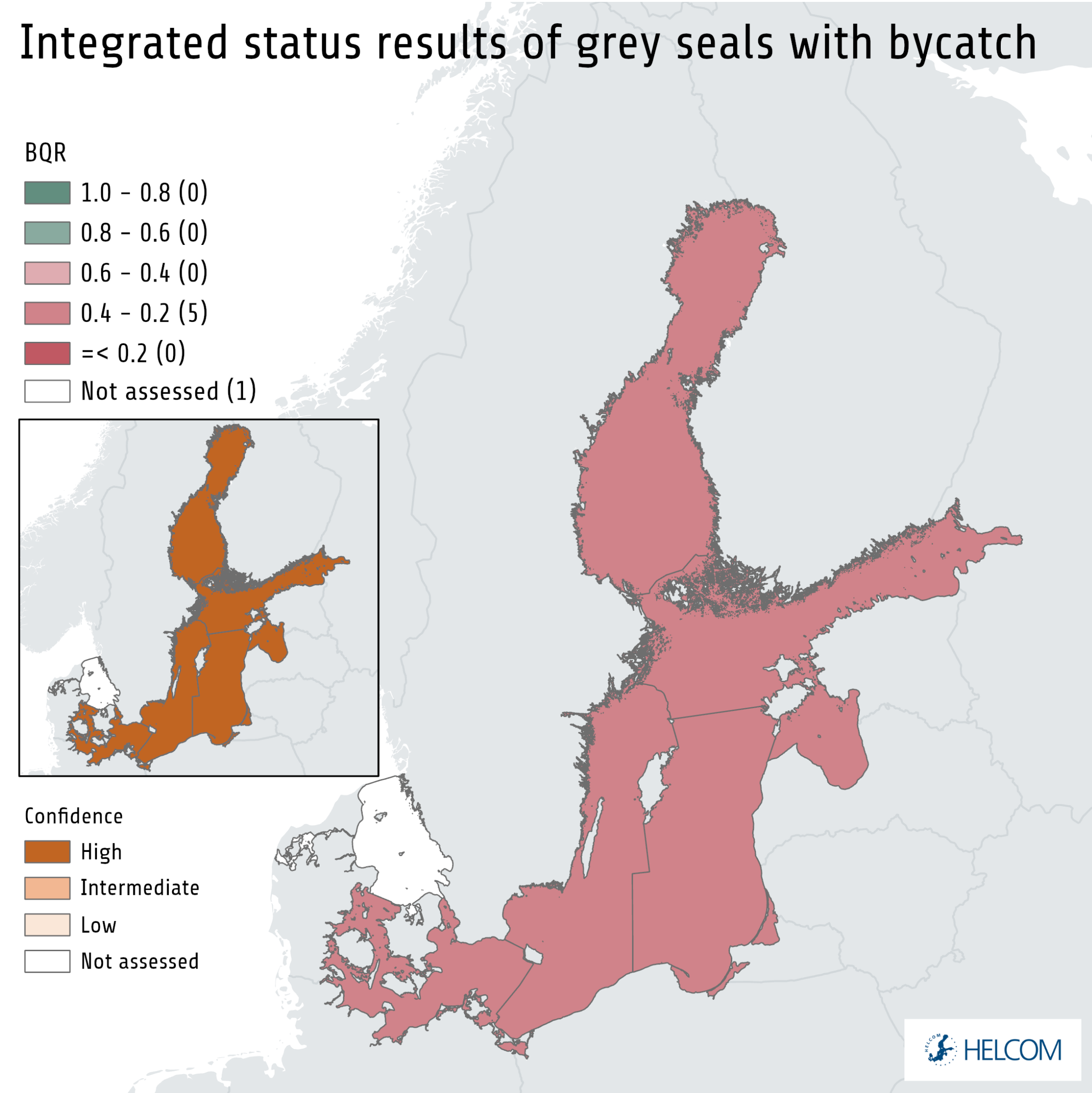


Figure 9.5. Integrated biodiversity status assessment results for grey seal with bycatch included in the assessment, as generated by the BEAT tool. Values >0.6 represent good status. Confidence is presented in the map insert.

Ringed seal

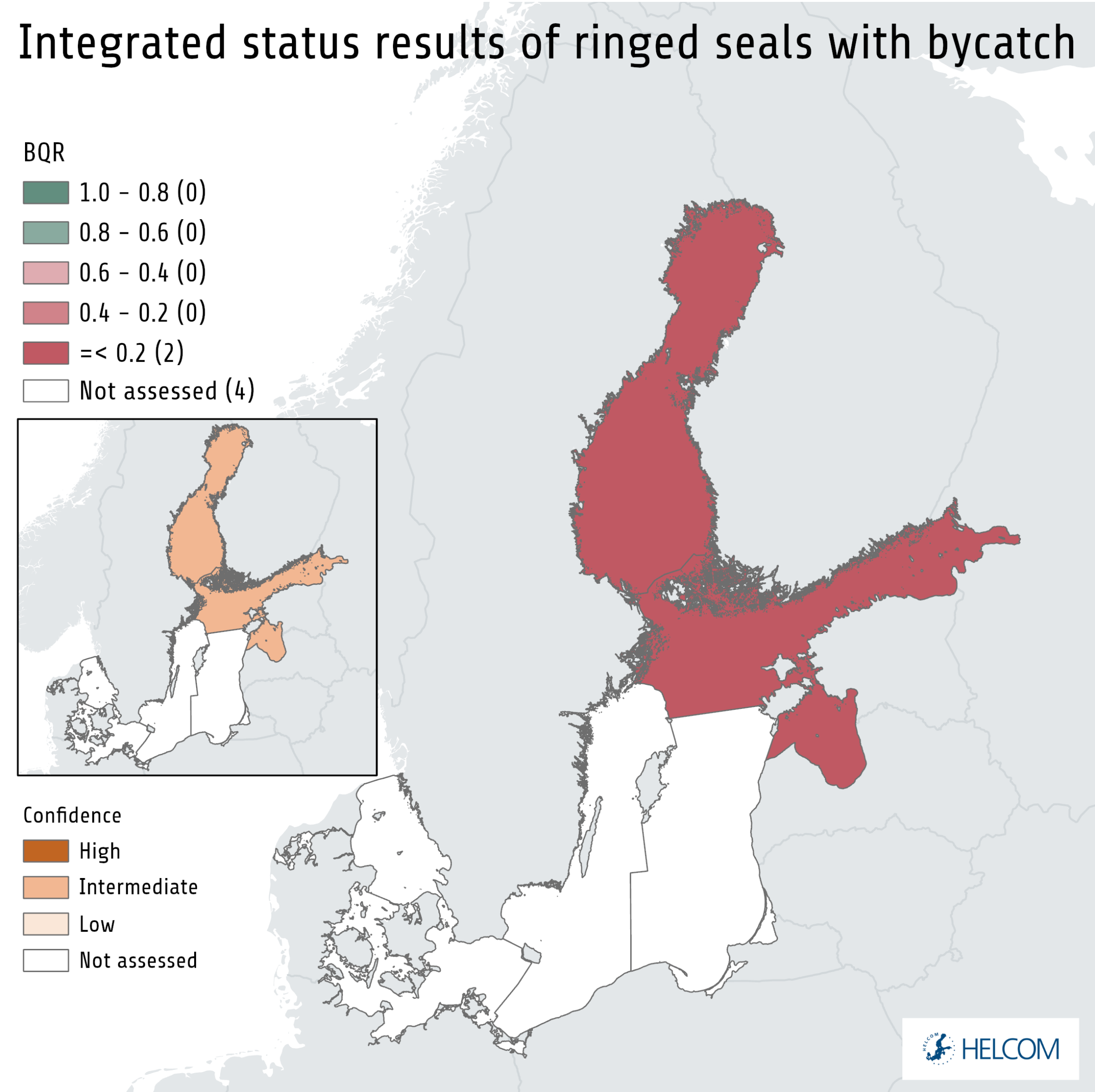


Figure 9.6. Integrated biodiversity status assessment results for ringed seal with bycatch included in the assessment, as generated by the BEAT tool. Values >0.6 represent good status. Confidence is presented in the map insert.

Table 9.7. BEAT output from the integrated assessment of ringed seals with bycatch included. The column "Sub-division" referes to the agreed name of each individual assessment area. "Spatial assessment unit level" indicates at what spatial resolution the assessment was conducted (see Section 2.3.2 or the HELCOM Monitoring and Assessment Strategy for more information on the assessment units used for HELCOM assessments). "Biological Quality Ration" represents the quantitative results of the integrated assessment for seals, when bycatch is included in the assessment, with results >0.6 constituting Good Status (see Section 2.1.1 for more information on the BEAT tool). The column "Status" indicates whether the quantitative assessment results achieve of fail the threshold for good status. The columns "Confidence" and "Confidence Class", respectively, provides a quantified value for confidence in the assessment and translates this value into a discreet confidence class, in line with the methodology outlined in Section 2.1.1. presented in Chapter 7. The confidence values in the table refer to the confidence in the integrated assessment including bycatch. For confidence in the integrated assessment results for ringed seal excluding bycatch, please see Chapter 7. The assessment includes the entire Baltic Sea populations of the species.

Sub-division	Spatial assessment unit level	Grey seal Biological Quality Ratio, including bycatch	Status including bycatch	Confidence	Confidence Class	Grey seal Biological Quality Ratio, excluding bycatch	Status excluding bycatch
South-Western Archipelago sea (Northern Baltic Proper, Åland Sea, Gulf of Finland and Gulf of Riga)	2	0.1	not good	0.71	Intermediate	0.1	not good
Gulf of Bothnia (Bothnian Bay, Bothnian Sea and The Quark)	2	0.2	not good	0.72	Intermediate	0.2	not good

Harbour seal

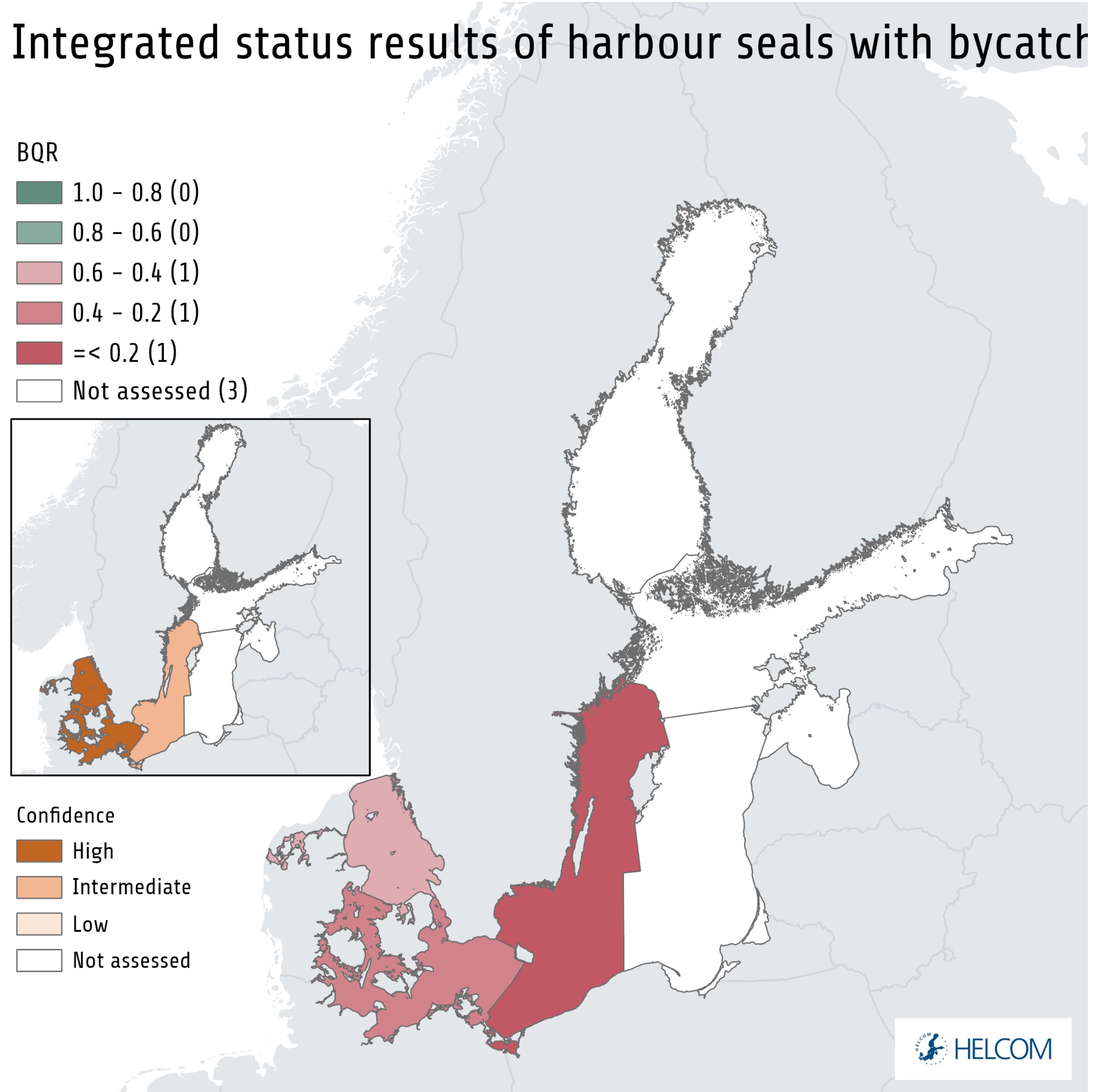


Figure 9.7. Integrated biodiversity status assessment results for harbour seals with bycatch included in the assessment, as generated by the BEAT tool. Values >0.6 represent good status. Confidence is presented in the map insert. Note that bycatch is only included for the Kalmarsund population in this integrated assessment and the evaluation of the Southwestern Baltic and Kattegat population is based only on other indictator evaluations, excluding bycatch.

With the exception of harbour seal in Bornholm and Western Gotland Basin, where the inclusion of bycatch in the status assessment results in a concrete deteriorated integrated assessment result, there are no changes between the assessment results across the integrated assessment results presented in chapter 7 (where bycatch is not included in the assessment) and those presented in this chapter (Figures 9.4-9.7 and Tables 9.5-9.8). It is worth noting that the evaluation of bycatch is severely hampered by lack of data.

Table 9.8. BEAT output from the integrated assessment of harbour seals with bycatch included. The column "Sub-division" referes to the agreed name of each individual assessment area. "Spatial assessment unit level" indicates at what spatial resolution the assessment was conducted (see Section 2.3.2 or the HELCOM Monitoring and Assessment Strategy for more information on the assessment units used for HELCOM assessments). "Biological Quality Ration" represents the quantitative results of the integrated assessment for seals, when bycatch is included in the assessment, with results >0.6 constituting Good Status (see Section 2.1.1 for more information on the BEAT tool). The column "Status" indicates whether the quantitative assessment results achieve of fail the threshold for good status. The columns "Confidence" and "Confidence Class", respectively, provides a quantified value for confidence in the assessment and translates this value into a discreet confidence class, in line with the methodology outlined in Section 2.1.1. presented in Chapter 7. The confidence values in the table refer to the confidence in the integrated assessment including bycatch. For confidence in the integrated assessment results for harbour seal excluding bycatch, please see Chapter 7. The assessment includes the entire Baltic Sea populations of the species.

Sub-divsion	Spatial assessment unit level	Harbour seal Biological Quality Ratio including bycatch	Status including bycatch	Confidence	Confidence Class	Harbour seal Biological Quality Ratio, excluding bycatch	Status excluding bycatch
Kattegat	2	0.6	not good	0.88	High	0.6	not good
South-Western Baltic (Arkona basin, Kiel Bay, Bay of Mecklenburg, The Sound and Belt Sea)	2	0.3	not good	0.79	High	0.3	not good
Kalmarsund area (Western Gotland Basin + Bornholm Basin)	2	0.2	not good	0.71	Intermediate	0.3	not good

9.2.3 Harbour porpoise

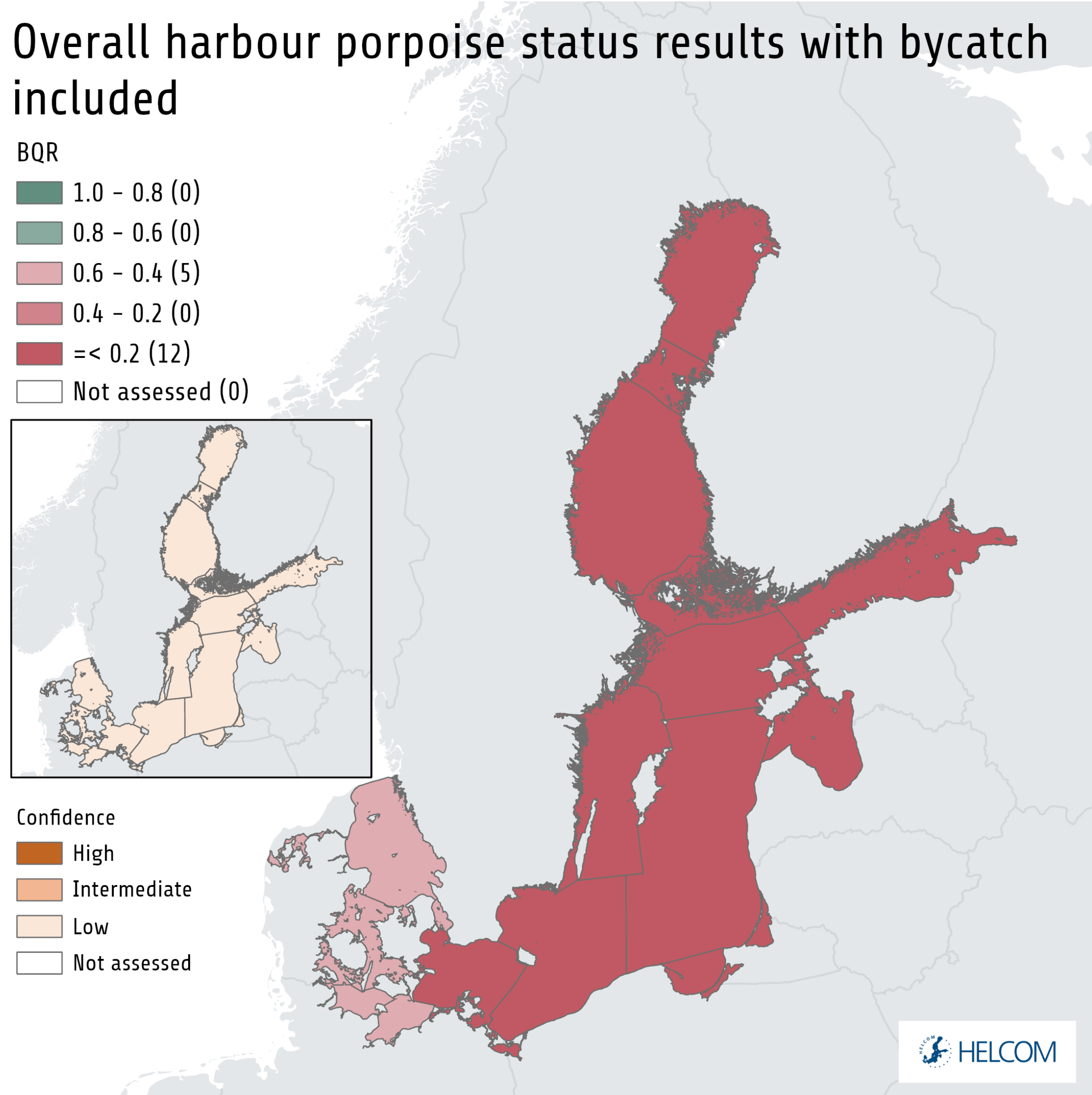


Figure 9.8 Integrated biodiversity status assessment results for harbour porpoise with bycatch included in the assessment, as generated by the BEAT tool. Values >0.6 represent good status. Confidence is presented in the map insert. It should be noted that this figure represents a combination of the evaluations on abundance, distribution and bycatch, thus although bycatch may not currently occur in for example the Gulf of Bothnia the overall integrated assessment still fails to achieve Good Environmental Status due to the other parameters evalauted.

The majority of the Baltic Sea falls under the lowest category with regards to status (Figure 9.8). There are no changes between the assessment results across the integrated assessment results presented in Chapter 7 (where bycatch is not included in the assessment) and those presented in this chapter (Table 9.9). It is worth noting that the evaluation of bycatch is severely hampered by lack of data and the confidence in the results are low.

Table 9.9. BEAT output from the integrated assessment of harbour porpoise with bycatch included. The column "Sub-basin" referes to the agreed name of each individual assessment area. "Spatial assessment unit level" indicates at what spatial resolution the assessment was conducted (see Section 2.3.2 or the HELCOM Monitoring and Assessment Strategy for more information on the assessment units used for HELCOM assessments). "Biological Quality Ration" represents the quantitative results of the integrated assessment for harbour porpoise, when bycatch is included in the assessment, with results >0.6 constituting Good Status (see Section 2.1.1 for more information on the BEAT tool). The column "Status" indicates whether the quantitative assessment results achieve of fail the threshold for good status. The columns "Confidence" and "Confidence Class", respectively, provides a quantified value for confidence in the assessment and translates this value into a discreet confidence class, in line with the methodology outlined in Section 2.1.1. presented in Chapter 7. The confidence values in the table refer to the confidence in the integrated assessment including bycatch. For confidence in the integrated assessment results for grey seal excluding bycatch, please see Chapter 7. The assessment includes the entire Baltic Sea populations of the species.

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

9.2.4 Indicator evaluation of drowned mammals and waterbirds in fishing gear

The results of the indicator evaluation 'Drowned mammals and waterbirds in fishing gear' demonstrate that significant mortality from bycatch in fishing gear is widespread across species of marine mammals and waterbirds in the Baltic Sea (HELCOM 2023n).

In this indicator marine mammals were evaluated on the population level. None of the populations of each of four species of marine mammals (harbour porpoise, ringed seal, harbour seal, grey seal) achieved good status (Figure 9.9). The harbour seal population of the South-western Baltic and Kattegat could not be evaluated. In mammals, the effect of additional anthropogenic mortality on the population is assessed using methods based on population models. For these models it does not make a difference if an animal is bycaught or killed in another way. Numbers of hunted seals often already contribute to removal from a population in a considerable amount. Since bycatch numbers are far from complete, the population effect might be larger than the sum of hunted and bycaught numbers suggest.

Waterbirds were evaluated on the geographical scale of subdivisions (aggregated sub-basins, see section 9.5.3 furhter details and a visual representation of the subdivisions), with evaluations available for a total of 11 species in four of the total seven subdivisions (Figure 9.10). The threshold for good status was not met in any case. The results of this indicator demonstrate that significant mortality from bycatch in fishing gear is widespread across species of marine mammals and waterbirds in the Baltic Sea. As in seals, in some species hunting may contribute to excess mortality which has a possible population impact.

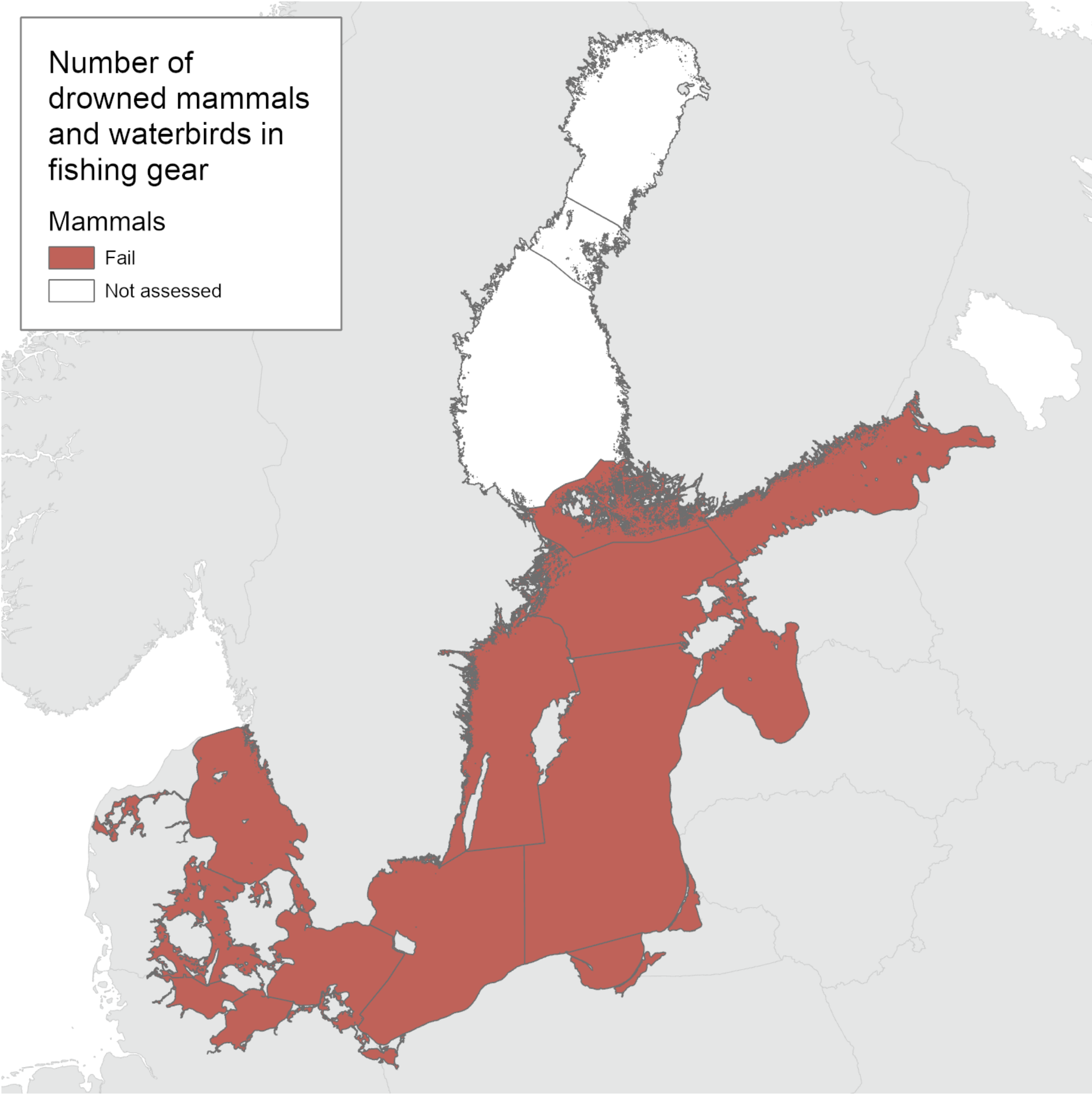


Figure 9.9. Status evaluation results based on evaluation of the indicator 'Number of drowned mammals and waterbirds in fishing gear': marine mammals. The evaluation is carried out using Baltic Sea sub-basins of Scale 2 HELCOM assessment units. (Source: HELCOM 2023n).

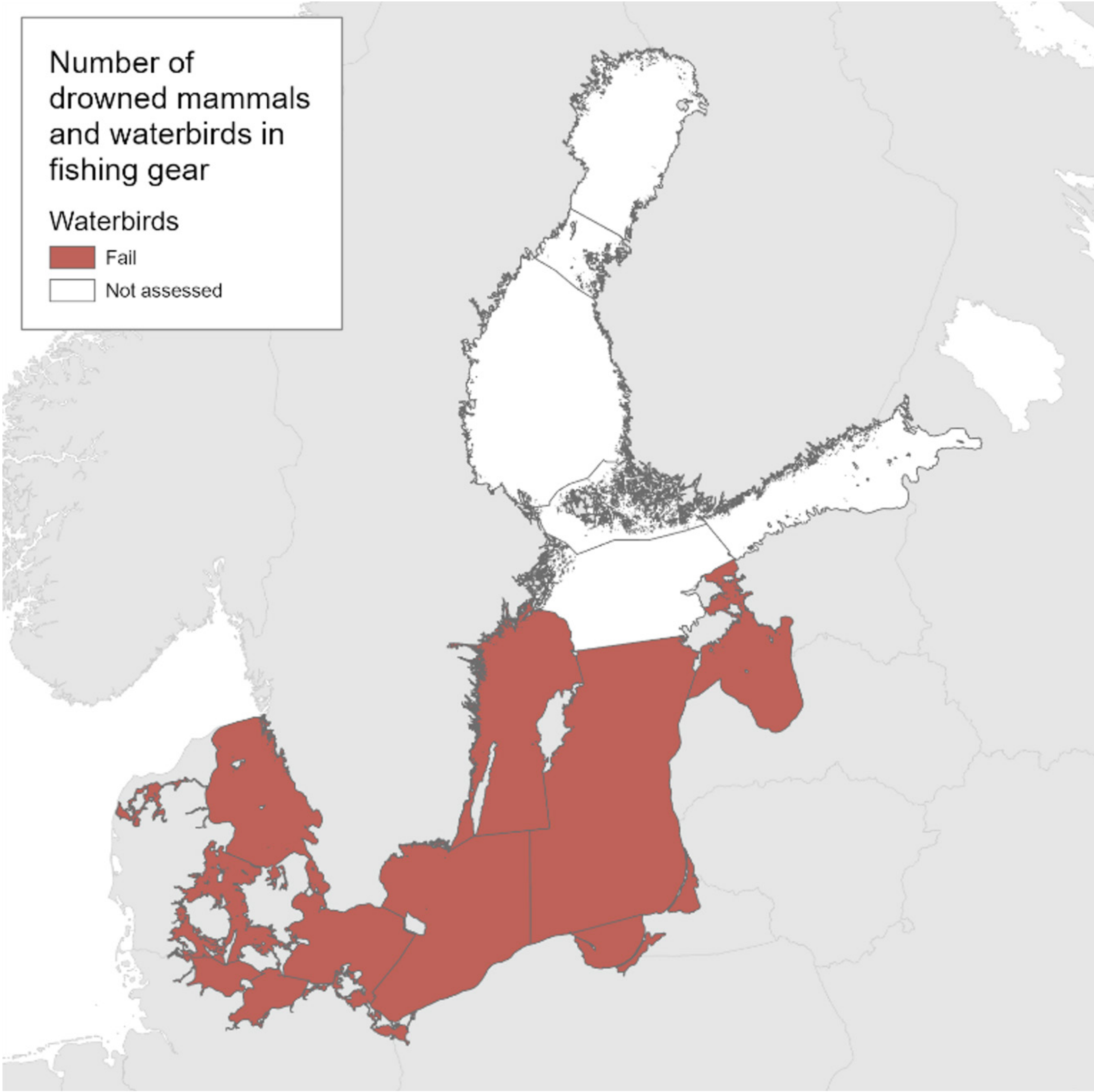


Figure 9.10. Status evaluation results based on evaluation of the indicator 'Number of drowned mammals and waterbirds in fishing gear': waterbirds. The evaluation is carried out using subdivisions of the Baltic Sea. (Source: HELCOM 2023n).

9.2.5 Threatened species included in the bycatch assessment

Most of the mammal populations and all bird populations included in the assessment are of conservation concern. E.g. all waterbird species evaluated are already classified as vulnerable, endangered or even critically endangered by HELCOM (HELCOM 2013c) (see Chapter 10, Table 9.10). In these species/populations, bycatch is a threat which continues to contribute to further decline and/or inhibiting recovery towards favourable conservation status. PBR- and mPBR-derived threshold values for marine mammals show that already small numbers of by-caught animals are problematic for marine mammal populations, and these low threshold valus are exceeded.

9.3. Changes over time for bycatch

9.3.1 Trends in status between assessments

No prior evaluation has been applied for bycatch, which in HOLAS II was only covered descriptively. Therefore it is not possible to directly compare status between assessment periods. Based on information from literature about the distribution of marine mammals and waterbirds as well as on bycatch in fishing gear (e.g., Brennecke *et al*., 2021, Morkūnas *et al*., 2022) it would be expected that no change in status category has occurred between HOLAS II (2011-2016) and HOLAS 3 (2016-2021).

9.3.2 Long term trends

Due to reduced fishing opportunities of cod (*Gadus morhua*) and herring (*Clupea harengus*) since 2018 and the prohibition of all targeted fishing for Western Baltic cod implemented since 2019, there was likely a decreased effort in commercial static net fisheries in parts of the region in recent years.

Bycatch of harbour porpoises in the Baltic Proper was reportedly high before the 1970's. Ropelewski (1957) reported for the Polish fishery annual bycatches between 16 and 250 porpoises (period 1922-1924) and between 23 and 114 porpoises (period 1928-1932). Lindroth (1962) reported 49 bycatches in Swedish salmon driftnet fisheries during a single year. Current lower bycatch numbers reflect the steep population decline since then (Koschinski 2002, Brennecke *et al*., 2021). This shows that a trend based bycatch evaluation alone would not reflect the status well as it does not account fully for population abundance aspects (e.g., potential risk of bycatch) or changes in fisheries pressures (e.g., level, extent, or gear use). For the harbour porpoise populations and the evaluated seal populations no reliable baseline data on bycatch rates exists, thus carrying out a sufficient trend analyses is problematic.

Bycatch of waterbirds in fishing gear, especially in static nets, is well known in the Baltic Region since at least the 1920s, when for example numerous black-throated divers (*Gavia arctica*) were reported to be caught in salmon drift nets (Schüz 1935).

Long term trends in the amount of mammal and waterbird bycatch are currently not available because

i) many studies have been running only for a short time,
ii) monitoring of waterbird and mammal bycatch is often insufficient, because the métiers responsible for bycatch are not covered adequately,
iii) monitoring using modern techniques (e.g., electronic monitoring with camera) is relatively new, rarely used and cannot provide long data series yet.

Table 9.10. Overview of species included in the assessment of bycatch which are listed as as vulnerable (VU), endangered (EN) or critically endangered (CR) on the HELCOM Red List (HELCOM 2013c).

Aythya marila (breeding)	Greater scaup	Birds	VU
Cepphus grylle arcticus (wintering)	Black guillemot	Birds	VU
Clangula hyemalis (wintering)	Long-tailed duck	Birds	EN
Gavia arctica (wintering)	Black-throated diver	Birds	CR
Gavia stellata (wintering)	Red-throated diver	Birds	CR
Melanitta fusca (wintering EN, breeding VU)	Velvet scoter	Birds	EN
Melanitta nigra (wintering)	Common scoter	Birds	EN
Mergus serrator (wintering)	Red-breasted merganser	Birds	VU
Podiceps auritus (breeding VU, wintering NT)	Slavonian grebe	Birds	VU
Podiceps grisegena (wintering)	Red-necked grebe	Birds	EN
Somateria mollissima (wintering EN, breeding VU)	Common eider	Birds	EN
Phoca hispida botnica	Baltic ringed seal	Mammals	VU
Phoca vitulina (Kalmarsund population)	Harbour seal	Mammals	VU
Phocoena phocoena (Baltic Sea population)	Harbour porpoise	Mammals	CR
Phocoena phocoena (Western Baltic subpopulation)	Harbour porpoise	Mammals	VU

9.4. Relationship of bycatch to drivers and pressures

9.4.1 Human activities and associated pressures

In the holistic assessments bycatch is counted as a pressure, i.e. it is an effect of one or several human activities which have negative consequences on components of the ecosystem, in this case marine mammals and waterbird species. However, due to the nature of this pressure where the population size is directly reduced, bycatch is integrated into species assessments, as presented in this chapter. The level of pressures affecting the status of biodiversity is assessed across a number of pressures and activities. Each part of the assessment focuses on one important aspect of a complex issue. The assessment presented in

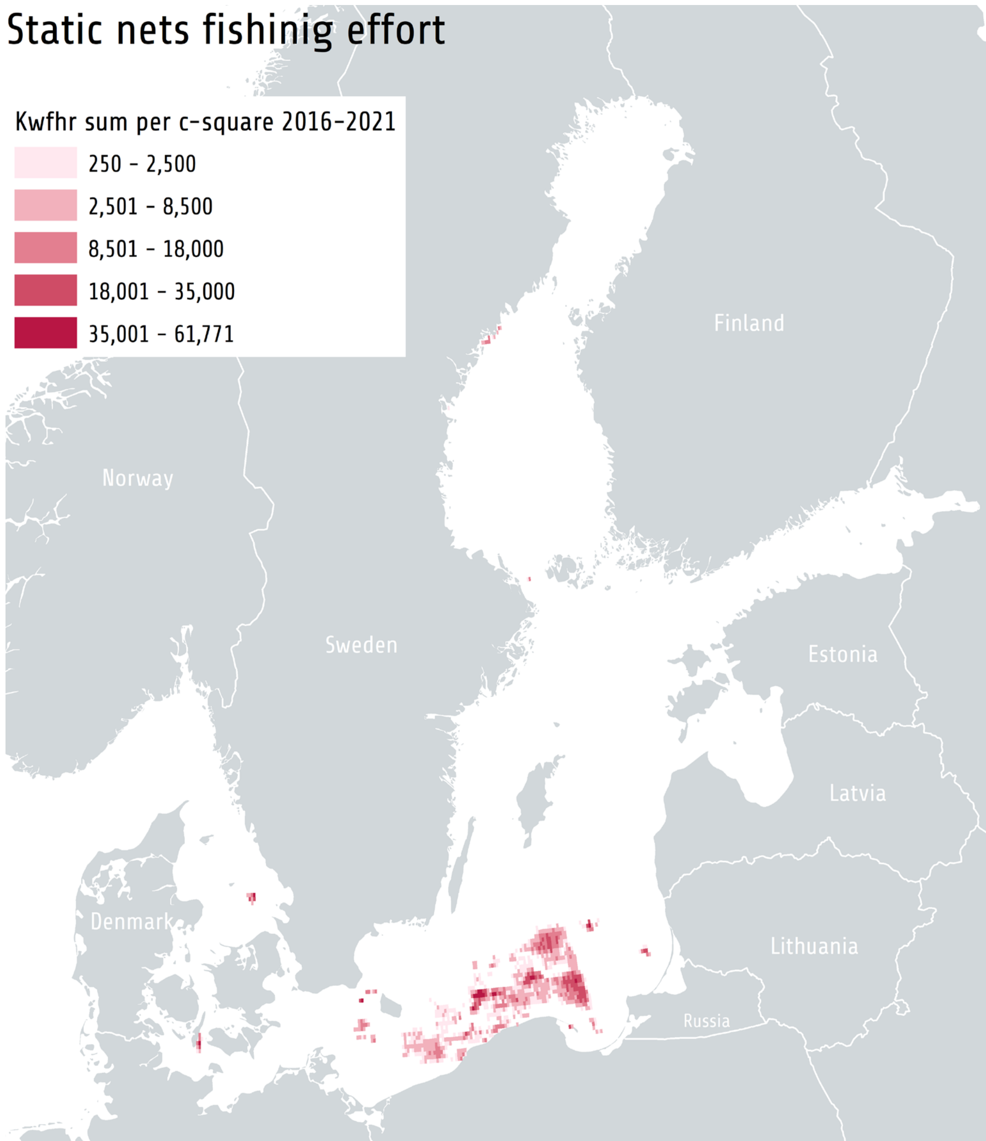


Figure 9.11. Spatial and temporal distribution of static net and bottom and pelagic tawling commercial fisheries in the Baltic Sea during the assessment period 2016-2021 based on VMS and logbook data. The spatial extent of pelagic trawling is larger than that of benthic trawling, see the Spatial Pressures and Impacts Assessment Thematic Assessment.

this chapter should be considered together with other biodiversity assessments in order to achieve an overall overview of the status of biodiversity.

Bycatch is, naturally, directly tied to the spatial distribution, intensity, type and timing of fishing activities. This can vary between fishing gear type as well as season, or linked to key processes in species life-cycles, with the combination of these two key factors (i.e., species occurrence/distribution and pressure occurrence/distribution) are major determinants of bycatch rate. Static nets and traps, and to a lesser degree also to longline fishing and trawling are significant pressures in relation to bycatch, see for example spatial and temporal distribution of static net and trawling fishing effort from commercial fisheries for the current assessment period (Figure 9.11). In addition to the overall sum of the pressure for the assessment period it is also important to note that significant temporal variation occurs (see box 9.1).

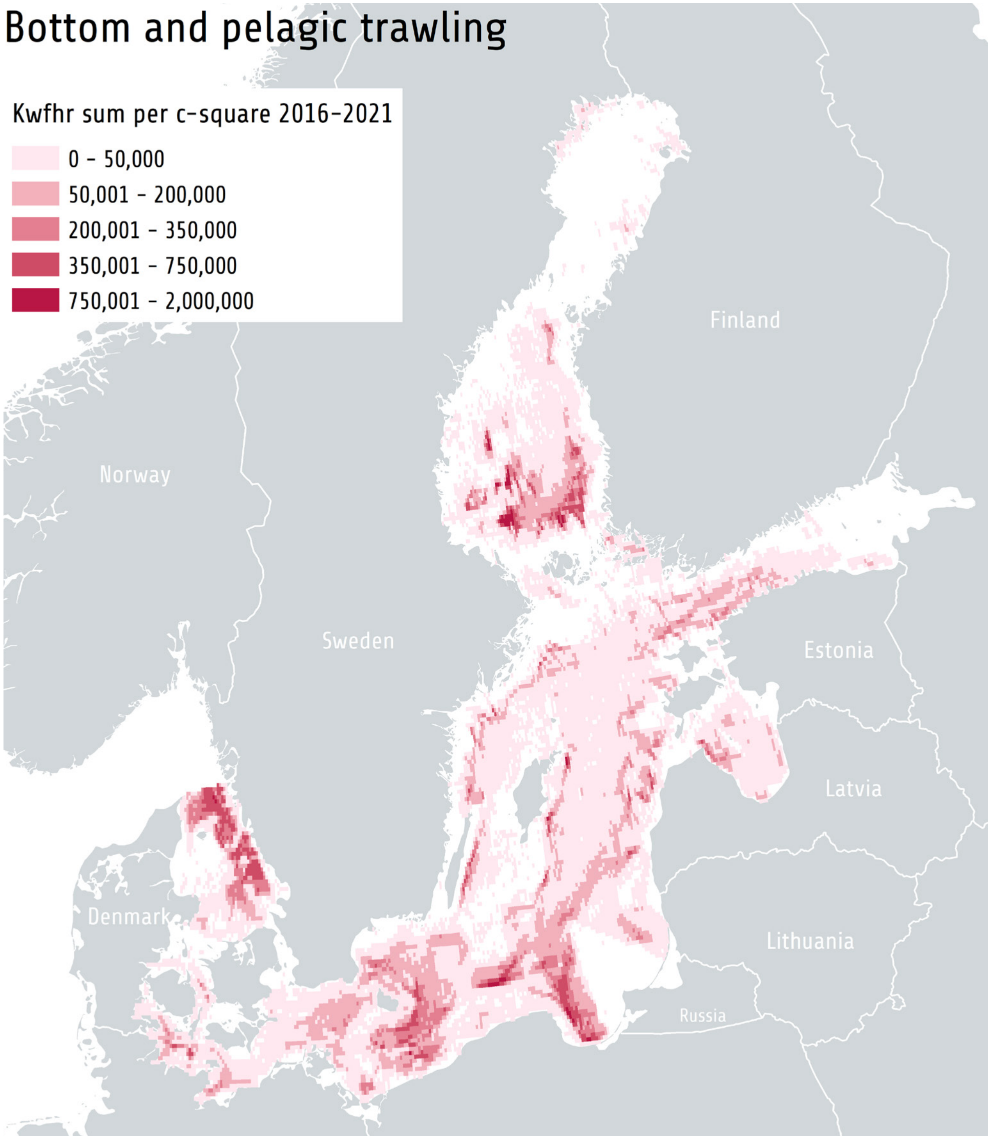
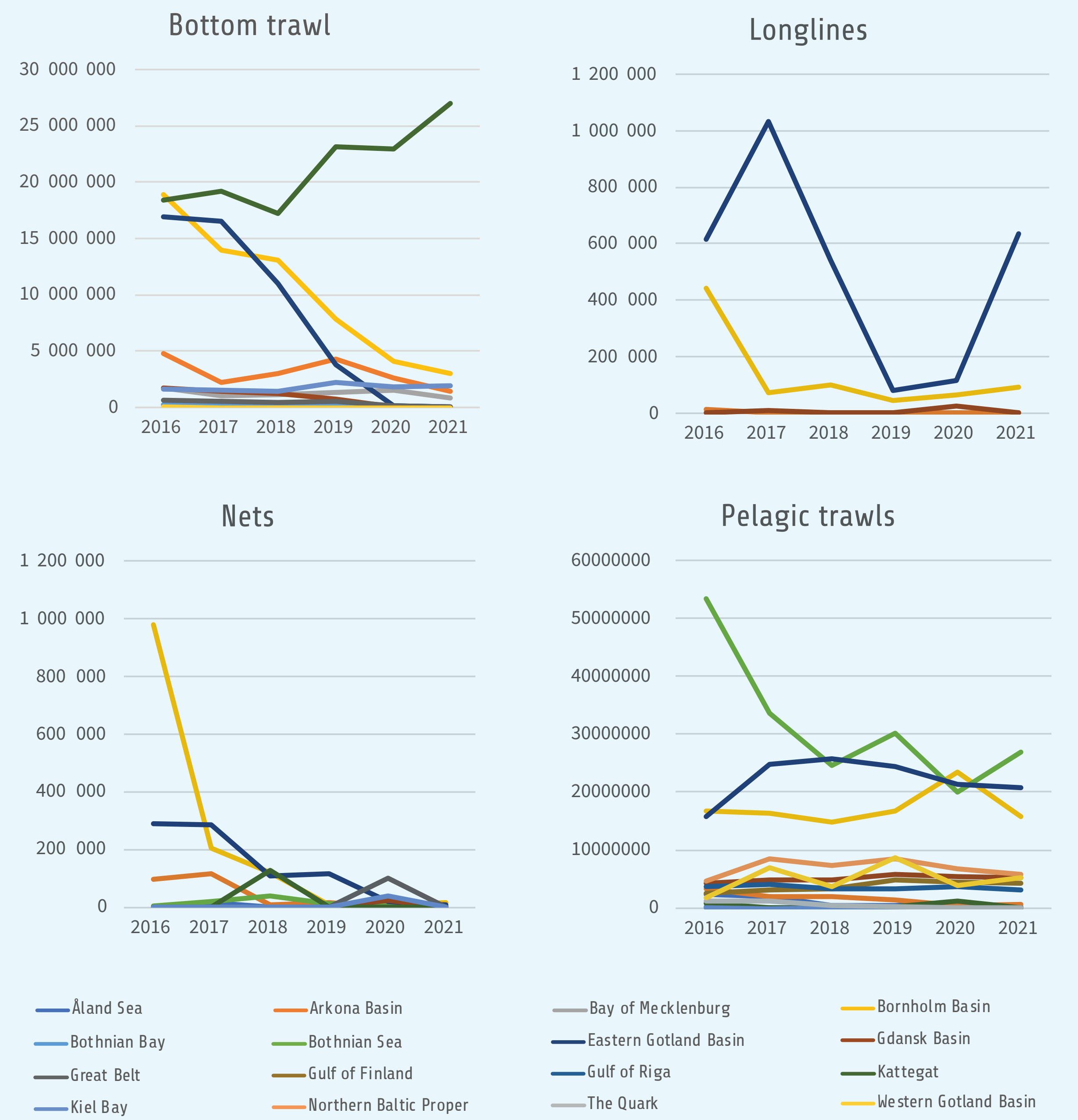


Figure 9.11. (continued). Spatial and temporal distribution of static net and bottom and pelagic tawling commercial fisheries in the Baltic Sea during the assessment period 2016–2021 based on VMS and logbook data. The spatial extent of pelagic trawling is larger than that of benthic trawling, see the Spatial Pressures and Impacts Assessment Thematic Assessment.

Box 9.1. Fishing effort and gear type trends – relevance for bycatch

Fishing effort (kWfhrs) with various gears differs greatly depending on the target species. The type of gear used, in addition to fishing effort and the distribution of species at risk of byctahc are key components in understadning temporal and spatial variation in bycatch. As shown in Figure B9.1 fishing effort and the gear type uses can vary significantely spatially in the Baltic Sea and a decrease in gillnet fisheries (i.e. the fisheries with the higest risk of bycatch) is particularly clear during this assessment period. In the Central Baltic where the cod fishery, previously the dominating fishery effort in the Baltic, has been banned since 2019 the reduction in fishing effort should conceivably also significantly reduce the risk of bycatch (see for example outcoms of bycatch risk study). In should be noted that the results provided are based on fishing effort records for vessels 12 meters and above, and although they provide relative trends, no analysis has currently been caried out linking them directly to bycatch occurrence and the presented data does not cover effort with vessels below 12 m or recreational fisheries.



In the Baltic Sea, marine mammals and waterbirds are exposed to a number of pressures from various human activities, both directly and indirectly. The pressures act variably with regards to seasons, but the effects are cumulative and include carry-over effects from one season to another. The pressure relevant for this assessment is the "extraction of, or mortality/injury to, wild species (by commercial and recreational fishing and other activities)", which is directly linked to fishing by static nets and traps, but to a lesser degree also to longline fishing and trawling.

Box 9.2. Bycatch risk mapping

Identification or estimation of high-risk areas for bycatch can be used to evaluate the relative level of pressure on non-target populations from fishing activities (e.g. porpoise, seals and waterbirds), while accounting for effort and species distribution patterns. Risk analyses can thereby identify areas where implementation of effective mitigation measures that reduce bycatch mortality should be undertaken as they show where possible preventative measures could be considered. It also supports identification of areas where monitoring of bycatch may need to be intensified.

In the HELCOM ACTION project (2018-2021) a first attempt was made to produce bycatch risk maps for harbour porpoise based on 1) logbook data and porpoise distribution (Baltic Proper) and 2) based on a modelling approach (Western Baltic).

Using detailed logbook data and predicted spatiotemporal porpoise distribution, the project established the relative bycatch risk along the Swedish (Figure Box 9.2.1) and Polish coasts (Figure Box 9.2.2).

For the second method, which used modelling as a basis for the areas Kattegat and in Inner Danish waters, previous satellite-tracking of harbour porpoises showed some clear seasonal distribution shifts between the different populations in this area (Sveegaard *et al.*, 2011), highlighting potential conflicting areas between the cetaceans and gillnet fishers. In addition, Kindt-Larsen *et al.* (2016) demonstrated that, for the Skagerrak population, harbour porpoise captures were proportional to the intensity of the fishing effort in areas where there is a known overlap between porpoise densities and gillnet fishing activities (Figure Box 9.2.3 and Figure Box 9.2.4). It is important to acknowledge that applying a single common method to identify the areas of high risks of bycatch is not currently feasible at the scale of the entire Baltic Sea, thus different data strands and approaches needs to be combined in various ways to provide management support. Further, effort data is often only collected at a spatial resolution of ICES statistical rectangles. Fishing around shallow banks which may be attractive to birds and fishers are obscured by the coarse spatial resolution.

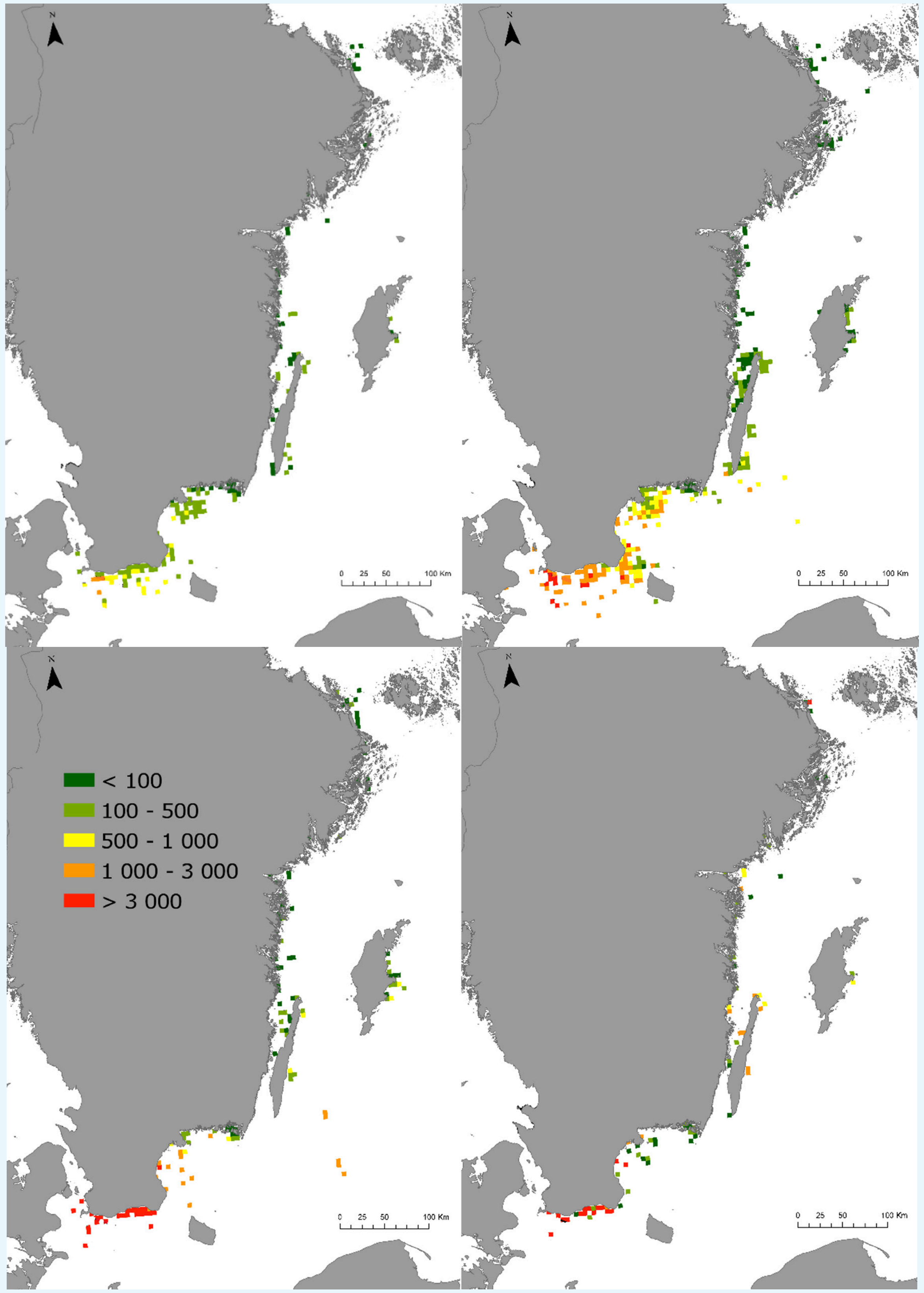


Figure Box 9.2.1. Relative bycatch risk for harbour porpoise, estimated as the probability of harbour porpoise detection during May 2011–April 2013 (data from Carlén et al. (2018)) multiplied by gillnet fishing effort reported to the Swedish Agency for Marine and Water Management for 2019. Top left: Feb-Apr 2019; top right: May-July 2019; lower left: Aug-Oct 2019 (gillnet effort data after implementation of cod fishing ban); lower right: Jan 2019 (gillnet effort data before the cod fishing ban) and Nov-Dec 2019 (gillnet effort data after the cod fishing ban). (Source: HELCOM ACTION 2021b).

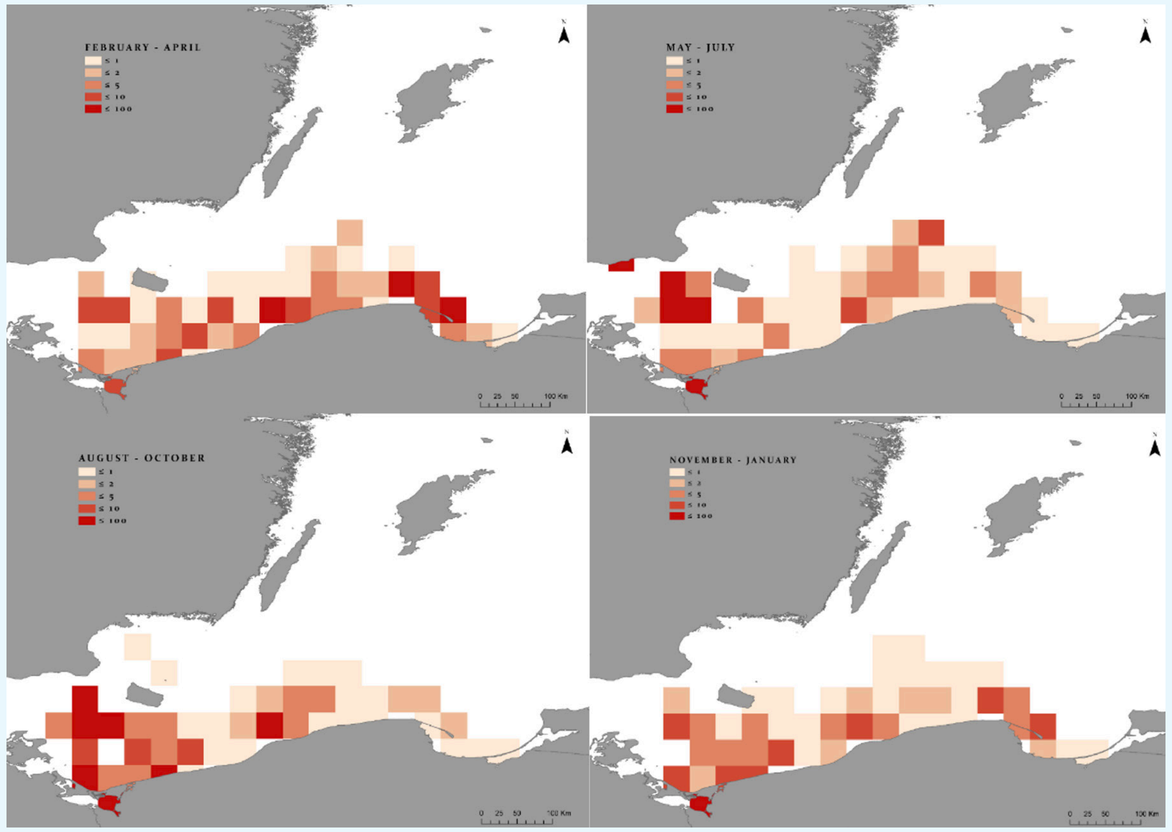


Figure Box 9.2.2. Relative bycatch risk for harbour porpoise, estimated as the probability of harbour porpoise detection during May 2011–April 2013 (data from Carlén et al. (2018)) multiplied by gillnet fishing effort reported by the National Fisheries Monitoring Centre database in Poland; top left: Feb–Apr 2018; top right: May–July 2018; lower left: Aug–Oct 2018 ; lower right: Jan 2018 and Nov–Dec 2018. (Source: HELCOM ACTION 2021b).

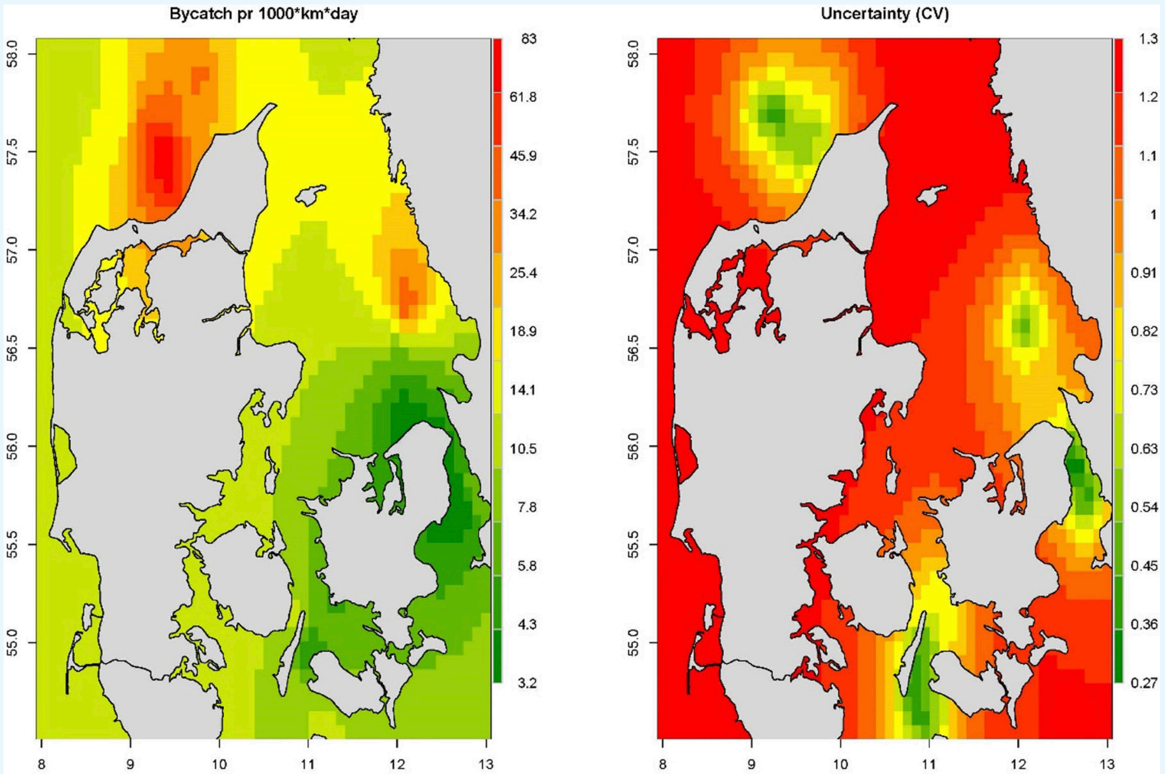


Figure Box 9.2.3. Left: Estimated bycatch per unit effort (number of porpoise per 1000 km.day). Right: Uncertainty of the estimates on left map (coefficient of variation). The green/yellow regions in the uncertainly map (right) indicate where data are present, whereas red areas are unsampled and thus quite uncertain. (Source: HELCOM ACTION 2021b).

Marine mammal populations suffer from bycatch, most often in combination with threats from other activities. It is difficult to assign which activity adds to what extent to population effects. In particular, many pressures (such as contaminants, disturbance, prey depletion, habitat degradation or habitat loss, e.g., Sonne *et al*., 2020, Rebryk *et al*., 2022, Brandt *et al*., 2018, Owen et al., 2021) are indirect as they affect the viability but do not result in direct mortality. Bycatch, hunting of seals or underwater explosions cause direct mortality and the effect on the population is evident in terms of a reduction in the numbers of individuals (see Figure 7.28 and table 7.13 in Chapter 7 for an overview of spatial distribution and intensity of hunting pressure for seals). Since marine mammals have a late sexual maturity and produce only a low number of offspring (at maximum one per year), they are extremely vulnerable to lethal anthropogenic pressures.

Waterbird populations suffer from the extraction of individuals due to bycatch (Tasker *et al.* 2000, Žydelis *et al*. 2009, Žydelis *et al*. 2013, Lewison *et al*. 2014, Northridge *et al*. 2017), and some species are still under pressure from hunting (see Figure 6.14 and tables 6.11 and 6.12 in Chapter 6 for an overview of spatial distribution and intensity of hunting pressure).

9.4.2 Climate change

There are two important aspects of possible impact of climate change related to this bycatch assessment. The first involves a likely spatiotemporal shift of fisheries (maybe also combined with the use of other gears) and of mammal or waterbird distribution, both related to availability of fish and/or prey and ice-free water, which would in turn affect the risk for bycatch. The other is related to a possible reduced fitness of species/populations due to e.g., reduced availability of prey of a suitable quality and quantity. This in turn would negatively affect the population. Then greater efforts would be needed to preserve the population, also with respect to reducing bycatch.

The ringed seal population of the Southwestern Archipelago Sea, Gulf of Finland and Gulf of Riga is already suffering serious impact of climate change. Availability of suitable breeding ice is known to affect pup survival. Reduced ice cover severely limits the population's growth rate (Sundqvist *et al.* 2012). At the same time reduced ice cover opens new fishing opportunities in winter which may increase the bycatch risk. All anthropogenic pressures will need to be consequently reduced in order to compensate for the reduced or even negative population growth.

Distribution shifts of fish populations (Heath *et al.* 2012) and reduced recruitment of fish species (Polte *et al.* 2021) caused by climate change are already being reported leaving stocks with a lesser resilience to climate-driven changes. Distribution shifts of prey may be partly compensated for by mammals and waterbirds by shifting their distribution range as well which might have implications for the risk of being by-caught. A reduced availability of suitable quantities and quality of important prey species for mammals and waterbirds by climate change and/or overfishing likely will affect their overall fitness. In the North Sea it has been shown that feeding on prey of lesser quality reduces the fitness of harbour porpoises and leaves them starving even with filled stomachs (Leopold *et al.* 2015). Prey energy density has been shown to govern harbour porpoise reproductive success (Ijsseldijk *et al.* 2021).

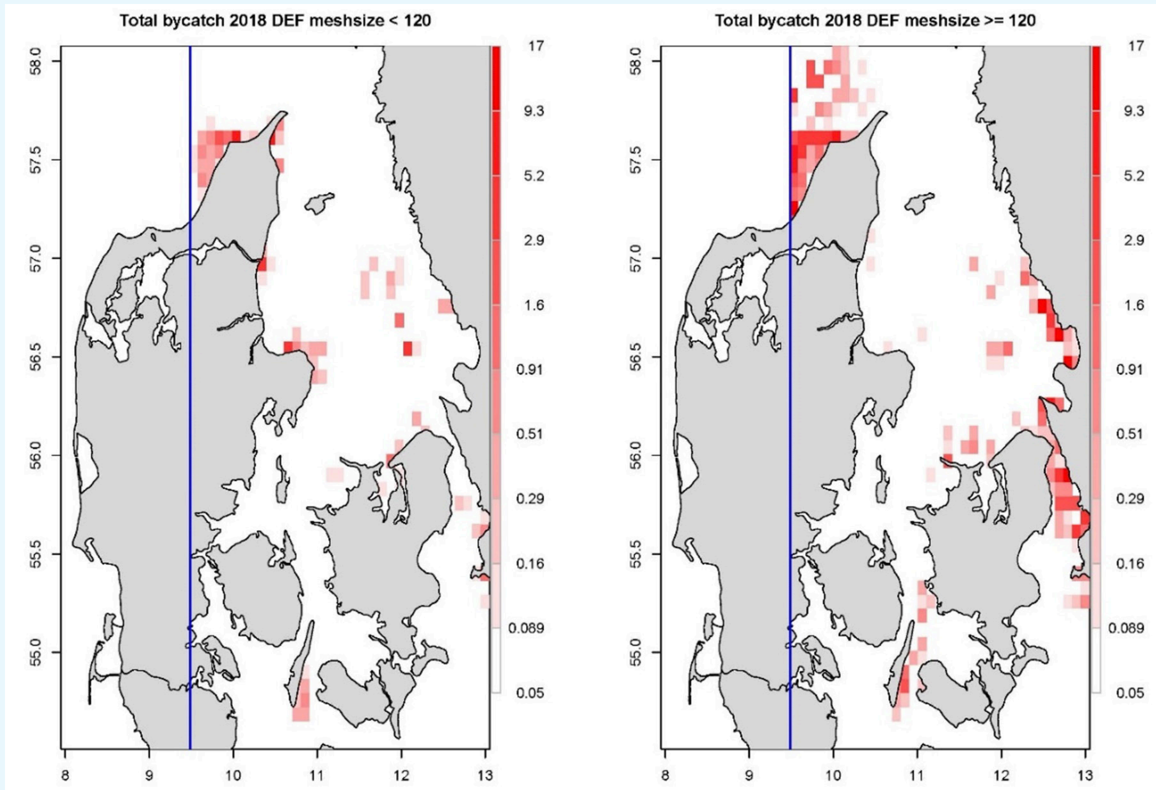


Figure Box 9.2.4. Estimated porpoise bycatch for the year 2018. Left: total porpoise bycatch in gillnets using mesh sizes <120 mm; Right: total porpoise bycatch in gillnets using mesh sizes ≥120 mm. These estimates were obtained by multiplying the estimated fishing effort and the estimated mean porpoise bycatch rates. The blue vertical line indicates the western border beyond which there was no effort data provided. Only Danish and Swedish effort data were available, so these estimates do not take into account additional bycatch from the German gillnet fleet, notably in the most southern end of the maps. (Source: HELCOM ACTION 2021b).

Due to higher winter air temperatures and consequently less ice cover of the Baltic Sea in winter (HELCOM/Baltic Earth 2021, Meier *et al.* 2022), many waterbird species have been shifting their winter distribution northeastwards – including also diving species such as common goldeneye, greater scaup and smew (Pavón-Jordán *et al.* 2015, 2019, Marchowski *et al.* 2017). This not only leads to longer presence of a larger number of waterbirds prone to bycatch in the Baltic Sea, but also fisheries are less restricted by sea ice, so that the exposure of waterbirds to mortality is likely to have increased. Further, due to distributional shifts waterbirds overwinter in increasing numbers in unprotected areas (Pavón-Jordán *et al.* 2020). Thus, a mismatch between winter distribution and protected areas may have arisen, with possible consequences for measures to prevent bycatch, which need to be adapted spatially and temporally. A higher variability in winter temperatures and ice covered areas might also lead to a higher variability in the use of wintering areas making it difficult to tailor specific spatiotemporal mitigation measures.

9.5. Assessment methodological details

The integrated assessment of bycatch was done using the BEAT tool, developed by HELCOM for the purpose of assessing the status of biodiversity. For more information on how the BEAT tool functions please see Chapter 2 and for a description of the integrated assessment methodology specifically for by-catch see Annex 1, Section A1.7.

Bycatch is applied only for wintering waterbirds since it is noted in more southernly regions to be the period with the strongest impact and also since the limited amount of actual bycatch data available makes a direct assessment in the breeding season impossible at this stage. Thus, the bycatch indicator was integrated with the wintering waterbird indicator using the one-out-all-out approach to reflect that a species cannot be in good status if bycatch exceeds the defined threshold. The integration with the remaining waterbird indicator (i.e., the abundance of waterbirds in the breeding season) was then carried out in the same manner as described above.

Scarcity of bycatch data coupled with incomplete knowledge on fishing effort as well as unavailable conservation objectives call for a consequent application of the precautionary principle. In this assessment, with respect to bycatch and fishing effort some assumptions had to be made as the current inadequate data collection of bycatches and reporting of effort does not allow nearly precise estimates, this has been accounted for when assigning confidence to the indicator evaluation results underpinning the integrated assessment.

9.5.1 Handling confidence for bycatch assessment

It is important to note that while the confidence in the integrated results of the assessment tool BEAT are frequently listed as high for the assessment of bycatch, this reflects the robustness of the assessment process and the sufficient data quality fo the other indicator evaluations also included, and is not reflective of the quality of the data underpinning the bycatch assessment itself assessment. The BEAT tool produces an integrated confidence assessment in parallel to the status assessment. The integrated confidence is calculated based on four confidence aspects, namely accuracy, temporal coverage, spatial representation and methodological confidence, classified into 'high', 'intermediate' or 'low', for each assessment unit and indicator (Table 9.11). To enable the integration, the confidence estimates originally provided in categorical form (as low, intermediate and high) were translated into numerical values (0, 0.5 and 1), where higher values mean higher confidence. BEAT first averages the categories per indicator and then integrates the confidence result to a single confidence score according to the relevant integration structure. When presenting the results, confidence scores below 0.5 were classified as low, from 0.5 up to and including 0.75 as intermediate and above 0.75 as high.

This frequently results in a high confidence for the bycatch assessment overall, however, based on the availability of data the overall confidence in this assessment is low. The assessment results are heavily influenced by the indicator on bycatch (HELCOM 2023n), which is suffering from a lack of data. The issue of bycatch is further complicated by factors such as the behaviours or seasonality of the species vulnerable to entanglement in fishing gears. These issues mean that optimal assessments require data with a high degree of resolution but also often a sufficient frequency to address seasonality. The following table presents an evaluation of the confidence in four categories based on the input to the indicator evaluation which underpins the assessment.

1. Accuracy of estimate: A compliance check would allow showing a clear signal whether good status is achieved or not ('high'), show general achievement of good status but with some outliers and variation in the data ('intermediate') or only show good status achievement with only a probability <70% ('low'). This scoring based on expert opinion was used for the HOLAS 3 BEAT tool in case data does not allow calculation of a standard error.
2. Temporal coverage: This is a measure of the temporal coverage of the assessment period. Bycatch is subject to year-to-year variation. If monitoring data covers all six years the confidence is 'high', for three or four years of data 'intermediate' is chosen and otherwise 'low'.
3. Spatial representability: This is a measure of the spatial coverage with respect to HELCOM sub-basins. If monitoring data is considered to cover the full spatial variation of the indicator parameter in the assessment area (covering at least 90% of the variation) the confidence is 'high'. For 70 to 89% of the variation 'intermediate' is chosen and otherwise 'low'. The choice was made on the basis of expert knowledge.
4. Methodological confidence: This relates to quality of the monitoring and whether it is according to existing HELCOM or other internationally accepted guidelines ('high'), whether the data is from mixed sources partly quality assured ('intermediate') or data not collected according to guidelines or not quality assured ('low').

Future work will require to address these uncertainties specifically when better data are available.

9.5.2 Data collection and monitoring

Monitoring

Commission Delegated Decision (EU) 2021/1167 (European Commission 2021) requires bycatch monitoring of protected

Table 9.11. Overview of categorical scoring of confidence for the bycatch assessment. The confidence parameters are derived from the underlying indicator evaluations (see respective indicator reports).

	Accuracy of estimate	Temporal coverage	Spatial representability	Methodological confidence
Harbour porpoise of the Kattegat, Belt Sea and Western Baltic	intermediate	high	low	intermediate
Harbour porpoise population of the Baltic Proper	low	high	low	low
Ringed seal population of the Southwestern Archipelago Sea, Gulf of Finland and Gulf of Riga	low	high	low	low
Ringed seal population of the Gulf of Bothnia	low	high	low	low
Harbour seal population in Kalmarsund	low	high	low	low
Harbour seal population of the South-western Baltic and Kattegat	low	high	low	low
Grey seal population of the Baltic Sea	low	high	low	low
Waterbirds Kattegat (Denmark, Evaluation Method 3)	high	high	low	intermediate
Waterbirds Belt Group (Denmark, Evaluation Method 3)	high	high	low	intermediate
Waterbirds Bornholm Group (Denmark, Evaluation Method 3)	high	high	low	intermediate
Waterbirds Bornholm Group (Germany, Evaluation Method 3)	high	high	low	low
Waterbirds Bornholm Group (Poland, Evaluation Method 2)	intermediate	high	low	intermediate
Waterbirds Gotland Group (Poland, Evaluation Method 2)	intermediate	high	low	intermediate
Waterbirds Gotland Group (Lithuania, Evaluation Method 3)	high	high	low	intermediate

mammal and waterbird species by those HELCOM Contracting Parties who are also EU Member States. Current national discard/bycatch monitoring programmes carried out under the EU data collection framework (DCF) only to a very limited extent target marine mammal and bird bycatches.

Thus, monitoring activities relevant to the assessment are only partially carried out by HELCOM Contracting Parties (see HELCOM Monitoring Manual). These consist generally of DCF at-sea monitoring with a low on-board observer coverage in métiers and fleet segments relevant to marine mammal and waterbird bycatch, with the exception of Denmark and recently Sweden, for which electronic monitoring in static net fisheries can provide data with a level of high confidence. In other areas, self-reported data from logbooks are being reported which are likely incomplete and do not allow extrapolations on fleet effort. These can at best be considered as absolute minimum estimates.

Monitoring programmes are carried out under the EU Data Collection Framework (DCF). However, DCF monitoring effort has focused primarily on the problem of discard. Available resources have thus been allocated to large vessels operating active gears for which bycatch of protected, endangered and threatened species is a minor issue, rather than on the more problematic small vessels using static nets which are responsible for most of the bycatch in the Baltic Sea. Thus bycatch of marine mammals and waterbirds is not adequately addressed but rather recorded opportunistically at best not providing the needed data to enhance the confidence of the indicator.

Monitoring of bycatch of cetaceans under Annex XIII of the EU regulation 2019/1241 lays measures concerning bycatches of cetaceans in fisheries using onboard observers but is limited to vessels >15 m and hence results in the lowest observer coverage of fisheries posing greatest threat to porpoises in the Baltic Sea (ICES 2013). The Regulation obliges Member States to monitor cetacean bycatch in static nets. However, monitoring under Regulation 2019/1241 is not suited to the data needs for the assessment of bycatch because only vessels >15 m are covered by the observer programme and the majority of Baltic static net fisheries is carried out by small vessels which use the same gear. Under Annex VIII of EU Regulation 2019/1241 vessels are allowed to set 9 km (vessel length <12 m) or even 21 km (vessel length >12 m) of static net, respectively, illustrating the high risk of bycatch even by small vessels (European Commission 2019).

Only very limited data are collected for protected waterbird taxa under DCF, and it is not possible to estimate effort or coverage. Besides national differences there are large differences in coverage between fishing métiers favouring larger vessels and mainly trawlers. As a result, from these programmes there are no robust estimates of by-caught waterbirds and marine mammals for various types of fishing gear (mainly gillnets and entangling nets) in the Baltic Sea, because so far no adequate observer coverage has been achieved with existing monitoring programmes such as DCF and EU Regulation 2019/1241. On the other hand, the results of pilot studies such as interviews are frequently questioned by fishermen and fisheries authorities. Especially in métiers which have been identified by pilot studies as fisheries with a high risk for mammal or bird bycatch, monitoring is inadequate and a revision of existing monitoring programmes is urgently needed.

All HELCOM Contracting Parties which are also EU Member States are further obliged to carry out monitoring to provide estimates of population sizes in accordance with the requirements of the Habitats Directive and the Birds Directive. Not all Contracting Parties currently comply with Article 12 Habitats Directive as monitoring in place that is sufficient to provide information that can facilitate achieving the target that incidental capture and killing does not have a significant negative impact on the species. Some countries like Denmark have been engaged in developing monitoring based on on-board video cameras recently. In Denmark, this programme is now fully integrated to the regular national monitoring programme of Danish fisheries (i.e., DCF or EU-MAP), and a similar programme is on tracks in Sweden.

Data

Bycatch estimates of harbour porpoises from Kattegat, Belt Sea and the Sound were taken from Larsen *et al.* (2021) and Glemarec *et al.* (2022) as results from a Danish REM study. Further marine mammal bycatch data was added from a compilation of reported bycatches and strandings data compiled by HELCOM EG MaMa, from NAMMCO & IMR (2019) and Vanhatalo *et al.* (2014).

Bycatch data for waterbird Evaluation Method 2 under the indicator Drowned waterbirds and mammals in fishing gear in Polish waters were supplied by Dominik Marchowski (unpublished data based on Polish bird surveys, bycatch rates published by Psuty *et al.* (2017) and effort data from fishermen's declarations submitted to the Polish Fisheries Monitoring Centre). Estimates of annual adult mortality used for Evaluation Method 2 were taken from Bird *et al.* (2020)

Bycatch data for waterbird Evaluation Method 3 under the indicator Drowned waterbirds and mammals in fishing gear in Danish waters was taken from Larsen *et al.* (2021) and Glemarec *et al.* (2022). Data for waterbird Evaluation Method 3 in Lithuanian waters was taken from Morkūnas *et al.* (2022). Data for waterbird Evaluation Method 3 in German waters was taken from German seabird surveys from November to April (2016-2021) which also record the distribution of static net flags, and further from scientific case studies in German waters (Schirmeister 2003, Erdmann *et al.* 2005, Bellebaum & Schirmeister 2012).

Poor data has limited the full application of needed evaluatons on bycatch and remains a hinderance hampering the assessmentin this current assessment period. This includes key data such as data from harmonised and standardised monitoring proesses across the region, bycatch rate information (derived in part from the former information), as well as relevant information that covers all fisheries effort (e.g., small vessels for example). It has thus not been possible yet to fully relate the amount of bycatch to the management objective that bycatch is not threatening the viability of populations.. It has however been possible to utilise available data from national and published sources to carry out an evaluation fro HOLAS 3, though further work remains required. However, in the case of threatened cetacean and seal populations with a very low number of individuals left, a strict threshold value of zero bycatch was exceeded, bycatch occurred at levels above an aceptabel level. Despite this being possible to apply it should also be note that the data remains insufficient to fully reflect the level of bycatch has in such cases a single event provides a high confidence evaluation of status. Establishing effective monitoring of fishing effort and bycatch is needed in order to allow more precise evaluations as in this example.

With respect to bycatch-monitoring there are large differences between countries and the data quality achieved. Dedicated bycatch-surveys and Remote Electronic Monitoring using cameras produce a high data quality if they are conducted in a representative manner including all relevant fishing métiers. Onboard observers in the frame of the EU Data Collection Framework (DCF)

Table 9.12. Assessments units used for marine mammal populations in terms of inhabited subbasins (HELCOM assessment unit scale 2), which are painted blue for occurrence.

HELCOM sub-basin	Harbour porpoise		Ringed seal		Harbour seal		Grey seal	Integration
	Kattegat, Belt Sea and Western Baltic	Baltic Proper	Southwestern Archipelago Sea, Gulf of Finland and Gulf of Riga	Gulf of Bothnia	Kalmarsund	South-western Baltic and Kattegat	Baltic Sea	
Kattegat	■					■	■	■
Great Belt	■					■	■	■
The Sound	■					■	■	■
Kiel Bay	■					■	■	■
Bay of Mecklenburg	■					■	■	■
Arkona Basin	■					■	■	■
Bornholm Basin		■					■	■
Gdansk Basin		■					■	■
Western Gotland Basin		■			■		■	■
Eastern Gotland Basin		■	■				■	■
Gulf of Riga			■					■
Northern Baltic Proper		■	■				■	■
Åland Sea		■	■				■	■
Gulf of Finland			■					■
Bothnian Sea				■				■
The Quark				■				■
Bothnian Bay				■				■

can also produce high quality data. However, this requires a protocol which takes specific needs of bycatch monitoring guidelines into account as observers normally focus on the commercial fish catch. Monitoring effort in general needs to be increased to allow robust evaluations. ICES (2018b) showed that métiers relevant for waterbird and mammal bycatch are relatively undersampled whereas other métiers which have less or no bycatch are over-sampled.

9.5.3 Assessment scales

Marine mammals are evaluated on the basis of populations, and the assessment units reflect the range these populations inhabit (Table 9.12). With the exception of the Kalmarsund population of harbour seal, all populations live in more than one Baltic Sea subbasin (HELCOM assessment unit scale 2). Therefore, the bycatch evaluation is applied to all subbasins in which the respective population occurs.

Waterbirds are evaluated in seven subdivisions, which are defined by the merging of up to four of the 17 sub-basins of the Baltic Sea (i.e. HELCOM assessment unit scale 2), the latter following a recommendation by the Joint OSPAR/HELCOM/ICES Working Group on Marine Birds for the waterbird abundance indicators (Figure 5.15). The seven subdivisions are named as follows:

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

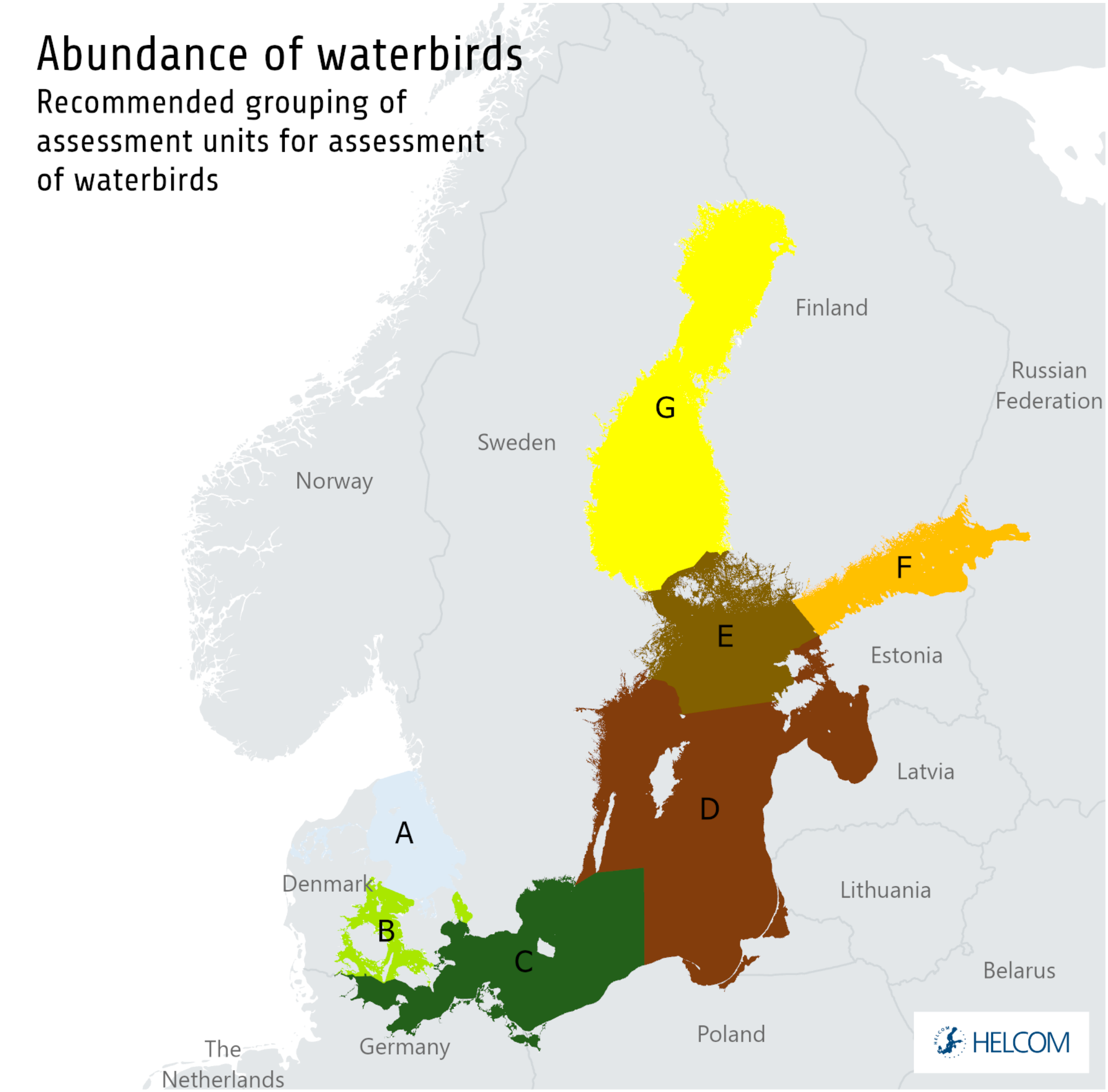


Figure 5.15. Grouping of 17 sub-basins (HELCOM assessment unit scale 2) to seven subdivisions as spatial units for waterbird indicators as recommended by JWGBIRD (ICES 2018b).

9.5.4 Assessment methodological details

The methodology used for the integrated assessment of bycatch is presented in Annex 1, in the respective sections for the various species groups (A1.4 Waterbird integrated assessment methodology and A1.5 Mammal integrated assessment methodology).

9.6. Follow up and needs for the future with regards to bycatch

9.6.1 HELCOM Actions

In order to minimise bycatch measures can be put in place which limit or remove the risk of entanglement. For echolocating cetacean species, which in the Baltic Sea comprises only the harbour porpoise, the primary measure relates to the use of acoustic deterrent devices (also known as pingers). For all species concerned by bycatch, other measures include changes in what fishing gear is used, and temporal or permanent spatial closures of fisheries using certain gears. A good understanding of what measures to implement in what areas is vital to ensure that the measures have the intended effect.

In HELCOM the countries around the Baltic Sea actively work to share information on topics related to bycatch, identify additional measures, as well as agree on joint action. The bycatch assessment in HOLAS 3 provides input to the Baltic Sea Action Plan's Biodiversity and nature conservation segment's ecological objectives 'Viable populations of all native species', 'Natural distribution, occurrence and quality of habitats and associated communities' and 'Functional, healthy and resilient foodwebs' as well as the management objectives 'Human induced mortality, including hunting, fishing, and incidental bycatch, does not threaten the viability of marine life' and 'Reduce or prevent human pressures that lead to imbalance in the foodweb'.

HELCOM Contracting Parties have agreed the following actions which either directly or indirectly addresses bycatch:

Code	Action
B8	By 2022 at the latest, specify knowledge gaps on all threats to the Baltic Proper harbour porpoise population, and by 2023 for the western Baltic population, including by-catch and areas of high by-catch risk, underwater noise, contaminants and prey depletion. Knowledge gaps related to areas of high by-catch risk are to be addressed and by 2028 at the latest additional areas of high by-catch risk for both Baltic Sea populations are to be determined. To strengthen the Baltic harbour porpoise population, by 2025 identify possible mitigation measures for threats other than by-catch and implement such measures as they become available.
B11	Maintain an updated map of the sensitivity of birds to threats such as wind energy facilities, wave energy installations, shipping and fisheries. Complete, as a first step, the mapping of migration routes, staging, moulting and breeding areas based on existing data by 2022. By 2025 further develop these maps by incorporating new data, post-production investigation information and addressing the subject of cumulative effects from these activities in space and time.
B21	By 2025 protect the ringed seal in the Gulf of Finland, including to significantly reduce by-catch and to improve the understanding of the other direct threats on the seals, and urge transboundary co-operation between Estonia, Finland and Russia to support achieving a viable population of ringed seals in the Gulf.
B22	Update the HELCOM Red List Assessments by 2024, including identifying the main individual and cumulative pressures and underlying human activities affecting the red listed species.
B23	By 2025 develop, and by 2027 implement, and enforce compliance with ecologically relevant conservation plans or other relevant programmes or measures, limiting direct and indirect pressures stemming from human activities for threatened and declining species. These will include joint or regionally agreed conservation measures for migrating species.
B24	Develop tools for and regularly assess the effectiveness of other conservation measures for species besides marine protected areas (MPAs), with the first assessment to be done by 2025, as well as assess the effect on species through risk and status assessments by 2029.
S43	Reduce the negative impacts of fishing activities on the marine ecosystem and to this end, support the development of fisheries management including technical measures to minimize unwanted by-catch of fish, birds and marine mammals and achieve the close to zero target for by-catch rates of relevant species by 2024, especially the Baltic proper population of harbour porpoise by 2022.
S44	Invite the competent authorities to immediately, but no later than 2022, implement mitigation measures in the Baltic proper, in order for by-catch of harbour porpoise to be significantly reduced, with the aim of reaching by-catch rates close to zero.
S45	Invite the competent authorities to implement operational conservation measures for the Belt Sea population of harbour porpoise by 2024 such as permanent and/or spatial-temporal closures for relevant fishing métiers in risk areas where technical mitigation measures are insufficient to reach conservation goals.
S46	Promote effective mitigation measures to minimize by-catch of harbour porpoise in the Baltic Sea area inter alia via cooperation with the Baltic Sea Fisheries Forum (BALTFISH), and evaluate and promote adjusted measures as needed by 2025.
S47	Continually test, promote and introduce new technical and operational by-catch mitigation measures such as alternative and seal safe gears in cooperation with competent authorities with the aim to, as appropriate, replace fishing gear proven to be problematic with respect to by-catch, with evaluation of measures every five years starting in 2023, and regularly update the HELCOM questionnaire on trials of alternative fishing gears and fishing techniques.
S48	Develop and implement effective data collection for more reliable data on incidentally by-caught birds and mammals and fishing effort consistent and fully in line with the data needs identified by the International Council for the Exploration of the Sea (ICES). Relevant sources of data are e.g. the EU Control Regulation and additional national or regional coordinated data collection programmes or projects for filling data-gaps outlined in the HELCOM Roadmap on fisheries data
S49	Maintain, develop and extend regulatory or voluntary schemes to protect key seabird areas and seasons by establishing appropriate fisheries measures in line with conservation objectives and to monitor incidental catches of seabirds by 2025. Extend and develop outreach programmes for the fisheries sector concerning their possible impacts on seabird populations.

These actions aim at analysing and implementing operational conservation measures and promoting effective mitigation measures to achieve the close to zero target for bycatch rates of relevant waterbird and mammal species, especially the Baltic proper population of harbour porpoise and setting up conservation schemes for key seabird areas. Further aims are testing, promoting and introducing new technical and operational bycatch mitigation measures (with specific reference to alternative gear) and finally developing and implementing effective data collection for more reliable data on incidentally by-caught birds and mammals and fishing effort for which there has long been a legal obligation (specifically under the EU Birds and Habitats Directive, Common Fisheries Policy and the Data Collection Multiannual Programmes).

In addition to the actions outlined in the 2021 Baltic Sea Action Plan, HELCOM has adopted Recommendations which also address bycatch. For the three seal species occurring in the Baltic Sea, the HELCOM Recommendation (27-28/2) adopted in 2006 recommends:

- to take effective measures for all populations in order to prevent illegal killing, and to reduce incidental bycatches to a minimum level and if possible, to a level close to zero;
- to develop and to apply where possible non-lethal mitigation measures for seals to reduce incidental bycatch and damage to fishing gear, as well as to support and coordinate the development of efficient mitigation measures.

For harbour porpoise the HELCOM Recommendation 17/2, adopted in 1996 and updated in 2020, recommends:

- give highest priority to avoiding bycatches of harbour porpoises, particularly following the recommendations of ASCOBANS and the Jastarnia Plan, in order to achieve the ecological objective of the Baltic Sea Action Plan. Bycatch of harbour porpoise, shall be significantly reduced with the aim to reach bycatch rates close to zero, recognizing that the Baltic Proper population of harbour porpoise is more threatened than the Western Baltic, Belt Sea and Kattegat population;
- take action for collection and analysis of data on pressures such as bycatch, disturbance, including underwater noise, pollutants, changes in food base and prey quality, habitat deterioration, climate change, and human activities associated with the listed pressures;
- implementing effective and adequate protection measures for the species both inside and outside HELCOM MPAs.

Bycatch, which is a pressure that is not specific only to the Baltic Sea, is also recognised and addressed under several other international commitments, both at the EU level and beyond.

9.6.2 Other international commitments

At the EU level the MSFD and Habitats and Birds Directives (European Commission 2009), respectively, functions as a key commitment and the HELCOM holistic assessment also directly or indirectly addresses the following qualitative descriptors and criteria of the MSFD for determining Good Environmental Status (European Commission 2008a, criteria of the Commission Decision 2017/848 (European Commission 2017a):

Descriptor 1: 'Biological diversity is maintained. The quality and occurrence of habitats and the distribution and abundance of species are in line with prevailing physiographic, geographic and climatic conditions'

- Criterion D1C1 (mortality rate from bycatch)
- Criterion D1C2 (population abundance)
- Criterion D1C3 (population demographic characteristics)
- Criterion D1C4 (species distribution)

Descriptor 4: 'All elements of the marine foodwebs, to the extent that they are known, occur at normal abundance and diversity and levels capable of ensuring the long-term abundance of the species and the retention of their full reproductive capacity',

- Criterion D4C1 (diversity of trophic guild)
- Criterion D4C2 (balance of total abundance between trophic guilds)
- Criterion D4C4 (productivity)

The EU Habitats Directive lists the harbour porpoise as a strictly protected species (Annex IV) which requires Member States to establish a system of strict protection in their natural range. The harbour porpoise and the three seal species are further listed in Annex II, meaning that they are also to be protected by the means of the Natura 2000 network.

The EU Birds Directive aims to protect, inter alia, habitats of endangered and migratory birds to ensure their conservation in Europe. This not only refers to birds needing specific conservation measures (Article 4 (1)) and listed in Annex I (black-throated diver, red-throated diver, Slavonian grebe, Steller's eider, smew), but also to all migratory species (Article 4 (2)). Therefore, all waterbird species breeding, wintering and staging during migration in the Baltic Sea are covered by the Directive.

While broad commitments have been made to achieve Good Environmental Status under the EU Marine Strategy Framework Directive (MSFD), and to Favourable Conservation Status under the Habitats Directive, translating these goals into specific targets on bycatch limits under these legislations is as yet unspecified by the EU. However, the EU Regulation 2019/1241 on Technical Measures in Art. 3, 2.(b) formulates the aim to ensure that incidental catches of sensitive marine species, including those listed under Directives 92/43/EEC and 2009/147/EC, that are a result of fishing, are minimised and where possible eliminated so that they do not represent a threat to the conservation status of these species.

The threshold setting for waterbirds in the indicator on 'Number of drowned mammals and waterbirds in fishing gear' (HELCOM 2023n) uses a legal interpretation of this in which 'small numbers' are defined as an approximation of 'zero bycatch', which acknowledges that small numbers of seabirds will probably still be caught even when the most effective mitigation measures are in place.

EU legislation clearly requires Member States to take measures prohibiting deliberate killing or capture by any method (Article 5 Birds Directive; Article 12 Habitats Directive) which also includes the mere acceptance of the possibility of killing or capture (Case C221/04 Commission v Spain [2006] ECR I4515, paragraph 71). This applies to only Annex IV species not to Annex V species (seals).

Article 12, paragraph 4 of the Habitats Directive requires that Member States shall establish a system to monitor the incidental capture and killing of the animal species listed in Annex IV (a) (European Commission 1992). In the light of the information gathered, Member States shall take further research or conservation measures as required to ensure that incidental capture and killing does not have a significant negative impact on the species concerned. Member States of the EU are further obliged to develop national programmes for monitoring fisheries, including on board monitoring, under the EU Regulation 2017/1004 (European Commission 2017b). These programmes include detailed data on fleet capacity and fishing effort by metier and fishing area. The Commission Delegated Decision (EU) 2021/1167 (European Commission 2021) requires that bycatch is to be monitored for all marine mammal species protected under **Annex II, IV and V** of the Habitats Directive. Besides cetacean and seal species this also includes the Eurasian otter. Due to lack of data, a bycatch evaluation for the Eurasian otter was not possible for HOLAS 3 but will be further explored towards future assessments.

In May 2020, ICES published scientific advice on emergency measures to prevent bycatch for Baltic Proper harbour porpoise in the Northeast Atlantic, and since then two Joint Recommendations have been submitted by the Baltic Sea regional fisheries body BALTFISH to the European Commission. In February 2022, a Delegated Act based on those two Joint Recommendations came into force, closing static net fisheries in important harbour porpoise areas, some all year round and some part of the year, depending on their location in relation to the known seasonal distribution of the Baltic Proper population. The Delegated Act also stipulates mandatory pinger use in a couple of Marine Protected Areas (MPAs).

Further, with reference to the Birds Directive, the Delegated Decision requires bycatch monitoring of all waterbird and seabird species, including migratory species. A proposed action in the *Action Plan for reducing incidental bycatches of seabirds in fishing gears* includes the monitoring of seabird incidental bycatch with a minimum coverage of 10% of the fisheries (European Commission 2012) which is far from being reached in relevant gears (ICES 2021c). As a voluntary instrument within the framework of EU and international environmental and fishery legislation and conventions, the action plan aspires to provide a management framework to minimise incidental bycatch by implementing effective mitigation measures as much as possible in line with the objectives of the EU Common Fisheries Policy (CFP), i.e. to cover all components of the ecosystem.

The Agreement on the Conservation of Small Cetaceans of the Baltic, North East Atlantic, Irish and North Seas (ASCOBANS) aims to achieve and maintain a favourable conservation status of small cetaceans. Six of the nine Baltic Sea countries are Parties to the Convention (Denmark, Germany, Sweden, Poland, Lithuania and Finland).

All waterbird species occurring in the Baltic Sea are subject of the Agreement on the Conservation of African-Eurasian Migratory Waterbirds (AEWA), for which Denmark, Germany, Sweden, Lithuania, Latvia, Estonia and Finland are Contracting Parties.

The indicator supports the UN Sustainable Development Goal 14: 'Conserve and sustainably use the oceans, sea and marine resources for sustainable development.'

An overview of current measures in place in the Baltic is provided in table 9.13 (adapted from ICES; 2022).

The majority of current measures are targeted at marine protected areas around the Baltic Sea (Table 9.13). To minimise bycatch of harbour porpoise, ICES has adviced that, besides measures taken within protected areas, bycatch has to be mitigated throughout the entire population range. In addition, to adhere to the Marine Strategy Framework Directive (MSFD), the Habitats Directive (including its Natura 2000 marine protected areas network goals) and some of the main objectives of the Common Fisheries Policy (CFP), HELCOM Contracting Parties who are also EU Member States need to take further measures also in areas not designated as MPAs. These can include mandatory large scale use of deterrents such as pingers, or a stepwise reduction of static net fishing effort in commercial and recreational fisheries which could be replaced by alternative fishing gear proven to avoid bycatch (e.g., pots, traps and longlines) for commercial fisheries. It could also include implementing permanent or seasonal closures for static net fisheries in areas that are known to be important for species prone to bycatch.

9.6.3 Needs for future assessments

Unfortunately, a severe lack of data on bycatch and fishing effort prevents undertaking a more exact examination of the true extent and the impact of bycatch on the populations. In order to assess bycatch numbers from bycatch rates (derived from bycatch monitoring), it is extremely important to have reliable effort data in all relevant métiers, which is currently not the case. Whereas large vessels have VMS and report their fishing effort in their (electronic) logbooks, smaller vessels do not report their effort in a comparable way. In some countries, fishers are only required to keep sales notes, other countries require monthly journals and even others coastal logbooks. Effort might be given in different metrics (days at sea, hours fished, gear dimensions x time, etc.). The European Commission and Member States are aware of this, but improving legislation is difficult and coordinating CPs is also

Table 9.13. Summary of current mitigation measures in the Baltic and associate legislation.

Measure	Area	Legal act
All driftnets are prohibited	**Whole Baltic Sea**	**REGULATION (EU) 2019/1241**
For vessels 12m and more, when using bottom-set gill net or entangling net "active acoustic deterrent devices" are mandatory.	Baltic Sea Area delimited by a line running from the Swedish coast at the point at longitude 13° E, thence due south to latitude 55° N, thence due east to longitude 14° E, thence due north to the coast of Sweden; and, Area delimited by a line running from the eastern coast of Sweden at the point at latitude 55°30' N, thence due east to longitude 15° E, thence due north to latitude 56° N, thence due east to longitude 16° E thence due north to the coast of Sweden	REGULATION (EU) 2019/1241, COMMISSION DELEGATED REGULATION (EU) 2022/303
For vessels 12m and more, when using bottom-set gill net or entangling net "active acoustic deterrent devices" are mandatory	Baltic Sea sub-division 24 (except for the area covered above)	REGULATION (EU) 2019/1241, COMMISSION DELEGATED REGULATION (EU) 2022/303
For all vessels using static gear "active acoustic deterrent devices" are mandatory	In the West and East of the "sandbank Ryf Mew" (Inner and Outer Puck Bay, within and outside the Natura 2000 site "Zatoka Pucka Półwysep Helski" (PLH220032)	REGULATION (EU) 2019/1241, COMMISSION DELEGATED REGULATION (EU) 2022/303
For all vessels using static gear "active acoustic deterrent devices" are mandatory from 1 May to 31 October.	Natura 2000 site "Sydvästskånes utsjövatten" (SE0430187),	REGULATION (EU) 2019/1241, COMMISSION DELEGATED REGULATION (EU) 2022/303
Fishing permitted only with pots, fish traps and longlines	Northern Midsea Bank	REGULATION (EU) 2019/1241, COMMISSION DELEGATED REGULATION (EU) 2022/303
Fishing with all types of static nets is prohibited	Natura 2000 site "Hoburgs bank och Midsjöbankarna" (SE0330308), "Southern Midsea Bank"	REGULATION (EU) 2019/1241, COMMISSION DELEGATED REGULATION (EU) 2022/303
Fishing with all types of static nets is prohibited from November to 31 January	Natura 2000 site "Adler Grund and Rønne Banke" (DK00VA261), Natura 2000 site "Adlergrund" (DE1251301), Natura 2000 site "Westliche Rönnebank" (DE1249301), Natura 2000 site "Pommersche Bucht mit Oderbank" (DE1652301), Natura 2000 site "Greifswalder Boddenrandschwelle und Teile der Pommerschen Bucht" (DE1749302), Natura 2000 site "Ostoja na Zatoce Pomorskiej" (PLH990002), The marine part of the Natura 2000 site "Wolin i Uznam" (PLH320019), Natura 2000 site "Pommersche Bucht" (DE1552401)	REGULATION (EU) 2019/1241, COMMISSION DELEGATED REGULATION (EU) 2022/303
Fishing with all types of static nets is prohibited from November to 30 April	Natura 2000 site "Sydvästskånes utsjövatten" (SE0430187)	REGULATION (EU) 2019/1241, COMMISSION DELEGATED REGULATION (EU) 2022/303

difficult because a solution would require additional resources. The *HELCOM Roadmap on fisheries data in order to assess incidental bycatch and fisheries impact on benthic biotopes in the Baltic Sea* (HELCOM 2020d) describes the data needs with respect to bycatch monitoring and reporting of fishing effort.

Monitoring effort in general needs to be increased to allow robust evaluations, including ensuring sufficient and representative coverage of all métiers and all fleet segments at a relevant temporal scale. The European Commission has included bycatch monitoring of protected bird and mammal species in the Commission Delegated Decision (EU) 2021/1167. Further participation of HELCOM Contracting Parties on a regional scale is necessary for the implementation process in order to ensure suitable monitoring methods and sufficient coordinated coverage, as well as effort monitoring, are developed into meaningful parameters (static net fishing effort must be measured in length of nets * soak time). Effort must also be given as Days at Sea in order to enable comparisons with earlier years. So far, only fishing effort from logbooks and VMS data can be used for bycatch extrapolations from observer or Remote Electronic Monitoring data (ICES 2021c). The additional effort by small commercial vessels for which only monthly journals, landing declarations or sales notes are available without precise information about the spatial distribution of fishing effort and their temporal extent as well as effort by recreational fishermen must be estimated and taken into account. Then the uncertainty in the fishing effort estimates which underlie the bycatch estimate needs to be specified by also adding a 95 % confidence interval.

REM has been shown to be a cost-effective method for bycatch monitoring (Kindt-Larsen *et al.* 2012) which can deliver robust bycatch estimates based on high-quality data (Larsen *et al.* 2021, Glemarec *et al.* 2022). Onboard observers in the frame of the EU Data Collection Framework (DCF) can also produce high quality data. However, this requires a protocol which takes specific needs of bycatch monitoring guidelines into account as observers normally focus on the commercial fish catch. This is a major drawback as fisheries producing highest bycatches in the Baltic Sea are less in the focus of observer programmes. Observer coverage needs to be corrected if observers are engaged with other duties (e.g., measuring fish under deck) (ICES 2018a). Reporting of bycatches in log-books (self-reporting) or port controls are the least reliable method and they do not account for fishing effort, meaning that they do not allow extrapolating results to the effort of the whole fleet. Previously, logbooks did not even have a field to report bycatches of mammals and seabirds. Thus, self-reporting and port controls do not allow indicator evaluations. In some cases however, monitoring would need a full coverage of fisheries because populations are so depleted that even very low bycatch numbers which are hard to detect further threaten the population. In these cases implementing effective mitigation measures such as time-/area closures, gear restrictions or technical measures are a matter of urgency.

As specific points to be addressed in future bycatch evaluations, also seal bycatch data based on REM must distinguish between species. A model must be developed to allow estimating what proportion of by-caught seals to assign to each species/population. Further, European otters should also be included in future bycatch evaluations as the coastal distribution of parts of the population overlapping with commercial as well as recreational small scale net and trap fisheries suggests that this population may be of conservation concern.

In the absence of high-resolution data on effort and bycatch rates, the bycatch figures reported by the scientific community (e.g., ICES WGBYC) are likely underevaluating mortality from bycatch in some cases and, consequently, may not reflect the true extent of the impact of bycatch on populations (Peltier *et al.* 2016, Morkūnas *et al.* 2022).

A detailed analysis of improvements regarding data availability and quality can be found in the *HELCOM Roadmap on fisheries data in order to assess incidental bycatch and fisheries impact on benthic biotopes in the Baltic Sea* (HELCOM, 2020d).

In addition to sufficient monitoring of bycatch and fishing effort the uncertainties identified as part of the assessment show that population size, trend analyses and other sources of anthropogenic mortality are a prerequisite for getting a more reliable evaluation. In addition, all threshold values based on population modelling require that a a conservation objective be defined and all anthropogenic mortality be taken into account. For waterbirds, the aim is to apply population modelling in order to quantify the impact of bycatch mortality on population growth. If sufficient bycatch and fishing effort data are available, such an approach is feasible on the level of bird populations, as has been shown for a benthivorous duck species, the greater scaup (Marchowski *et al.* 2020).

Towards the next holistic assessment a stronger application of fisheries effort information could support a clearer understanding of the relationship with thrends or changes, and the overall topic of bycatch.

The shortcomings in relation to population estimates, trend analyses and the level of anthropogenic impacts on these populations means that only low confidence can be assigned to this assessment. High priority should be given to improvement of these shortcomings.

10. Threatened species in the Baltic Sea region

Assessment results in short

— Almost 2800 species or subspecific assessment units were considered in the Red List assessment and about 1750 were evaluated according to the IUCN Red List criteria. In all, 4% of those were regarded as threatened (VU, EN, CR), which means that they are in danger of becoming extinct in the Baltic Sea.
— Three species were found to be already regionally extinct in the HELCOM area: two fish, American Atlantic sturgeon and the common skate, and one bird, the gull-billed tern.
— All in all eight taxa, all vertebrates, were categorised as Critically Endangered (CR). The overall numbers of taxa in the categories Endangered (EN) and Vulnerable (VU) were 18 and 43, respectively. Additionally, 36 taxa were assessed Near Threatened (NT) and 37 as Data Deficient (DD). The overall proportion of threatened taxa was 8.3%.

10.1. Introduction to threatened species and regional Red List assessment

The global rate of species extinction is already at least tens to hundreds of times higher than the average rate over the past 10 million years and is accelerating (IPBES 2019b). The risk of extinction is tracked through so called Red List assessments and in 2013 HELCOM published the HELCOM Red List of Baltic Sea species in danger of becoming extinct (HELCOM 2013c). This was the first threat assessment for Baltic Sea species that covered all marine mammals, fish, birds, macrophytes, and benthic invertebrates.

HELCOM is in the process of reviewing the threat status of species in the Baltic Sea, with the aim to produce an updated Red list for Baltic Sea species by the end of 2024.

Iterative assessments of the Red List of species provides a reference point and shows the trend of the assessed species throughout their distribution. The results from an updated Red List are also a prerequisite to addressing other related topics, such as MPA related assessments, possible effects of climate change, and ecosystem services etc.

Regularly reviewing the status of Baltic Sea species enables the tracking of long-term trends in the status of the Baltic Sea biodiversity and show changes in the status of species or the impact of pressures. This allows us to assess whether actions taken to halt the loss of biodiversity have been effective or if more or different measures are needed.

10.2. Assessment results for threatened species

Almost 2800 species or subspecific assessment units were considered in the Red List assessment and about 1750 were evaluated according to the IUCN Red List criteria. In all, 4% of those were regarded as threatened (VU, EN, CR), which means that they are in danger of becoming extinct in the Baltic Sea.

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Table 10.1. Baltic Sea species threatened with extinction based on the HELCOM Red List (HELCOM 2013c).

Species scientific name	Species name in English	Species group	Threat status
Alisma wahlenbergii		Macrophytes	VU
Chara braunii	Braun`s stonewort	Macrophytes	VU
Hippuris tetraphylla	Fourleaf Mare's Tail	Macrophytes	EN
Lamprothamnium papulosum	Foxtail stonewort	Macrophytes	EN
Nitella hyalina	Many-branched stonewort	Macrophytes	VU
Persicaria foliosa		Macrophytes	EN
Zostera noltii	Dwarf eelgrass	Macrophytes	VU
Abra prismatica		Invertebrates	VU
Atelecyclus rotundatus	Circular crab/Old mans face crab	Invertebrates	VU
Clelandella miliaris		Invertebrates	VU
Cliona celata	Yellow boring sponge	Invertebrates	VU
Deshayesorchestia deshayesii		Invertebrates	VU
Epitonium clathrus	Common wentletrap/European wentletrap	Invertebrates	VU
Haploops tenuis		Invertebrates	EN
Haploops tubicola		Invertebrates	VU
Hippasteria phrygiana	Rigid cushion star	Invertebrates	VU
Hippolyte varians	Chamaeleon prawn	Invertebrates	VU
Lunatia pallida	Pale moonsnail	Invertebrates	VU
Macoma calcarea	Chalky macoma	Invertebrates	VU
Modiolus modiolus	Northern horsemussel	Invertebrates	VU
Nucula nucleus	Common nut clam	Invertebrates	VU
Parvicardium hauniense	Copenhagen cockle	Invertebrates	VU
Pelonaia corrugata		Invertebrates	VU
Scrobicularia plana	Peppery furrow shell	Invertebrates	VU
Solaster endeca	Purple sun star	Invertebrates	VU
Stomphia coccinea	Spotted swimming anemone	Invertebrates	VU
Acipenser oxyrinchus	American Atlantic sturgeon	Fish	RE
Anguilla anguilla	European eel	Fish	CR
Coregonus maraena	Whitefish	Fish	EN
Dipturus batis	Common skate	Fish	RE
Gadus morhua	Atlantic cod	Fish	VU
Galeorhinus galeus	Tope shark	Fish	VU
Lamna nasus	Porbeagle	Fish	CR
Merlangius merlangus	Whiting	Fish	VU
Molva molva	Ling	Fish	EN
Petromyzon marinus	Sea lamprey	Fish	VU

Species scientific name	Species name in English	Species group	Threat status
Raja clavata	Thornback ray	Fish	VU
Salmo salar	Salmon	Fish	VU
Salmo trutta	Trout	Fish	VU
Squalus acanthias	Spurdog / Spiny dogfish	Fish	CR
Thymallus thymallus	Grayling	Fish	CR
Anser fabalis fabalis (wintering)	Taiga bean goose	Birds	EN
Arenaria interpres (breeding)	Ruddy turnstone	Birds	VU
Aythya marila (breeding)	Greater scaup	Birds	VU
Calidris alpina schinzii (breeding)	Southern dunlin	Birds	EN
Cepphus grylle arcticus (wintering)	Black guillemot	Birds	VU
Charadrius alexandrinus (breeding)	Kentish plover	Birds	CR
Clangula hyemalis (wintering)	Long-tailed duck	Birds	EN
Gavia arctica (wintering)	Black-throated diver	Birds	CR
Gavia stellata (wintering)	Red-throated diver	Birds	CR
Gelochelidon nilotica (breeding)	Gull-billed tern	Birds	RE
Hydroprogne caspia (breeding)	Caspian tern	Birds	VU
Larus fuscus fuscus (breeding)	Lesser black-backed gull	Birds	VU
Larus melanocephalus (breeding)	Mediterranean gull	Birds	EN
Melanitta fusca (wintering EN, breeding VU)	Velvet scoter	Birds	EN
Melanitta nigra (wintering)	Common scoter	Birds	EN
Mergus serrator (wintering)	Red-breasted merganser	Birds	VU
Philomachus pugnax (breeding)	Ruff	Birds	VU
Podiceps auritus (breeding VU, wintering NT)	Slavonian grebe	Birds	VU
Podiceps grisegena (wintering)	Red-necked grebe	Birds	EN
Polysticta stelleri (wintering)	Steller's eider	Birds	EN
Rissa tridactyla (breeding EN, wintering VU)	Black-legged kittiwake	Birds	EN
Somateria mollissima (wintering EN, breeding VU)	Common eider	Birds	EN
Xenus cinereus (breeding)	Terek sandpiper	Birds	EN
Phoca hispida botnica	Baltic ringed seal	Mammals	VU
Phoca vitulina (Kalmarsund population)	Harbour seal	Mammals	VU
Phocoena phocoena (Baltic Sea population)	Harbour porpoise	Mammals	CR
Phocoena phocoena (Western Baltic population)	Harbour porpoise	Mammals	VU

In the 2013 HELCOM Red List assessment, the proportions of threatened (categories CR, EN, and VU) and all red-listed (threatened and RE, NT, and DD) species are rather low, 3.9% and 8.3%, respectively, compared to other regions/global assessments. In the interpretations of the results, it should first be noted that the IUCN Red List criteria are especially designed to find species with a high risk of (regional) extinction. The IUCN Red List criteria do not highlight populations that have declined, e.g. some decades ago, but are not declining any more, unless they have become threatened merely due to the small size of the remaining population. The low proportion of threatened species likely also relates to the lack of data and to the composition of the species list considered in the assessment. The majority of the species considered are macrophytes and benthic invertebrates, both of which are much more poorly known than the vertebrate groups. It is impossible to estimate how many threatened species have been left unevaluated due to the severe or complete lack of data, however 37 species were categorized as data deficient, i.e. data were so uncertain that both CR and LC are plausible categories, combined with a suspicion of an existing threat. In total, 818 species that were included in the Baltic Sea checklist (HELCOM 2012) were left out of the assessment (Not Evaluated).

The composition of the considered species list also affects the overall proportion of taxa assessed as threatened in other ways. For example, small animals, which constitute a great majority of the fauna included in the current assessment, tend to have larger population sizes compared to large animals. As a result, they can only seldom be redlisted according to the criteria relating to small population size. Data allowing, smaller animals might become red-listed according to criteria that relate to population declines but the IUCN Red List criteria restrict the time-frame of decline estimation to 10 years or three generations, whichever is the longer period. Small animals also tend to be shortlived, which means that for most of them the time period for population decline estimation is thus only 10 years. However, as such population trend data is virtually non-existent for most of the Baltic Sea invertebrates and macrophytes, these species cannot be red-listed on the basis of potential declines either. It is also important to note that compared to most other regional seas (e.g. the Mediterranean Sea), the Baltic Sea and especially its western parts have naturally unstable conditions for many environmental factors that control the distribution of species. This favours communities including a high percentage of generalists that are adapted to variable environmental factors. The proportion of specialists is also low due to the young geological age of the Baltic Sea. As a consequence, the proportion of threatened or red-listed species is lower than would be expected in other regional seas inhabiting higher proportions of specialists.

Within the groups of macrophytes and benthic invertebrates, the Red Lists mainly include species that are rare and have further declined. In many cases, the rarity in the HELCOM area is related to their salinity requirements (either high or low). Many of the red-listed species are characteristic components of shallow, sheltered bays, lagoons or inlets. Eutrophication effects are more pronounced in such habitats due to reduced water exchange, and the same areas are also hot spots for tourism, exposed to several construction activities and commercial use, such as aquaculture.

With regard to vertebrates, the Red Lists do not have such a strong inclination towards geographically restricted populations or towards certain regions. The red-listed fish, birds, and mammals include taxa from different regions rather evenly and also widely distributed taxa that have experienced dramatic overall declines.

At first glance, the percentages of threatened and red-listed species in the HELCOM assessment appear to be considerably lower than those found in similar regional assessments that have been conducted country-wise. It is quite likely that the reasons for the apparent difference in the Finnish, Swedish and HELCOM proportions of threatened species lies rather in the taxonomic or distributional differences in the compositions of the groups of assessed species than in genuine differences between environments.

10.3. Changes over time for threatened species

The 2013 Red List is the third evaluation by HELCOM concerning threatened species, but the first to evaluate all species groups using the IUCN Red List criteria. The earlier HELCOM list of threatened and/or declining species and biotopes/ habitats (HELCOM 2007) was based on expert judgment. It listed species and biotopes considered either threatened or declining or both without giving specific criteria or justifications for the decisions. This means that the 2007 and the 2013 assessment are not comparable in such a way that any genuine trends in the status of the Baltic Sea species could be revealed by comparing their results.

However, the 2024 Red List will be using agreed IUCN assessment methodology and thus the results will be comparable to the 2013 assessment.

When comparing red list assessment results across assessments it is important to account for what underpins a change in assessment category. This change can be a direct result of measures taken to improve status, or to increased pressures, but can also be the results of improved knowledge or data availability. For example, for habitat generalists taxa, the lack of data is usually more severe for rare rather than the common species as the accumulation of data depends on sampling that, from the species´ point of view, is more or less random. Therefore, it is possible that when the proportion of evaluated species grows together with accumulating data in the future, the proportion of threatened species may also rise in the forthcoming HELCOM assessments.

10.4. Relationship of threatened species to drivers and pressures

When looking at species under threat it is important to understand what human activities, and subsequent pressures, has driven them to be under threat of extinction, i.e. identifying past threats. An overview of current distribution of activities and pressures can be found in the Thematic Assessment on Spatial Distribution of Pressures and Impacts (HELCOM 2023a). But it is also vital to understand what threats these species are facing in the future, to be able to take action before their situation further deteriorates. In most cases, the same threat factors that have been considered as reasons for the taxa becoming threatened, i.e. past and current threats, are assumed to be important also in the future. The red list assessment look at both of these, past and future, and identifies the human activities and pressures with significant negative impact on one or more of the red listed species. Table 10.2 and 10.3 shows what activities and pressures were identified.

Table 10.2. Overview of human activities which caused threat to species on the red list, in the past, the present or the future.

Activity	
Changes in agricultural management	intensification of management, conversion of grassland to cropland etc.
Construction	all marine construction activities, e.g. wind power farms, gas pipelines, bridges, dredging, ports, coastal defence barriers, also coastal terrestrial construction, if relevant (vacation homes or roads), also noise from construction or operation.
Ditching	ditching and draining of mires and coastal meadows.
Extra-regional threats	e.g. fi shing, hunting or habitat changes affecting migratory species outside the HELCOM marine area.
Fishing	both commercial and recreational fishing, surface and mid-water fishery, bottom-trawling, coastal stationary fishery, gil-lnets. Selective extraction of species.
Hunting:	selective extraction of species, including incidental non-target catches.
Mining and quarrying	extraction of bottom substrates
Tourism	detrimental effects of tourism, e.g. trampling of beaches or cleaning of algal belts from sandy beaches.
Water traffic	physical impact due to traffic, e.g. erosion caused by anchoring, boat wakes and other vessel effects, also noise.

The assessment concluded that none of the red-listed species seems to be under a pressure from only a single, specific, human activity. Rather, each species faces a multitude of pressures. If counted over all species groups, eutrophication is the most commonly mentioned past and current threat and also the most commonly mentioned threat in the future for the red-listed species (Figure 10.1). Eutrophication is an important threat or reason for becoming threatened, especially among macrophytes and benthic invertebrates. It affects in many ways, e.g. by increasing turbidity and reducing the penetration of light in the water. Increased nutrient levels also benefit opportunistic macrophytes, for example filamentous algae growing on other macrophytes. The colonisation of hard bottoms by macroalgae suffers from increased siltation due to the excessive growth of phytoplankton, which may prevent the attachment of algae spores on substrates. Siltation is assumed to be one of the main reasons for becoming threatened also among benthic invertebrates. In addition to eutrophication, siltation is also caused by bottom trawling, which is very intensive in some areas. With the enhanced growth of phytoplankton and opportunistic macrophytes, the amount of organic matter ending to the bottom increases, and so does the consumption of oxygen in the decomposition of this biomass. Oxygen deficiency related to eutrophication is an important factor for many benthic invertebrates and also some fish. In many cases, the detrimental effects of eutrophication are indirect, such as in cases where populations of invertebrates or fish are declining together with their habitats, e.g. macrophyte meadows. More information on the current status of eutrophication can be found in the HELCOM Thematic Assessment of Eutrophication (HELCOM 2023d).

Table 10.3. Overview of pressures resulting from human activities which caused threat to species on the red list, in the past, the present or the future.

Pressure	How does it cause a threat?
Non-indigenous species	competition, predation, hybridization, diseases, ecosystem changes by introduced species.
By-catch	by-catch by fishing, concerns both non-target species of fish and also other animals, such as waterbirds or marine mammals
Climate change	all detrimental effects of climate change
Competition and predation	competition and predation by native species, especially if promoted by human activities, such as rabies vaccination for foxes, improved food availability for gulls due to fishery and refuse disposal.
Contaminant pollution	all pollution to waters by hazardous substances, except for oil spills which have their own code (coastal industry, riverine load of heavy metals, discharges of radioactive substances, atmospheric deposition of metals and dioxins, polluting ship accidents excluding oil spills)
Epidemics	large-scale epidemics or diseases.
Eutrophication	detrimental effects of nutrient enrichment that can be defi ned in more detail, e.g. anoxia and hypoxia, excessive growth of algae, reduction in water transparency, or siltation.
Litter	plastic waste, ghost nets etc. Entanglement and ingestion.
Migration barriers	dams by hydroelectric power plants or other river constructions preventing spawning migrations of fish.
Overgrowth of open areas	e.g. coastal meadows or shallow water areas that become overgrown due to lack of management (related to eutrophication and interfloral competition, incl. expansion of reed).
Human disturbance	e.g. disturbance due to people visiting bird islands or passing by too close to bird colonies, hauling-out areas of seals, etc., also disturbance of species due to hunting activities (especially species other than those targeted by hunting)
Random threat factors	used only for species that are so rare that even random catastrophic events can destroy their populations
Oil spills	oil spills from ship accidents, also from oil terminals, refineries, oil rigs. Oiling and contamination.

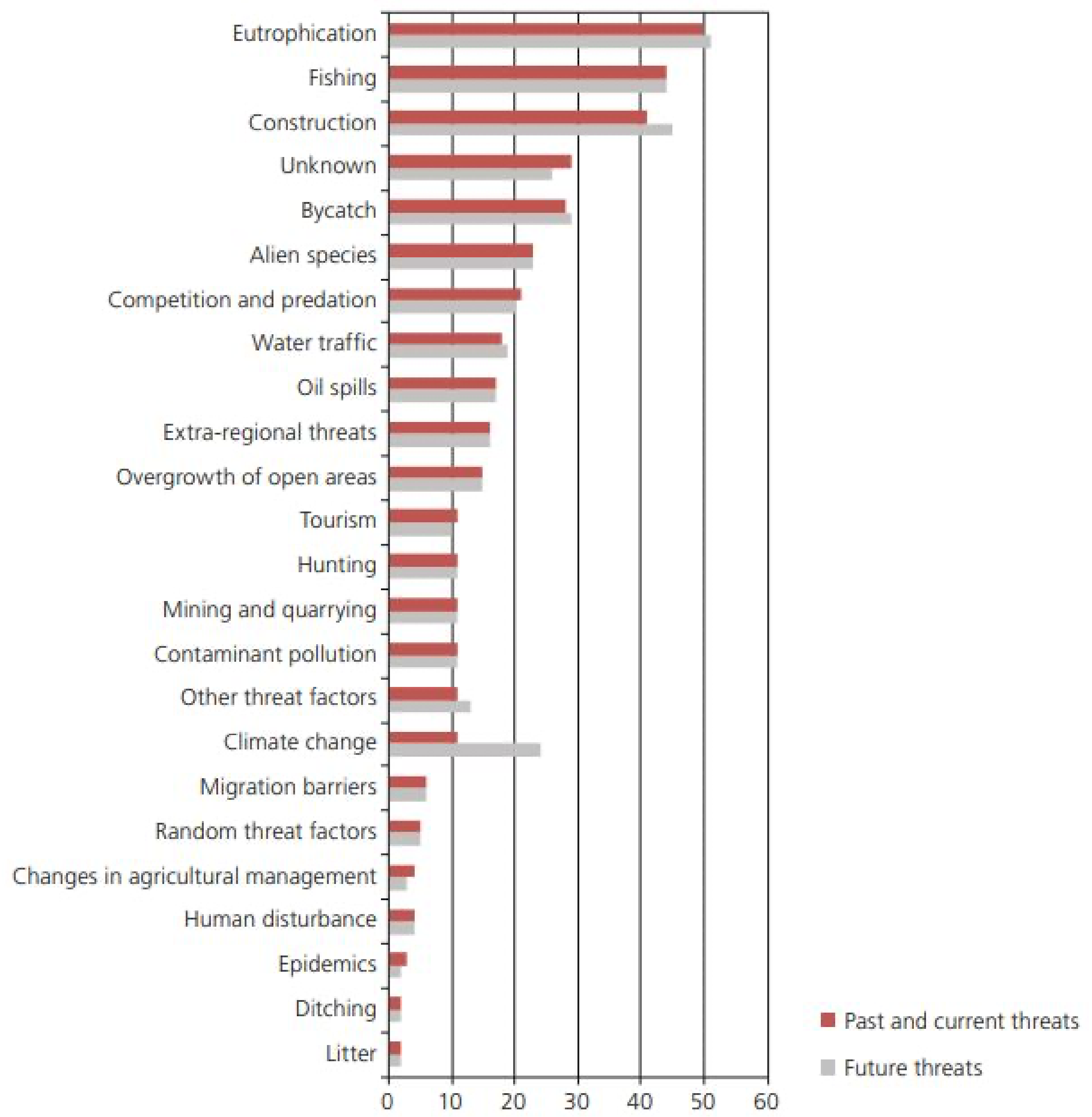

Figure 10.1. Past and current threats (reasons for becoming threatened) for the red-listed species and future threats, counted over all species groups. The x-axis shows the number of red-listed species for which the threat was regarded important by the HELCOM Red List experts and reported in the Species Information Sheets. (Source: HELCOM 2013c).

Fishing, construction activities, unknown reasons, and bycatch are the next most important threats, both in the past and in the future.

Fishing or fisheries is mentioned as an essential threat for many fish species and it includes both commercial and recreational fishing. The latest overview of the distribution and intensity of fishing can be found in the Thematic Assessment Report on the Spatial Distribution of pressures and Impacts, prepared as part of the HOLAS 3 assessment (HELCOM 2023a). Fishing also includes bottom trawling, which is among the most important threats for many red-listed benthic invertebrates, and, as a consequence, impacts the birds which prey on them. In addition to having a direct impact on the seabed and its fauna, the use of bottom touching fishing gear also increases siltation over larger areas. Recreational fisheries also pose a threat to some threatened species, particularly as these are less regulated and often data deficient. The use of gillnets in recreational fishing is often only loosely regulated, however, gillnets pose a great risk for many diving bird species, with tens of thousands of birds caught in nets annually (please see section 9 of this report for an overview of bycatch). Recreational angling poses a problem in some areas since there are clearly less restrictions than for commercial fisheries.

Construction includes many coastal and off-shore activities, e.g. wind power farms, gas pipelines, bridges, dredging, ports, coastal defence barriers, and also terrestrial construction, such as vacation homes. Construction causes both the direct destruction of habitats and indirect effects, such as increased turbidity and siltation around construction sites.

Many macrophytes and benthic invertebrates require near-coast sheltered soft-bottom habitats, such as bays, estuaries and lagoons, which are under great human pressures and have changed dramatically over the past decades. One of the changes is the restriction of hydrodynamics between the sea and estuaries or lagoons.

For benthic invertebrates and macrophytes that are, in general, more poorly known species groups the reasons behind the threatened status of a species can often be unknown Bycatch is an important which concerns sharks and rays, many waterbirds that drown in gillnets, and also marine mammals in the Baltic Sea Invasive species have been identified as an important reason behind negative trends for birds. particularly mammalian predators such as the mink, raccoon and raccoon dog.

Climate change is a special case that has been regarded as an important factor much more often for the future than for the past in the assessment. In 2021 HELCOM, together with Baltic Earth, published the Baltic Sea Climate Change Fact Sheet (HELCOM/Baltic Earth 2021), which outlines the already occurring and the expected effects and impacts of climate change across a large number of topics, many of which are relevant for threatened species.

More precise information on the species specific threats can be found in the Species Information Sheets prepared for each redlisted species which are available on the HELCOM website as well as in the Climate change fact sheet (HELCOM/Baltic Earth 2021).

10.5. How was the assessment of threatened species carried out?

The assessment for Red Listed species follows the Red List criteria of the International Union for Conservation of Nature (IUCN). Assessment methodological details can be found in the HELCOM Red List of Baltic Sea species in danger of becoming extinct (HELCOM 2013c).

The HELCOM Checklist of Baltic Sea macrospecies (HELCOM 2020b) facilitate the Red List assessment by providing a comprehensive overview of species occurring in the Baltic Sea, both current and historical. Observational data for species are readily available via the HELCOM Biodiversity Database (BioBase). BioBase also provides vital infrastructure for reporting, storing and querying data to support the assessments, as well as providing agreed data formats, preliminary quality checks of reported data and a way to ensure direct links with the World Register of Marine Species (WoRMS). The data for the assessment is collected through targeted data calls incorporating all the countries around the Baltic Sea. Several of the countries have been working to updated their national red lists and it is expected that new data will become available through the national processes for the majority of the species groups.

10.6. Follow up and needs for the future with regards to threatened species

10.6.1 HELCOM actions

Like all HELCOM assessments, an updated Red List assessment functions as an integral part of keeping track of the progress and effectiveness of both HELCOM and other relevant commitments and can help to increase the effectiveness and efficiency of measures by targeting areas or species identified to be of priority.

The Red List is intrinsically linked to a broad set of commitments within HELCOM and provides relevant information for assessing the fulfilment of the updated HELCOM Baltic Sea Action Plan, HELCOM Recommendations 37-2 and 40-1, as well as a number of Recommendations targeting relevant species directly. For the extinct sturgeon HELCOM has developed an Action Plan, underpinned by a dedicated programme, focused on the reintroduction of sturgeon in the Baltic Sea.

HELCOM Recommendation 37-2 states that HELCOM Contracting Parties are to make an inventory of existing and planned national and regional conservation-, recovery- and/or action plans as well as other relevant programmes and measures for the protection of species which are threatened according to the 2013 HELCOM Red List. For the purposes of this report a summary of this inventory has been compile, illustrating the measures being taken to protect threatened species across the region (Table 10.4).

Other international commitments

In addition to commitments under HELCOM, the Red List assessment work and results contribute to a number of other international commitments.

The EU Biodiversity Strategy request EU Member States to ensure no deterioration in conservation trends and status of all protected habitats and species by 2030. In addition, Member States will have to ensure that at least 30% of species and habitats not currently in favourable status are in that category or show a strong positive trend.

European Union nature protection legislation includes two directives: the Birds Directive (Council Directive 2009/147/EC on the conservation of wild birds) and the Habitats Directive (Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora) (European Commission 1992, European Commission 2010). These directives are based on the Bern Convention (Convention on the Conservation of European Wildlife and Natural Habitats), a binding international legal instrument on the conservation of species and habitats for the EU Member States. Of the bird species included in this Red List assessment, 11 are listed in Annex II A of the Birds Directive (bean goose (*Anser fabalis*), greylag goose, Eurasian wigeon, gadwall (*Mareca strepera*), common teal, mallard, northern pintail, northern shoveler (*Spatula clypeata*), common pochard, tufted duck, common coot), and 20 in Annex II B (mute swan, greater white-fronted goose (*Anser albifrons*), brent goose (*Branta bernicla*), greater scaup, common eider, long-tailed duck, common scoter, velvet scoter, common goldeneye, redbreasted merganser, goosander, lapwing (Vanellinae), ruff (*Calidris pugnax*), black-tailed godwit (*Limosa limosa*), common black-headed gull (*Chroicocephalus ridibundus*), common gull, herring gull, Caspian gull (*Larus cachinnans*), greater black-backed gull, lesser black-backed gull).

In addition to the above mentioned nature protection directives, there are also water-related EU directives that support the protection of marine biota and habitats. The Water Framework Directive (WFD) aims at achieving a good ecological and chemical status in the coastal waters and the Marine Strategy Framework Directive (MSFD).

The Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES) regulates the international trade of fauna and flora. The species are listed in the three appendices according to their global or regional extinction status (CITES 2012). It includes and fully obligates all the Baltic Sea countries. Only one of the HELCOM Red List species is listed on the CITES appendices. European eel is listed under Appendix II, which means that its trade must be controlled in order to avoid utilisation incompatible with their survival. In the HELCOM Red List, the species is categorised as Critically Endangered.

The Bonn Convention (Convention on the Conservation of Migratory Species of Wild Animals, CMS) is an intergovernmental treaty focusing on the protection of migratory species. It has been concluded under the United Nations Environmental Programme (CMS 2003). All Baltic Sea countries, except Russia, are parties in the convention. CMS agreements that have direct relevance in the Baltic Sea area and species under threat are the Agreement on Conservation of Small Cetaceans in Baltic Sea and in North Sea (ASCOBANS) and the African-Eurasian Migratory Water Bird Agreement (AEWA). The ASCOBANS Agreement concerns the harbour porpoise, which has been categorised as Vulnerable for its Western Baltic subpopulation and Critically Endangered for its Baltic Sea subpopulation in the HELCOM Red List. Water bird species to which the AEWA Agreement applies are nearly all listed on the HELCOM Red List of threatened species. These agreements are legally binding treaties which are being executed under Action Plans. For example, the Jastarnia Plan (a Recovery Plan for Baltic harbour porpoises) under the ASCOBANS agreement was adopted by the Contracting Parties in 2009.

The Ramsar Convention protects wetlands of international importance. All the Baltic Sea countries are Contracting Parties in this intergovernmental treaty for the conservation of wetlands which came into force as early as 1975. The convention plays a role especially in the protection of birds for which the coastal wetlands are important habitats. On a larger scale, the wetlands also contribute to the mitigation of eutrophication of the Baltic Sea as they work as fi lters of nutrients and organic matter coming from the drainage area. In this sense, the protection of the sites not directly in the sea area but in the drainage basin is also important.

Further measures

The list of measures, in combination with the upcoming updated Red List of species can be used to determine which additional activities are needed to mitigate the identified pressures and/or impacts and support the development or amendment of conservation-, recovery- and/or action plans for HELCOM threatened species. It can also support future efforts to align the development with neighbouring countries or relevant organizations, to ensure improved effectiveness and efficiency.

In addition to direct measures for the individual species the assessment recognises that further measures to curb eutrophication, limit impact of fisheries (on fish species but also in relation to bycatch and impact on seabed) and the reverse habitat loss would benefit threatened species.

10.6.2 Needs for future assessments

Improved spatial information on distribution of species, as well as longer timeseries would improve the robustness of the assessment. Based on the current knowledge gaps and needs, further information especially for macrophytes and benthic invertebrates on a HELCOM level is much needed.

Table 10.4			Denmark		Estonia		Finland		Germany		Latvia		Lithuania		Poland		Sweden	
			Category	Additional category (if relevant)	Category	Additional category (if relevant)	Category	Additional category (if relevant)	Category	Additional category (if relevant)	Category	Additional category (if relevant)	Category	Additional category (if relevant)	Category	Additional category (if relevant)	Category	Additional category (if relevant)
Alisma wahlenbergii	Macrophytes	VU	6. not present		6. not present		1.2 Conservation measures - general	3. Others, including legal	6. not present		6. not present		6. not present		3. Others, including legal		1.2 Conservation measures - general	
Chara braunii	Macrophytes	VU	6. not present		5. No measures		2.2 Spatial protection - no management plan	3. Others, including legal	6. not present		6. not present		6. not present		1.1 Conservation measures - targeted		1.1 Conservation measures - targeted	
Hippuris tetraphylla	Macrophytes	EN	6. not present		6. not present		1.2 Conservation measures - general	3. Others, including legal	6. not present		6. not present		6. not present		1.1 Conservation measures - targeted		1.1 Conservation measures - targeted	
Lamprothamnium papulosum	Macrophytes	EN			6. not present		6. not present		5. No measures		6. not present		6. not present		6. not present		5. No measures	
Nitella hyalina	Macrophytes	VU	6. not present		6. not present		2.2 Spatial protection - no management plan	3. Others, including legal	6. not present		6. not present		6. not present		6. not present		5. No measures	
Persicaria foliosa	Macrophytes	EN	6. not present		6. not present		1.2 Conservation measures - general	3. Others, including legal	6. not present		6. not present		6. not present		3. Others, including legal		1.2 Conservation measures - general	
Zostera noltii	Macrophytes	VU	2.1 Spatial protection – management plan		6. not present		6. not present		3. Others, including legal		6. not present		6. not present		6. not present		4. Under development	1.1 Conservation measures - targeted
Abra prismatica	Invertebrates	VU	5. No measures		6. not present		6. not present		6. not present		6. not present		6. not present		3. Others, including legal	2.2 Spatial protection - no management plan	1.2 Conservation measures - general	
Atelecyclus rotundatus	Invertebrates	VU	6. not present		6. not present		6. not present		6. not present		6. not present		6. not present		5. No measures		5. No measures	
Clelandella miliaris	Invertebrates	VU	2.2 Spatial protection - no management plan	4. Under development	6. not present		6. not present		6. not present		6. not present		6. not present		6. not present		4. Under development	1.1 Conservation measures - targeted
Cliona celata	Invertebrates	VU			6. not present		6. not present		6. not present		6. not present		6. not present		6. not present		5. No measures	

Table 10.4			Denmark		Estonia		Finland		Germany		Latvia		Lithuania		Poland		Sweden	
			Category	Additional category (if relevant)	Category	Additional category (if relevant)	Category	Additional category (if relevant)	Category	Additional category (if relevant)	Category	Additional category (if relevant)	Category	Additional category (if relevant)	Category	Additional category (if relevant)	Category	Additional category (if relevant)
Deshayesorchestia deshayesii	Invertebrates	VU	6. not present		6. not present		6. not present		5. No measures		6. not present		6. not present		6. not present		4. Under development	1.1 Conservation measures - targeted
Epitonium clathrus	Invertebrates	VU	2.2 Spatial protection - no management plan	4. Under development	6. not present		6. not present		6. not present		6. not present		6. not present		6. not present		5. No measures	
Haploops tenuis	Invertebrates	EN	2.2 Spatial protection - no management plan	4. Under development	6. not present		6. not present		6. not present		6. not present		6. not present		5. No measures		5. No measures	
Haploops tubicola	Invertebrates	VU	2.2 Spatial protection - no management plan	4. Under development	6. not present		6. not present		6. not present		6. not present		6. not present		6. not present		5. No measures	
Hippasteria phrygiana	Invertebrates	VU	2.1 Spatial protection – management plan	5. No measures	6. not present		6. not present		6. not present		6. not present		6. not present		6. not present		1.1 Conservation measures - targeted	
Hippolyte varians	Invertebrates	VU	2.2 Spatial protection - no management plan	4. Under development	6. not present		6. not present		6. not present		6. not present		6. not present		3. Others, including legal	2.2 Spatial protection - no management plan	4. Under development	1.1 Conservation measures - targeted
Lunatia pallida	Invertebrates	VU			6. not present		6. not present		6. not present		6. not present		6. not present		3. Others, including legal		1.1 Conservation measures - targeted	
Macoma calcarea	Invertebrates	VU	2.1 Spatial protection – management plan	5. No measures	6. not present		6. not present		5. No measures		??		??		3. Others, including legal		4. Under development	1.1 Conservation measures - targeted
Modiolus modiolus	Invertebrates	VU	2.1 Spatial protection – management plan	5. No measures	6. not present		6. not present		5. No measures		6. not present		6. not present		3. Others, including legal		4. Under development	1.1 Conservation measures - targeted
Nucula nucleus	Invertebrates	VU	2.2 Spatial protection - no management plan	4. Under development	6. not present		6. not present		5. No measures		6. not present		6. not present		1.1 Conservation measures - targeted		1.1 Conservation measures - targeted	

Table 10.4			Denmark		Estonia		Finland		Germany		Latvia		Lithuania		Poland		Sweden	
			Category	Additional category (if relevant)	Category	Additional category (if relevant)	Category	Additional category (if relevant)	Category	Additional category (if relevant)	Category	Additional category (if relevant)	Category	Additional category (if relevant)	Category	Additional category (if relevant)	Category	Additional category (if relevant)
Parvicardium hauniense	Invertebrates	VU	2.1 Spatial protection – management plan	5. No measures	6. not present		2.2 Spatial protection - no management plan	3. Others, including legal	5. No measures		??		6. not present		6. not present		1.1 Conservation measures - targeted	
Pelonaia corrugata	Invertebrates	VU	5. No measures		6. not present		6. not present		6. not present		6. not present		6. not present		3. Others, including legal	2.2 Spatial protection - no management plan	1.2 Conservation measures - general	
Scrobicularia plana	Invertebrates	VU	5. No measures		6. not present		6. not present		5. No measures		6. not present		6. not present		3. Others, including legal		1.2 Conservation measures - general	
Solaster endeca	Invertebrates	VU	6. not present		6. not present		6. not present		6. not present		6. not present		6. not present		3. Others, including legal		1.2 Conservation measures - general	
Stomphia coccinea	Invertebrates	VU	5. No measures		6. not present		6. not present		6. not present		6. not present		6. not present		6. not present		4. Under development	1.1 Conservation measures - targeted
Acipenser oxyrinchus	Fish	RE	7. RE		7. RE		7. RE		1.1 Conservation measures - targeted		7. RE		1.1 Conservation measures - targeted		3. Others, including legal	2.2 Spatial protection - no management plan	1.2 Conservation measures - general	
Anarhichas lupus	Fish	EN	5. No measures		6. not present		6. not present		6. not present		6. not present		6. not present		3. Others, including legal		7. RE	
Anguilla anguilla	Fish	CR	3. Others, including legal		1.1 Conservation measures - targeted		1.1 Conservation measures - targeted		1.1 Conservation measures - targeted		2.1 Spatial protection – management plan		1.1 Conservation measures - targeted		6. not present		5. No measures	
Coregonus maraena	Fish	EN	1.1 Conservation measures - targeted		5. No measures		3. Others, including legal		5. No measures	1.1 Conservation measures - targeted	??		??		6. not present		5. No measures	
Dipturus batis	Fish	RE	2.2 Spatial protection - no management plan		6. not present		6. not present		7. RE		7. RE		7. RE		6. not present		5. No measures	

State of the Baltic Sea
Third HELCOM holistic assessment 2016–2021

Biodiversity
10. Threatened species

Table 10.4			Denmark		Estonia		Finland		Germany		Latvia		Lithuania		Poland		Sweden	
			Category	Additional category (if relevant)	Category	Additional category (if relevant)	Category	Additional category (if relevant)	Category	Additional category (if relevant)	Category	Additional category (if relevant)	Category	Additional category (if relevant)	Category	Additional category (if relevant)	Category	Additional category (if relevant)
Gadus morhua	Fish	VU	1.1 Conservation measures - targeted		5. No measures		3. Others, including legal	1.1 Conservation measures - targeted	5. No measures		??		??		6. not present		5. No measures	
Galeorhinus galeus	Fish	VU	2.2 Spatial protection - no management plan		6. not present		6. not present		6. not present		6. not present		6. not present		6. not present		1.1 Conservation measures - targeted	
Lamna nasus	Fish	CR	2.2 Spatial protection - no management plan		6. not present		6. not present		6. not present		6. not present		6. not present		3. Others, including legal	2.2 Spatial protection - no management plan	1.2 Conservation measures - general	
Merlangius merlangus	Fish	VU	5. No measures		2.1 Spatial protection – management plan	2.2 Spatial protection - no management plan	6. not present		5. No measures		6. not present		6. not present		6. not present		1.2 Conservation measures - general	
Molva molva	Fish	EN	5. No measures		6. not present		6. not present		6. not present		6. not present		6. not present		6. not present		4. Under development	1.1 Conservation measures - targeted
Petromyzon marinus	Fish	VU	2.2 Spatial protection - no management plan		2.1 Spatial protection – management plan	2.2 Spatial protection - no management plan	6. not present		3. Others, including legal		6. not present		6. not present		3. Others, including legal		1.2 Conservation measures - general	
Raja clavata	Fish	VU	2.2 Spatial protection - no management plan		6. not present		6. not present		6. not present		6. not present		6. not present		3. Others, including legal		1.2 Conservation measures - general	
Salmo salar	Fish	VU	5. No measures		2.1 Spatial protection – management plan	2.2 Spatial protection - no management plan	1.1 Conservation measures - targeted		5. No measures		1.2 Conservation measures - general		1.1 Conservation measures - targeted		6. not present		5. No measures	
Salmo trutta	Fish	VU	5. No measures		5. No measures		1.1 Conservation measures - targeted		5. No measures	1.1 Conservation measures - targeted	1.2 Conservation measures - general		1.1 Conservation measures - targeted		6. not present		5. No measures	
Squalus acanthias	Fish	CR	2.2 Spatial protection - no management plan		6. not present		6. not present		6. not present		6. not present		6. not present		3. Others, including legal	2.2 Spatial protection - no management plan	1.2 Conservation measures - general	

Table 10.4			Denmark		Estonia		Finland		Germany		Latvia		Lithuania		Poland		Sweden	
			Category	Additional category (if relevant)	Category	Additional category (if relevant)	Category	Additional category (if relevant)	Category	Additional category (if relevant)	Category	Additional category (if relevant)	Category	Additional category (if relevant)	Category	Additional category (if relevant)	Category	Additional category (if relevant)
Thymallus thymallus	Fish	CR	2.2 Spatial protection - no management plan		5. No measures		5. No measures	4. Under development	6. not present		6. not present		1.2 Conservation measures - general		3. Others, including legal	2.2 Spatial protection - no management plan	1.2 Conservation measures - general	
Anser fabalis fabalis (wintering)	Birds	EN	2.1 Spatial protection – management plan	1.1 Conservation measures - targeted	2.1 Spatial protection – management plan	2.1 Spatial protection – management plan	6. not present		2.2 Spatial protection - no management plan		6. not present		6. not present		6. not present		5. No measures	
Arenaria interpres (breeding)	Birds	VU	3. Others, including legal		1.2 Conservation measures - general	2.1 Spatial protection – management plan	5. No measures	3. Others, including legal	6. not present		6. not present		6. not present		3. Others, including legal		7. RE	
Aythya marila (breeding)	Birds	VU	5. No measures		1.2 Conservation measures - general	2.1 Spatial protection – management plan	1.1 Conservation measures - targeted	4. Under development	2.1 Spatial protection – management plan		6. not present		6. not present		6. not present		1.1 Conservation measures - targeted	
Calidris alpina schinzii (breeding)	Birds	EN	2.2 Spatial protection - no management plan	3. Others, including legal	1.1 Conservation measures - targeted		1.2 Conservation measures - general		2.1 Spatial protection – management plan	3. Others, including legal	??		Under development (also spatial protection)		6. not present		5. No measures	
Cepphus grylle arcticus (wintering)	Birds	VU	3. Others, including legal		1.2 Conservation measures - general	2.1 Spatial protection – management plan	6. not present		2.2 Spatial protection - no management plan		??		??		1.1 Conservation measures - targeted		1.1 Conservation measures - targeted	
Charadrius alexandrinus (breeding)	Birds	CR	3. Others, including legal		5. No measures		6. not present		2.1 Spatial protection – management plan	3. Others, including legal	6. not present		6. not present		3. Others, including legal	2.2 Spatial protection - no management plan	1.2 Conservation measures - general	
Clangula hyemalis (wintering)	Birds	EN	1.1 Conservation measures - targeted		1.2 Conservation measures - general	2.1 Spatial protection – management plan	4. Under development	1.1 Conservation measures - targeted	2.2 Spatial protection - no management plan		??		2.2 Spatial protection - no management plan		3. Others, including legal		1.2 Conservation measures - general	
Gavia arctica (wintering)	Birds	CR	3. Others, including legal		1.2 Conservation measures - general	2.1 Spatial protection – management plan	6. not present		2.2 Spatial protection - no management plan		??		6. not present		6. not present		5. No measures	
Gavia stellata (wintering)	Birds	CR	3. Others, including legal		1.2 Conservation measures - general	2.1 Spatial protection – management plan	6. not present		2.2 Spatial protection - no management plan		??		??		3. Others, including legal	2.2 Spatial protection - no management plan	1.2 Conservation measures - general	

Table 10.4			Denmark		Estonia		Finland		Germany		Latvia		Lithuania		Poland		Sweden	
			Category	Additional category (if relevant)	Category	Additional category (if relevant)	Category	Additional category (if relevant)	Category	Additional category (if relevant)	Category	Additional category (if relevant)	Category	Additional category (if relevant)	Category	Additional category (if relevant)	Category	Additional category (if relevant)
Gelochelidon nilotica (breeding)	Birds	RE	7. RE		5. No measures		6. not present		2.1 Spatial protection – management plan	3. Others, including legal	7. RE		7. RE		3. Others, including legal	2.2 Spatial protection - no management plan	1.1 Conservation measures - targeted	
Hydroprogne caspia (breeding)	Birds	VU	2.2 Spatial protection - no management plan	3. Others, including legal	1.2 Conservation measures - general	2.1 Spatial protection – management plan	1.2 Conservation measures - general	3. Others, including legal	2.1 Spatial protection – management plan	3. Others, including legal	6. not present		6. not present		3. Others, including legal	2.2 Spatial protection - no management plan	1.2 Conservation measures - general	
Larus fuscus fuscus (breeding)	Birds	VU	3. Others, including legal		1.2 Conservation measures - general	2.1 Spatial protection – management plan	5. No measures		6. not present		6. not present		6. not present		6. not present		4. Under development	1.1 Conservation measures - targeted
Larus melanocephalus (breeding)	Birds	EN	2.2 Spatial protection - no management plan	3. Others, including legal	5. No measures		6. not present		2.1 Spatial protection – management plan		6. not present		6. not present		3. Others, including legal		1.1 Conservation measures - targeted	
Melanitta fusca (wintering EN, breeding VU)	Birds	EN	1.1 Conservation measures - targeted		1.2 Conservation measures - general	2.1 Spatial protection – management plan	5. No measures	3. Others, including legal	2.1 Spatial protection – management plan		??		2.2 Spatial protection - no management plan		3. Others, including legal	2.2 Spatial protection - no management plan	4. Under development	1.1 Conservation measures - targeted
Melanitta nigra (wintering)	Birds	EN	2.2 Spatial protection - no management plan		2.1 Spatial protection – management plan	2.2 Spatial protection - no management plan	6. not present		2.2 Spatial protection - no management plan		??		??		6. not present		5. No measures	
Mergus serrator (wintering)	Birds	VU	2.2 Spatial protection - no management plan	3. Others, including legal	2.1 Spatial protection – management plan	2.2 Spatial protection - no management plan	6. not present		2.1 Spatial protection – management plan		??		??		6. not present		5. No measures	
Philomachus pugnax (breeding)	Birds	VU	2.2 Spatial protection - no management plan	3. Others, including legal	1.1 Conservation measures - targeted		1.2 Conservation measures - general	2.2 Spatial protection - no management plan	2.1 Spatial protection – management plan	3. Others, including legal	??		1.1 Conservation measures - targeted		6. not present		4. Under development	1.1 Conservation measures - targeted
Podiceps auritus (breeding VU, wintering NT)	Birds	VU	3. Others, including legal		2.1 Spatial protection – management plan	2.2 Spatial protection - no management plan	1.2 Conservation measures - general	2.2 Spatial protection - no management plan	2.1 Spatial protection – management plan	3. Others, including legal	??		6. not present		6. not present		5. No measures	
Podiceps grisegena (wintering)	Birds	EN	3. Others, including legal		2.1 Spatial protection – management plan	2.2 Spatial protection - no management plan	6. not present		2.1 Spatial protection – management plan	3. Others, including legal	6. not present		6. not present		6. not present		4. Under development	1.1 Conservation measures - targeted

State of the Baltic Sea
Third HELCOM holistic assessment 2016–2021

Biodiversity
10. Threatened species

Table 10.4			Denmark		Estonia		Finland		Germany		Latvia		Lithuania		Poland		Sweden	
			Category	Additional category (if relevant)	Category	Additional category (if relevant)	Category	Additional category (if relevant)	Category	Additional category (if relevant)	Category	Additional category (if relevant)	Category	Additional category (if relevant)	Category	Additional category (if relevant)	Category	Additional category (if relevant)
Polysticta stelleri (wintering)	Birds	EN	5. No measures		2.1 Spatial protection – management plan	2.2 Spatial protection - no management plan	5. No measures		6. not present		6. not present		2.2 Spatial protection - no management plan		6. not present		5. No measures	
Rissa tridactyla (breeding EN, wintering VU)	Birds	EN	3. Others, including legal		5. No measures		6. not present		6. not present		6. not present		6. not present		1.1 Conservation measures - targeted		1.1 Conservation measures - targeted	
Somateria mollissima (wintering EN, breeding VU)	Birds	EN	2.2 Spatial protection - no management plan		2.1 Spatial protection – management plan	2.2 Spatial protection - no management plan	5. No measures	3. Others, including legal	2.1 Spatial protection – management plan		??		??		6. not present		5. No measures	
Xenus cinereus (breeding)	Birds	EN	6. not present		5. No measures		1.2 Conservation measures - general		6. not present		??		6. not present		3. Others, including legal	2.2 Spatial protection - no management plan	1.2 Conservation measures - general	
Phoca hispida botnica	Mammals	VU	6. not present		1.1 Conservation measures - targeted		1.1 Conservation measures - targeted		6. not present		??		??		6. not present		5. No measures	
Phoca vitulina (Kalmarsund population)	Mammals	VU	6. not present		6. not present		6. not present		6. not present		6. not present		6. not present		6. not present		4. Under development	1.1 Conservation measures - targeted
Phocoena phocoena (Baltic Sea population)	Mammals	CR	1.1 Conservation measures - targeted		6. not present		1.1 Conservation measures - targeted		1.1 Conservation measures - targeted		6. not present		1.1 Conservation measures - targeted		3. Others, including legal		6. not present	
Phocoena phocoena (Western Baltic subpopulation)	Mammals	VU	1.1 Conservation measures - targeted		6. not present		6. not present		1.1 Conservation measures - targeted		6. not present		6. not present		6. not present		4. Under development	1.1 Conservation measures - targeted

11. Threatened habitats and biotopes in the Baltic Sea

Assessment results in short

- As this thematic assessment report is produced, HELCOM is in the process of reviewing the threat status of habitats and biotopes in the Baltic Sea, with the aim to produce an updated Red list of Baltic Sea habitats and biotopes by the end of 2024.
- In the last HELCOM Red List of underwater biotopes, habitats and biotope complexes, produced in 2013, approximately a quarter of assessed biotopes were red listed, while 73% were classified Least Concern (LC) and were therefore not seen to be at risk of collapse at the time of the assessment. Of the assessed HELCOM HUB biotopes (biotopes classified by the HELCOM Underwater Biotope and habitat classification system), 59 (28%) were red listed. One was categorized as Critically Endangered (CR), 11 were categorized as Endangered (EN), five were categorized as Vulnerable (VU), and 42 were categorized as Near Threatened (NT). Among the benthic aphotic biotopes, the proportion of red listed biotopes was the highest compared to the photic or the pelagic zone.
- According to the 2013 Red List, benthic aphotic biotopes characterized by macrofauna had the highest proportion of specific biotopes at risk of collapse. Only one of the biotopes, namely the Baltic aphotic muddy sediment dominated by ocean quahog, was assigned the threat category Critically Endangered (CR). As for biotope complexes, all of them were red listed, even though some of the underwater biotopes that characterize the biotope complex were not red listed. One of the biotope complexes, namely estuaries, was categorized as Critically Endangered, two as Endangered (EN), five as Vulnerable (VU) and two as Near Threatened (NT).
- The assessment justification and general descriptions of the biotopes, habitats and biotope complexes that were red listed (CR–NT) are given in the Biotope Information Sheets (BIS) available on the HELCOM website.

11.1. Introduction to threatened habitats and biotopes

Marine ecosystems, from coastal to deep sea, now show the influence of human actions, with coastal marine ecosystems showing both large historical losses of extent and condition as well as rapid ongoing declines (IPBES 2019b). The risk of extinction is tracked through so called Red List assessments and in 2013 HELCOM last published the HELCOM Red List of Baltic Sea underwater biotopes, habitats, and biotope complexes (HELCOM 2013b).

As this thematic assessment report is produced, HELCOM is in the process of reviewing the threat status of habitats and biotopes in the Baltic Sea, with the aim to produce an updated red list of Baltic Sea habitats and biotopes by the end of 2024.

11.1.1 Importance for the ecosystem and ecosystem health

In addition to their intrinsic value and their contribution to overall biodiversity, threatened coastal and marine habitats, biotopes and biotope complexes are also very important for rare or threatened species.

It is important to track long-term trends in the status of the Baltic Sea biodiversity and changes in the status of biotopes/habitats or the impact of pressures. This is achieved through regularly reviewing the status of Baltic Sea biotopes and habitats which enables assessing if actions taken to halt the loss of biodiversity have been effective or if more or different measures are needed.

11.1.2 Importance for Baltic Sea environmental management

An updated assessment of the Baltic Sea Red List of biotopes and habitats provides a reference point and shows the status trend of the assessed underwater biotopes and habitats throughout the Baltic Sea. The results from an updated Red List are also a prerequisite to addressing other related topics, such as MPA related assessments, possible effects of climate change, and ecosystem services etc.

11.2. Details on the assessment results for threatened habitats and biotopes

In 2013, the HELCOM Underwater Biotope and habitat classification system (HELCOM HUB) defined a total of 328 benthic and pelagic habitats (HELCOM 2013d). Of these HELCOM HUB biotopes, a threat assessment was made for 209 biotopes (Figure 11.1) Of the assessed biotopes, approximately a quarter were red listed, while 73% were classified Least Concern (LC) and were therefore not seen to be at a risk of collapse at the time of the assessment (Figure 11.1) (HELCOM 2013b).

Of the assessed HELCOM HUB biotopes, 59 (28%) were red listed (Table 11.1). One was categorized as Critically Endangered (CR), 11 were categorized Endangered (EN), five were categorized as Vulnerable (VU), and 42 were categorized as Near Threatened (NT) (Figure 11.1). Among the benthic aphotic biotopes, the proportion of red listed biotopes was the highest compared to the photic or the pelagic zone (Table 11.1) (HELCOM 2013b).

At the time of the assessment, benthic aphotic biotopes characterized by macrofauna had the highest proportion of specific biotopes at risk of collapse (Table 11.1, Figure 11.1). Only one of the biotopes was assigned the threat category Critically Endangered (CR). This biotope occurs in deep muddy areas and is dominated by the ocean quahog, a species that requires oxygenated, saline water for successful reproduction and growth during the first decade of its lifespan. The water mass under the halocline that contains oxygen was assessed as Endangered (EN). All these results are likely effects of the large-scale hypoxia in the deep parts of the Baltic Sea, coupled with the lack of strong saltwater inflows and eutrophication during the past decades (HELCOM 2023d).

All biotope complexes were red listed in the 2013 HELCOM Red List assessment, even though some of the underwater biotopes that characterize the biotope complex were not red listed. One of the biotope complexes, namely estuaries, was categorized as Critically Endangered, two as Endangered (EN), five as Vulnerable and two as Near Threatened (Figure 11.2).

The assessment justification and general descriptions of the biotopes, habitats and biotope complexes that were red listed (CR–NT) in the 2013 assessment are given in the Biotope Information Sheets (BIS). In total, 42 BIS were prepared for the red-listed

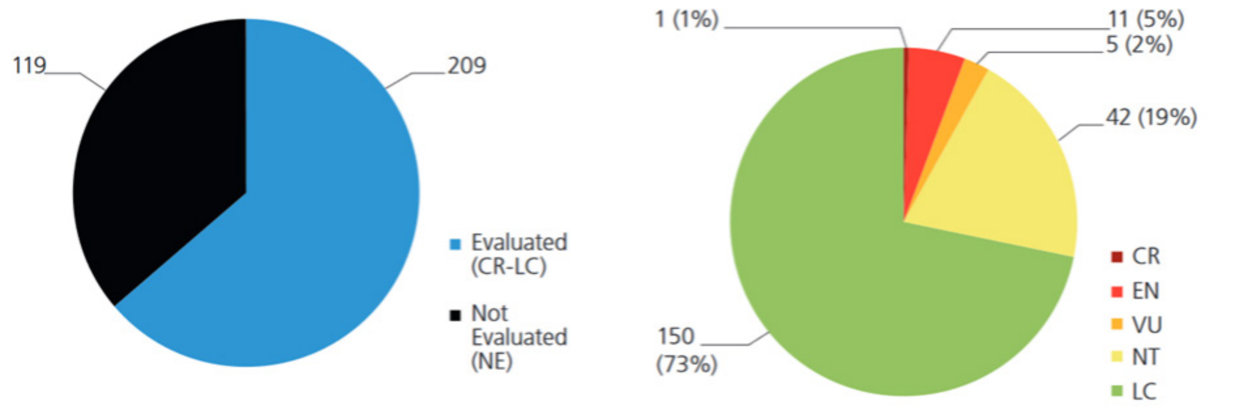

Figure 11.1. The proportion of HELCOM HUB biotopes that were assessed (CR–LC) (left) and the proportions of biotopes in the different categories in the assessed group (right) in the 2013 Red list. CR= Critically Endangered, EN= Endangered, VU= Vulnerable, NT= Near Threatened, LC= Least Concern. HELCOM 2013b. (source: HELCOM 2013b).

Table 11.1. Proportion of benthic photic, benthic aphotic and pelagic biotopes and habitats that were assessed and red listed in 2013 (HELCOM 2013b).

	Number of assessed HELCOM HUB biotopes	Red-listed HELCOM HUB biotopes
Benthic photic HELCOM HUB biotopes	141	29 (21%)
Benthic aphotic HELCOM HUB biotopes	62	28 (45%)
Pelagic HELCOM HUB biotopes	6	2 (33%)
Total	**209**	**59 (28%)**

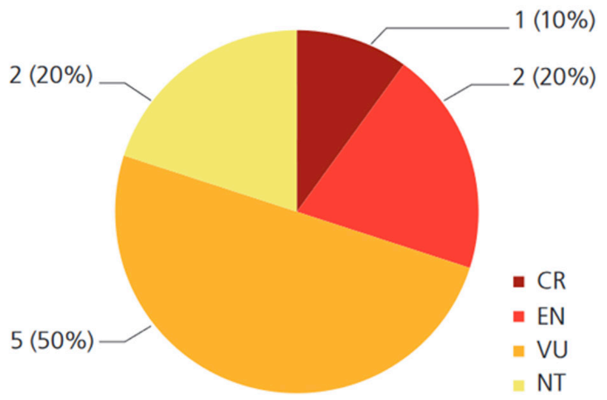

Figure 11.2. Proportion of the biotope complexes in the Red List categories. (source: HELCOM 2013b).

biotopes, habitats and biotope complexes. As some of the 59 red listed HELCOM HUB biotopes were seen to form one biotope in nature, only one Biotope Information Sheet was prepared for them.

The 2013 Red List of Baltic Sea biotopes and habitats is available in Table 11.2, and the HELCOM 2013 Red List of Baltic Sea biotope complexes in Table 11.3.

The Red List criteria only assess how much a biotope has declined in quantity or quality but does not specify the reason for the decline. Biotopes that exhibited a decline exceeding the threshold values of the Red List categories were analysed further to also identify the factors causing the decline (see section 11.4) (HELCOM 2013b).

Results of the HELCOM Red List assessment made on the scale of the whole Baltic Sea can differ significantly compared to national or regional Red lists or other threat assessments. For instance, the biotope complex 'Reefs' (1170) is considered to be more threatened in the southern parts of the Baltic Sea compared to the northern parts where they occur commonly. In the Baltic Sea wide assessment, a regionally threatened complex will not raise the overall threat status unless the decline constitutes a large percentage of the total area covered by the complex. The same principle applies to the assessment of biotopes and habitats. For instance, while the biotope dominated by *Zostera marina* is considered Vulnerable (VU) in Finland's national Red List of 2018 (Kontula & Raunio 2018), it was assessed as Near Threatened (NT) on the Baltic Sea scale in the 2013 HELCOM Red List (HELCOM 2013b).

Table 11.2. HELCOM 2013 Red List of Baltic Sea biotopes and habitats. The confidence in the threat assessment is described as High (H), Medium (M) or Low (L). CR= Critically Endangered, EN= Endangered, VU= Vulnerable, NT= Near Threatened, LC= Least Concern (HELCOM 2013b).

Biotope code	Biotope/Habitat name	Threat category	Confidence of threat assessment	Criterion for assessment
AB.H3L3	Baltic aphotic muddy sediment dominated by ocean quahog (*Arctica islandica*)	CR	M	A2
AA.M1Q2	Baltic photic mixed substrate dominated by stable aggregations of unattached*Fucus* spp. (dwarf form)	EN	L	A1
AA.H1Q2	Baltic photic mud dominated by stable aggregations of unattached *Fucus* spp. (dwarf form)	EN	L	A1
AA.I1Q2	Baltic photic coarse sediment dominated by stable aggregations of unattached*Fucus* spp. (dwarf form)	EN	L	A1
AA.J1Q2	Baltic photic sand dominated by stable aggregations of unattached *Fucus* spp. (dwarf form)	EN	L	A1
AA.D	Baltic photic maerl beds (unattached particles of coralline red algae)	EN	M	B1+2a(ii)
AB.D	Baltic aphotic maerl beds (unattached particles of coralline red algae)	EN	L	B1+2a(ii)
AB.B1E4	Baltic aphotic hard clay dominated by *Astarte* spp.	EN	M	B2c(ii)
AB.H3L5	Baltic aphotic muddy sediment dominated by *Astarte* spp.	EN	M	A1
AB.H2T1	Baltic aphotic muddy sediment characterized by sea-pens	EN	M	A1
AB.H1I2	Baltic aphotic muddy sediment dominated by *Haploops* spp.	EN	M	A1
AE.O5	Baltic Sea aphotic pelagic below halocline oxic	EN	L	A3
AA.G	Baltic photic peat bottom	VU	M	B2b
AB.J3L3	Baltic aphotic sand dominated by ocean quahog (*Arctica islandica*)	VU	M	A1

Table 11.2. (continued). HELCOM 2013 Red List of Baltic Sea biotopes and habitats. The confidence in the threat assessment is described as High (H), Medium (M) or Low (L). CR= Critically Endangered, EN= Endangered, VU= Vulnerable, NT= Near Threatened, LC= Least Concern (HELCOM 2013b).

Biotope code	Biotope/Habitat name	Threat category	Confidence of threat assessment	Criterion for assessment
AC	Baltic Sea seasonal ice	VU	L	A1+2a
AA.E1F1	Baltic photic shell gravel dominated by vase tunicate (*Ciona intestinalis*)	VU	L	B1a(ii)
AB.E1F1	Baltic aphotic shell gravel dominated by vase tunicate (*Ciona intestinalis*)	VU	L	B1a(ii)
AA.E3Y	Baltic photic shell gravel characterized by mixed infaunal macrocommunity in fine sand-like shell fragments	NT	L	B1a(ii)
AB.E3Y	Baltic aphotic shell gravel characterized by mixed infaunal macrocommunity in fine sand-like shell fragments	NT	L	B1a(ii)
AA.E1C4	Baltic photic shell gravel dominated by kelp	NT	L	B1a(ii)
AA.A1H2	Baltic photic rock and boulders dominated by erect moss animals (*Flustra foliacea*)	NT	L	A1
AB.A1H2	Baltic aphotic rock and boulders dominated by erect moss animals (*Flustra foliacea*)	NT	L	A1
AA.M1H2	Baltic photic mixed hard and soft substrates dominated by erect moss animals (*Flustra foliacea*)	NT	L	A1
AB.M1H2	Baltic aphotic mixed hard and soft substrates dominated by erect moss animals (*Flustra foliacea*)	NT	L	A1
AA.H1B4	Baltic photic muddy sediment dominated by Charales	NT	M	A1
AA.I1B4	Baltic photic coarse sediment dominated by Charales	NT	L	A1
AA.J1B4	Baltic photic sand dominated by Charales	NT	L	A1
AA.M1B4	Baltic photic mixed substrate dominated by Charales	NT	L	A1
AA.H1B7	Baltic photic muddy sediment dominated by common eelgrass (*Zostera marina*)	NT	M	A1
AA.I1B7	Baltic photic coarse sediment dominated by common eelgrass (*Zostera marina*)	NT	M	A1
AA.J1B7	Baltic photic sand dominated by common eelgrass (*Zostera marina*)	NT	M	A1
AA.M1B7	Baltic photic mixed substrate dominated by common eelgrass (*Zostera marina*)	NT	M	A1
AA.H1A2	Baltic photic muddy sediment dominated by sedges (Cyperaceae)	NT	M	A1
AA.H1B5	Baltic photic muddy sediment dominated by spiny naiad (*Najas marina*)	NT	M	A1
AA.J1B5	Baltic photic sand dominated by spiny naiad (*Najas marina*)	NT	L	A1
AA.H3L3	Baltic photic muddy sediment dominated by ocean quahog (*Arctica islandica*)	NT	M	A1
AA.J3L3	Baltic photic sand dominated by ocean quahog (*Arctica islandica*)	NT	M	A1
AA.H3L6	Baltic photic muddy sediment dominated by Unionidae	NT	L	A1
AA.I3L10	Baltic photic coarse sediment dominated by multiple infaunal bivalve species: *Macoma calcarea*, *Mya truncata*, *Astarte*spp., *Spisula* spp.	NT	L	A1
AB.I3L10	Baltic aphotic coarse sediment dominated by multiple infaunal bivalve species: *Macoma calcarea*, *Mya truncata*, *Astarte*spp., *Spisula* spp.	NT	L	A1
AA.J3L10	Baltic photic sand dominated by multiple infaunal bivalve species: *Macoma calcarea*, *Mya truncata*, *Astarte* spp., *Spisula*spp.	NT	L	A1
AB.J3L10	Baltic aphotic sand dominated by multiple infaunal bivalve species: *Macoma calcarea*, *Mya truncata*, *Astarte* spp., *Spisula*spp.	NT	L	A1
AA.I3L11	Baltic photic coarse sediment dominated by multiple infaunal polychaete species including*Ophelia* spp. (disregarding present bivalves)	NT	L	A1

Table 11.2. (continued). HELCOM 2013 Red List of Baltic Sea biotopes and habitats. The confidence in the threat assessment is described as High (H), Medium (M) or Low (L). CR= Critically Endangered, EN= Endangered, VU= Vulnerable, NT= Near Threatened, LC= Least Concern (HELCOM 2013b).

Biotope code	Biotope/Habitat name	Threat category	Confidence of threat assessment	Criterion for assessment
AB.I3L11	Baltic aphotic coarse sediment dominated by multiple infaunal polychaet species including*Ophelia* spp. (disregarding present bivalves)	NT	L	A1
AA.J3L11	Baltic photic sand dominated by multiple infaunal polychaete species including *Ophelia* spp. and *Travisia forbesii*(disregarding present bivalves)	NT	L	A1
AB.J3L11	Baltic aphotic sand dominated by multiple infaunal polychaete species including *Ophelia* spp. and *Travisia forbesii*(disregarding present bivalves)	NT	L	A1
AB.A1F1	Baltic aphotic rock and boulders dominated by sea squirts (Ascidiacea)	NT	L	A1
AB.M1F1	Baltic aphotic mixed hard and soft substrates dominated by sea squirts (Ascidiacea)	NT	L	A1
AB.A1G2	Baltic aphotic rock and boulders dominated by sea anemons (Actiniarida)	NT	L	A1
AB.M1G2	Baltic aphotic mixed hard and soft substrates dominated by sea anemons (Actiniarida)	NT	L	A1
AB.A1G3	Baltic aphotic rock and boulders dominated stone corals (Scleractinida)	NT	L	A1
AB.M1G3	Baltic aphotic mixed hard and soft substrates dominated stone corals (Scleractinida)	NT	L	A1
AB.A1G4	Baltic aphotic rock and boulders dominated by soft corals (Alcyonacea)	NT	L	A1
AB.M1G4	Baltic aphotic mixed hard and soft substrates dominated by soft corals (Alcyonacea)	NT	L	A1
AB.A1J	Baltic aphotic rock and boulders dominated by sponges (Porifera)	NT	L	A1
AB.M1J	Baltic aphotic mixed hard and soft substrates dominated by sponges (Porifera)	NT	L	A1
AB.H3N1	Baltic aphotic muddy sediment dominated by *Monoporeia affinis* and/or *Pontoporeia femorata*	NT	M	A1
AB.H4U1	Baltic aphotic muddy sediment dominated by meiofauna	NT	L	A1
AB.J3L7	Baltic aphotic sand dominated by striped venus (*Chamelea gallina*)	NT	L	A1

Table 11.3. HELCOM 2013 Red List of Baltic Sea biotope complexes. The confidence in the threat assessment is described as High (H), Medium (M) or Low (L). CR= Critically Endangered, EN= Endangered, VU= Vulnerable, NT= Near Threatened, LC= Least Concern. (HELCOM 2013b).

Code	Biotope complex (HD Annex 1 description, EUR 27)	Threat category	Confidence of threat assessment	Criterion for assessment
1130	Estuaries	CR	M	C1
1180	Submarine structures made by leaking gases	EN	M	B2c(ii)
1150	Coastal lagoons	EN	M	C1
1110	Sandbanks which are slightly covered by sea water all the time	VU	L	C1
1140	Mudflats and sandflats not covered by seawater at low tide	VU	L	C1
1160	Large shallow inlets and bays	VU	M	C1
1170	Reefs	VU	L	C1
1650	Boreal Baltic narrow inlets	VU	M	C1
1610	Baltic esker islands with sandy, rocky and shingle beach vegetation and sublittoral vegetation	NT	M	C1
1620	Boreal Baltic islets and small islands	NT	M	C1

The Baltic Sea biotopes are affected by several environmental gradients. In the case of the biotope dominated by eelgrass (*Zostera marina)*, for example, the low salinities along the Finnish coast may have made the biotope more sensitive to other pressures. The HELCOM Red List of biotopes, habitats and biotope complexes should not be viewed as a replacement of national or regional Red Lists, but as an overarching assessment of the threat of biotopes collapsing on the scale of the whole Baltic Sea and accordingly providing a framework for the interpretation of regional assessments.

During the 2013 Red List assessment process, the severe lack of long-term data on characteristics of all the different biotopes in the Baltic Sea became apparent, having implications on the assessment results.

11.3. Changes over time for threatened habitats and biotopes

The 2013 Red List is the third evaluation by HELCOM concerning threatened biotopes/habitats (previous assessments were released in 1998 and 2007), but the first one to evaluate biotopes, habitats and biotopes complexes using the IUCN Red List criteria. This means that the 1998, 2007 and the 2013 assessments are not comparable in such a way that any genuine trends in the status of the Baltic Sea biotopes, habitats or biotope complexes could be revealed by comparing their results. However, the same major threats to the biotopes, habitats and habitat complexes still remain, namely eutrophication, construction and dumping of dredged materials (HELCOM 2013b). A descriptive comparison of the 2013 assessment and the 1998 assessment is included in BSEP 138 (HELCOM 2013b).

The upcoming 2024 Red List will be using agreed IUCN assessment methodology and thus the results of that assessment will be comparable to the 2013 assessment.

When comparing red list assessment results across assessments it is important to account for what underpins a change in assessment category. This change can be a direct result of measures taken to improve status, or to increased pressures, but can also be the results of improved knowledge or data availability.

11.4. Relationship of threatened habitats and biotopes to drivers and pressures

When looking at biotopes under threat it is important to understand what human activities, and subsequent pressures, have driven them to be under threat of extinction, i.e., identifying past threats. An overview of current distribution of activities and pressures can be found in the Thematic Assessment on Spatial Distribution of Pressures and Impacts (HELCOM 2023a). But it is also vital to understand what threats these biotopes are facing in the future, to be able to take action before they further deteriorate. In most cases, the same threat factors that have been considered as reasons for the habitat/biotopes becoming threatened, i.e., past and current threats, are assumed to be important also in the future. The red list assessment looks at both of these, past and future, and identifies the human activities and pressures with significant negative impact on one or more of the red listed biotopes/habitats.

In the HELCOM Red List of Baltic Sea species in danger of becoming extinct, 24 different types of threats were identified (HELCOM 2013c). The same threats were used to assess the cause of decline for biotopes, excluding a few threat types that apply only to species (Table 11.4). Some of the listed threats were not identified as specific threats for the 2013 red listed biotopes but were considered to be potentially relevant in future updates of the red list.

The 2013 assessment concluded that eutrophication has had an adverse effect on the highest number of the red-listed HELCOM HUB biotopes in the past and it was predicted to continue to affect the biotopes negatively also in the future (Figure 11.3). Eutrophication was also considered to have affected most of the red listed biotope complexes in and adverse way (Figure 11.4).

Table 11.4. Overview of human activities which caused threat to species on the red list, in the past, the present or the future. (HELCOM 2013b).

Pressure	How does it cause a threat?
Non-indigenous species	competition, predation, hybridization, diseases, ecosystem changes by introduced species.
Climate change	all detrimental effects of climate change
Construction	all marine construction activities, for example wind power farms, gas pipelines, bridges, dredging, ports, coastal defense barriers, also coastal terrestrial construction, if relevant (vacation homes or roads), also noise from construction or operation
Contaminant pollution	all pollution to waters by hazardous substances, except for oil spills which have their own code (coastal industry, riverine load of heavy metals, discharges of radioactive substances, atmospheric deposition of metals and dioxins, polluting ship accidents excluding oil spills)
Ditching	Ditching and draining of mires and coastal meadows
Epidemics	large-scale epidemics or diseases
Eutrophication	detrimental effects of nutrient enrichment that can be defined in more detail, for example anoxia and hypoxia, excessive growth of algae, reduction in water transparency, or siltation
Fishing	both commercial and recreational fishing, surface and mid-water fishery, bottom-trawling, coastal stationary fishery, gillnets
Litter	plastic waste, ghost nets etc.
Mining and quarrying	extraction of bottom substrates
Oil spills	oil spills from ship accidents, also from oil terminals, refineries, oil rigs
Other threat factors	specific, known threat factors that are not covered by the other threat codes
Overgrowth of open areas	for example, coastal meadows or shallow water areas that become overgrown due to lack of management (related to eutrophication and interfloral competition, incl. expansion of reeds)
Random threat factors	used only for biotopes or habitats that are so rare that even random catastrophic events can destroy the occurrence (applied to biotopes assessed by B-criteria)
Tourism	detrimental effects of tourism, for example trampling of beaches, scuba diving
Unknown	threats are not known
Water traffic	physical impact due to traffic, for example erosion caused by anchoring, boat wakes and other vessel effects

Biodiversity
11. Threatened habitats and biotopes

Eutrophication has various impacts on biotopes: biotopes characterized by algae or plants are adversely affected by lower water clarity, whereas biotopes characterized by epibenthic filtering animals may be adversely affected by higher siltation levels. Certain organisms such as some annual filamentous algae and macrophytes as well as certain fish and bird species tend to benefit from eutrophication. The effects by which eutrophication threatens the biotopes have not been specified for the red listed biotopes (HELCOM 2013b). Information on the current status of eutrophication can be found in the HELCOM Thematic Assessment of Eutrophication (HELCOM 2023d).

In the 2013 assessment, climate change was considered to be a significant threat to the biotopes in the future, much more so than in the past. Information on the current and expected climate change impacts on benthic biotopes is available in the 2021 HELCOM/Baltic Earth Climate Change Fact Sheet (HELCOM/Baltic Earth 2021). In summary, many benthic species in the Baltic Sea exist at the edge of their distribution, and even small fluctuations in temperature and salinity can impact their abundance, biomass, and spatial distribution. In concurrence with trophic cascades and eutrophication, climate change might lead to major changes in biodiversity and ecosystem functions of benthic habitats (HELCOM/Baltic Earth 2021).

More precise information on the biotope specific threats can be found in the 2013 Biotope Information Sheets prepared for each red listed biotope, habitat, and biotope complex. The Biotope Information Sheets are available on the HELCOM website.

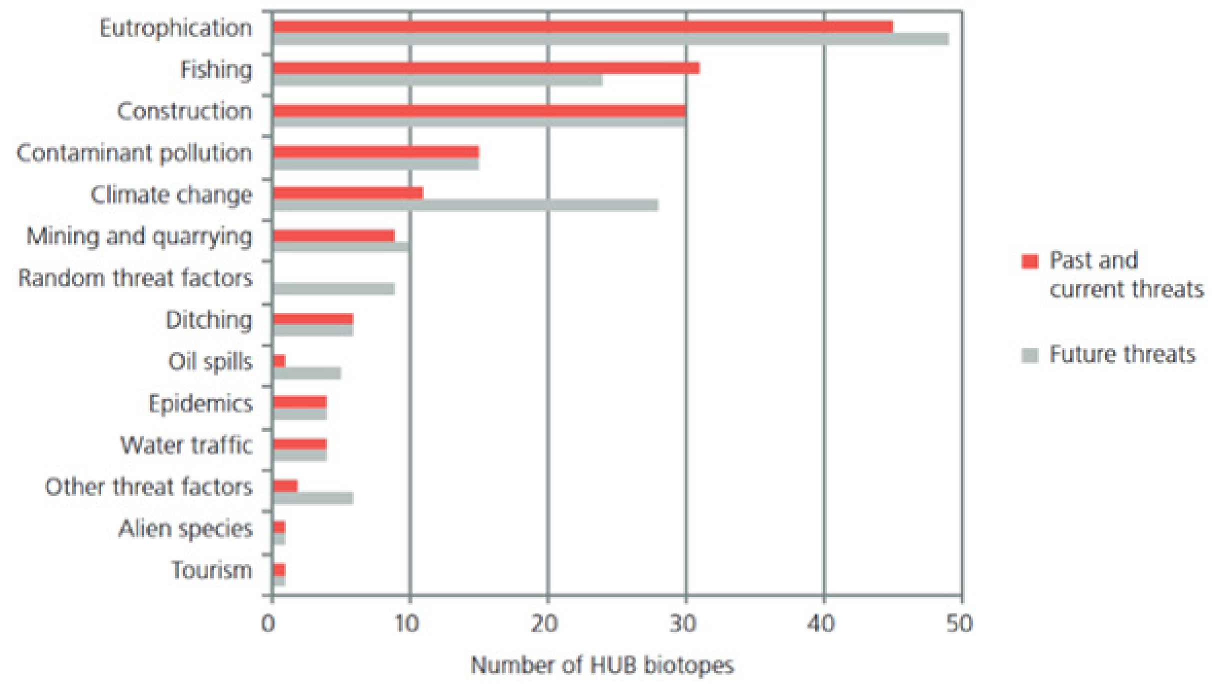

Figure 11.3. Past and current, and future threats (reasons for becoming threatened) for the red listed HELCOM HUB biotopes in 2013. The x-axis shows the number of red-listed HELCOM HUB biotopes for which the threat was regarded important by the HELCOM Red List experts. (Source: HELCOM 2013b).

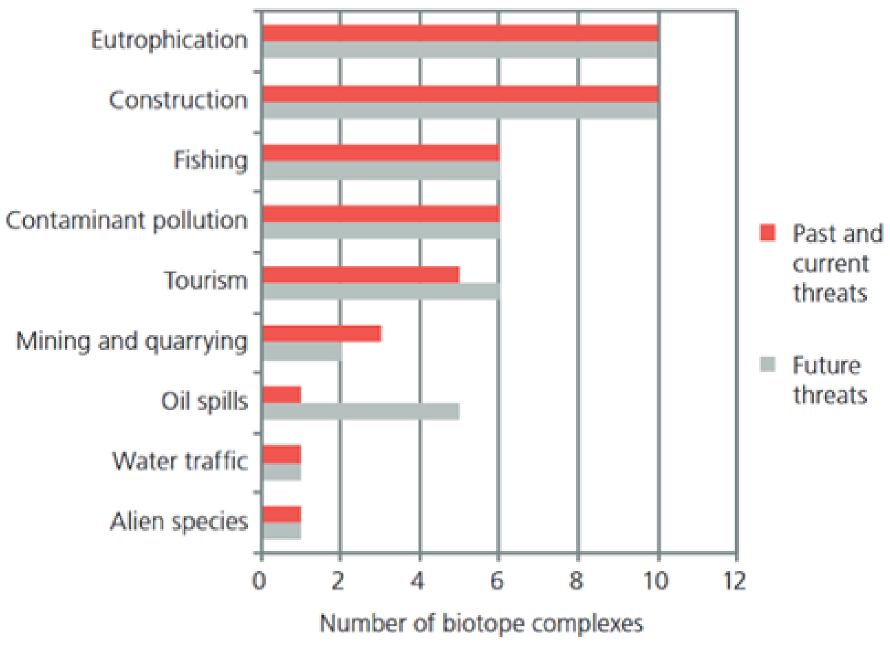

Figure 11.4. Past and current, and future threats (reasons for becoming threatened) for the red listed biotope complexes in 2013. The x-axis shows the number of red-listed biotope complexes for which the threat was regarded important by the HELCOM Red List experts. (Source: HELCOM 2013b).

11.5. How was the assessment of threatened habitats and biotopes carried out?

The 2013 HELCOM Red List assessment follows the Red List criteria of the International Union for Conservation of Nature (IUCN). The data for the assessment is collected through targeted data calls incorporating all the countries around the Baltic Sea. Several of the countries have been working to update their national red lists and it is expected that new data will become available through the national processes for the 2024 HELCOM Red List assessment.

Detailed information on the assessment process is available in HELCOM BSEP 138 (HELCOM 2013b).

11.6. Follow up and needs for the future with regards to threatened habitats and biotopes

11.6.1 Measures

HELCOM Action

Like all HELCOM assessments, an updated Red List assessment functions as an integral part of keeping track of the progress and effectiveness of both HELCOM and other relevant commitments and can help to increase the effectiveness and efficiency of measures by targeting areas or habitats/biotopes identified to be of priority.

The Red List is intrinsically linked to a broad set of commitments within HELCOM and provides relevant information for assessing the fulfilment of the updated HELCOM Baltic Sea Action Plan and HELCOM Recommendation 40/1 Conservation and protection of marine and coastal biotopes, habitats and biotope complexes, and also links to the HELCOM Recommendation 35/1 System of coastal and marine Baltic Sea protected areas (HELCOM MPAs).

HELCOM Recommendation 40/1 Conservation and protection of marine and coastal biotopes, habitats and biotope complexes was adopted in 2019 and includes a list of recommendations to effectively protect the HELCOM threatened biotopes, habitats, and biotope complexes. The Recommendation advices the Contracting Parties to regularly report on the activities to implement the Recommendation and the implementation is followed up by the HELCOM State & Conservation Working Group.

The Recommendation 40/1 among other things states that HELCOM Contracting Parties are to make an inventory of existing and planned national and regional conservation-, recovery- and/or action plans as well as other relevant programmes and measures for the protection underwater biotopes, habitats and biotope complexes that are threatened according to the 2013 HELCOM Red List. For the purposes of this report a summary of this inventory has been compiled, illustrating the measures being taken to protect threatened habitats/biotopes across the region (Annex x).

Other international commitments

In addition to commitments under HELCOM, the Red List assessment work and results contribute to a number of other international commitments.

The EU Biodiversity Strategy requests EU Member States to ensure no deterioration in conservation trends and status of all protected habitats and species by 2030. In addition, Member States will have to ensure that at least 30% of species and habitats not currently in favourable status are in that category or show a strong positive trend.

European Union nature protection legislation includes the Habitats Directive (Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora) (European Commission 1992, 2009d). This directive is based on the Bern Convention (Convention on the Conservation of European Wildlife and Natural Habitats), a binding international legal instrument on the conservation of species and habitats for the EU Member States.

In addition to the Habitats Directive, there are also water-related EU directives that support the protection of marine biota and habitats. The Water Framework Directive (WFD) aims at achieving a good ecological and chemical status in the coastal waters. The Marine Strategy Framework Directive (MSFD) aims to protect the marine environment more effectively across Europe and to reach good environmental status (GES) of the EU marine environment. The HELCOM threatened biotopes, habitats and biotope complexes can among others be associated with Descriptors 1 and 6 of Annex 1 of the MSFD and associated criteria in Decision (EU) 2017/848, thus their conservation contributes to the MSFD objective of achieving good environmental status of EU marine waters, for those Contracting Parties that are also EU Member States.

The Ramsar Convention protects wetlands of international importance. All the Baltic Sea countries are Contracting Parties in this intergovernmental treaty for the conservation of wetlands which came into force as early as 1975. The convention plays a role especially in the protection of birds for which the coastal wetlands are important habitats. On a larger scale, the wetlands also contribute to the mitigation of eutrophication of the Baltic Sea as they work as filters of nutrients and organic matter coming from the drainage area. In this sense, the protection of the sites not directly in the sea area but in the drainage basin is also important.

The Convention on Biological Diversity (CBD), which came into force in 1992 at the Rio Earth Summit, is dedicated to conserving biological diversity while promoting sustainable development. The post-2020 global biodiversity framework was adopted in December 2022 in the UN Biodiversity Conference (COP-15) in Montreal Canada.

The United Nations Sustainable Development Goals (SDGs) are at the core of the UN 2030 Agenda for Sustainable Development. The SDG 14 *Life below water* aims to conserve and sustainably use the oceans, seas and marine resources for sustainable development and is therefore also linked to threatened habitats and biotopes.

Additional measures

The list of measures, in combination with the upcoming updated Red List of habitats and biotopes can be used to determine which additional activities are needed to mitigate the identified pressures and/or impacts and support the development or amendment of conservation-, recovery- and/or action plans for HELCOM threatened habitats, biotopes, and biotope complexes. It can also support future efforts to align the development with neighbouring countries or relevant organizations, to ensure improved effectiveness and efficiency.

12. Spatial protection in the Baltic Sea

Assessment results in short

— As of December 2022, the Baltic marine protected area (MPA) network covers approximately 16.5% of the Baltic Sea (see Figure 12.1). Included in this are 178 HELCOM MPAs, amounting to about 13.2% of the Baltic Sea. Significant increase in spatial coverage is expected in the future and the overall level of ambition is high across the region.

12.1. Introduction to spatial protection

Spatial protection of the marine environment refers to measures put in place in a specific area for the purpose of controlling or limiting the adverse impacts of human activities on that area's biodiversity. In other words: the main aim is to ensure positive biodiversity outcomes. The most common form of spatial protection in the Baltic Sea are the marine protected areas (MPAs). An MPA is a "marine space designated and effectively managed to protect marine ecosystems, processes, habitats, and species, which can contribute to the restoration and replenishment of resources for social, economic, and cultural enrichment." (Reuchlin-Hugenholtz & McKenzie 2015). The main goal of the coastal and marine Baltic Sea protected areas (HELCOM MPAs) is to protect valuable marine and coastal habitats in the Baltic Sea. This is done by designating suitable areas which have particular nature values as protected areas, and by managing human activities within those areas (HELCOM 2020e).

In addition to MPAs, other effective area-based conservation measures (OECMs) can also be included in the concept of spatial protection. Within HELCOM, OECMs should be viewed as an additional tool towards achieving positive biodiversity outcomes by supporting and complementing the MPA network, which should function as the backbone and primary focus of area-based protection efforts By recognizing measures which exhibit positive effects on biodiversity, OECMs can help provide a better overall understanding of the casual and synergistic effects of measures on biodiversity overall. This can be used to improve status for biodiversity attributes and ecosystem aspects of conservation concern which are currently not well covered by conservation legislation. Identification of OECMs and recognition of their governance and management structures can also provide an opportunity to engage and support a range of new partners and sectors in conservation efforts.

12.1.1 Importance for the ecosystem or for ecosystem health

Conservation of the marine environment–its physical and ecological functioning and its biodiversity–is of utmost importance for maintaining natural processes, regulating ecosystem responses to major future challenges such as the mitigation of and adaptation to climate changes, and from the point of view of guaranteeing societal goods and benefits (Roberts *et al.*, 2017, Pantzar *et al.*, 2018). It includes maintaining diversity of species, genes, and ecosystems, as well as functions of the environment, such as nutrient cycling.

12.1.2 Importance for Baltic Sea environmental management

Marine protected areas (MPAs) are important environmental management tools that provide protection from the effects of human exploitation and activities, supporting the conservation of marine biological diversity, habitats, ecosystems and the processes they host, as well as resources in a broad sense. IPBES (2019) recognises that expanding and effectively managing the current global network of marine protected areas is important for safeguarding biodiversity, particularly in the context of climate change. Consequently, they are also expected to manage and enhance marine ecosystem services and material, non-material, consumptive and non-consumptive goods, and benefits for humans (Marcos *et al.* 2021).

In addition to managing pressures from human activities and ensuring measures to limit subsequent negative impact, biodiversity conservation has shown to have potential direct economic benefits for many sectors. Studies on marine systems also estimate that every euro invested in marine protected areas would generate a return of at least €3 (Brander *et al.* 2015).

12.2. Status of spatial conservation in the Baltic Sea

12.2.1 Marine Protected Areas

The purpose of assessing MPAs is to follow up on the development of the MPA network in the Baltic Sea and its management, to identify where further development is needed, and to evaluate commitments made in HELCOM with regard to MPAs. The overarching target is to achieve a coherent and effectively managed network of MPAs in the Baltic Sea, including not only the network of HELCOM MPAs, but also other protection programmes, such as Natura 2000 and Ramsar sites.

Conservation outcomes also depend on adaptive governance, strong societal engagement, effective and equitable benefit-sharing mechanisms, sustained funding, and monitoring and enforcement of rules. This section will therefore approach spatial protection from three sides, namely spatial coverage, coherence and effectiveness of management.

Variables assessed	Assessment scale	Quantitative/qualitative evaluation	Threshold value	Result	Source
Spatial coverage of the MPA network	1	Quantitative	30% of the Baltic Sea area (BSAP and EU Biodiversity strategy)		HELCOM Map and Data Services
Coherence of the MPA network	1	Qualitative/quantitative	Representativity (score of ≥1), replication (score of ≥1), adequacy (score of ≥1), connectivity (score of ≥1)		Ecological coherence assessment of the Marine Protected Area network in the Baltic Sea
MPA management effectiveness	1	Qualitative	NA		Methodology, test case and recommendations for assessing the management effectiveness of the Baltic Sea Marine Protected Area (MPA) network

State of the Baltic Sea
Third HELCOM holistic assessment 2016–2021

Biodiversity
12. Spatial protection

Spatial coverage

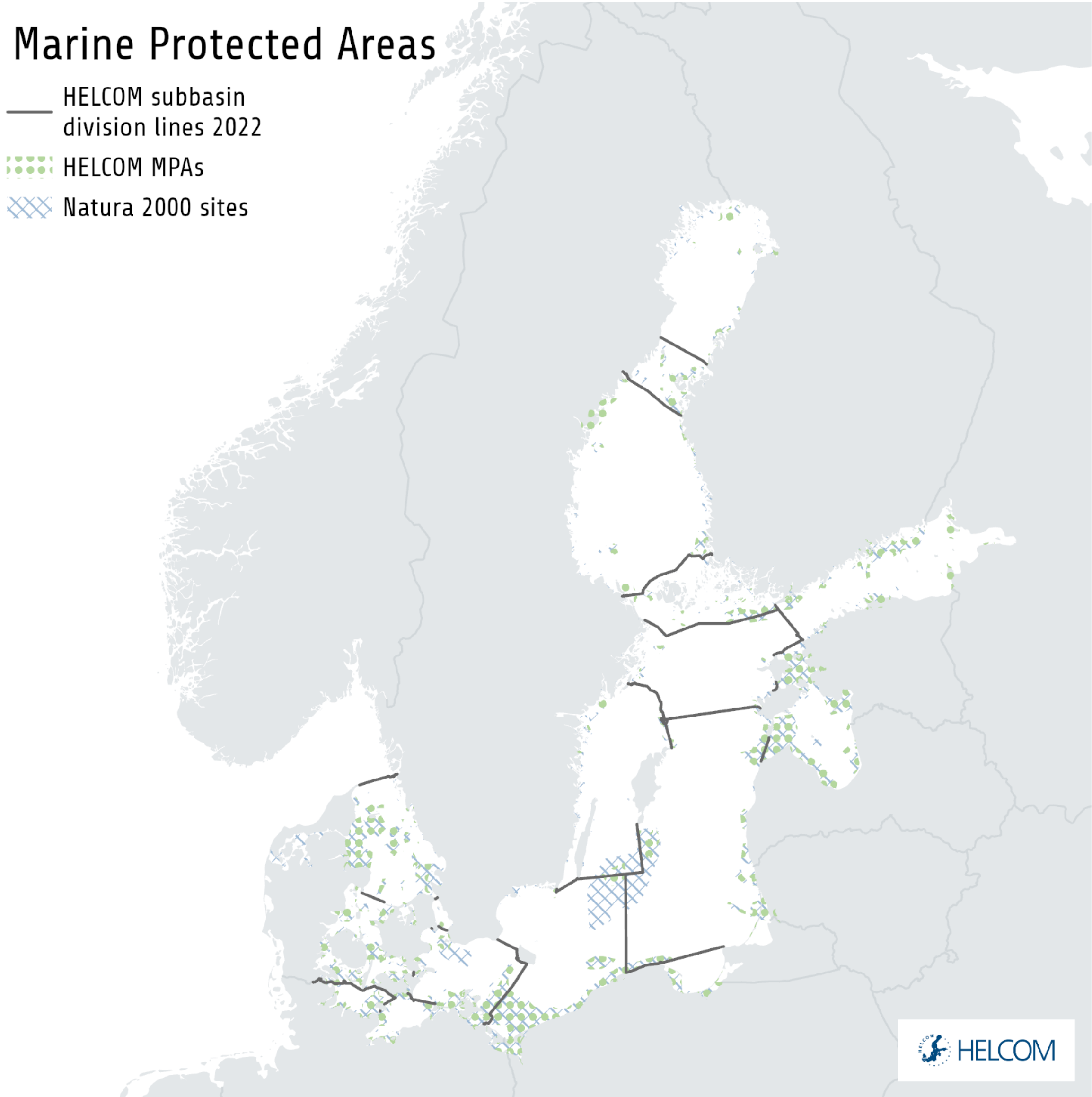

Figure 12.1. Distribution and spatial coverage of marine protected areas in the Baltic sea. Included are both HELCOM MPAs and Natura 2000 areas.

As of December 2022, the Baltic MPA network covers approximately 16.5% of the Baltic Sea (see Figure 12.1). Included in this are 178 HELCOM MPAs, amounting to about 13.2% of the Baltic Sea. Significant increase in spatial coverage is expected in the future and the overall level of ambition is high across the region, as illustrated by the commitments of the countries under the BSAP and HELCOM Recommendations, and the ongoing work to implement the EU Biodiversity Strategy 2030 (EU BDS).

MPAs in the Baltic are traditionally established to protect a subset of species, habitats or, more rarely, ecosystem processes under the Birds and Habitats Directives, regional conventions, or national law. Spatial protection of the Baltic Sea is characterized by several protection schemes overlapping in one geographical location. Natura 2000 areas in the Baltic Sea have often been designated as HELCOM MPAs, and some smaller Natura 2000 areas have been merged under one large HELCOM MPA. Overlapping Natura 2000 areas and HELCOM MPAs often have different shapes as the Natura 2000 areas may also include inland areas, while the HELCOM MPAs are restricted to the coastal zone and marine area. In addition, the HELCOM MPA network also includes Russian waters in the Baltic Sea, while the Natura 2000 network is restricted to marine areas under EU jurisdiction. Discounting MPAs designated by the Russian Federation, all but two of the 178 HELCOM MPAs include significant Natura 2000 components.

Coherence

Despite the spatial coverage of protected areas in the Baltic Sea the region faces substantial challenges in ensuring effectiveness, coherence, and positive protection outcomes, in existing MPAs. The Baltic Sea MPA network is currently not reaching its full potential, which means that it is neither complete nor coherent and thus, as recognised in SOER 2020 (European environment – state and outlook report), the protection benefits that the areas have the potential to provide are not realised. Achieving these protection outcomes is a prerequisite for the full implementation of the associated international commitments, under the EU, HELCOM and the global Convention on Biological Diversity (CBD).

The 2016 HELCOM assessment of coherence represents the first attempt at a quantitative approach for aggregating the results of the ecological coherence assessment (HELCOM 2016b). The quantitative aggregation indicates that it is highly unlikely that the network of HELCOM MPAs is ecologically coherent. The assessment of ecological coherence carried out in HELCOM considered four aspects, representativity, replication, adequacy and connectivity. Two of these aspects were evaluated to be at an acceptable level for supporting a coherent MPA network: the areal representation of different types of geographical features and broad scale habitats, and the replication of a set of indicative species and biotope complexes, as well the broad scale habitats. However, evaluations of adequacy, which considers the quality of the network, and connectivity, which measures how well the network supports the migration and dispersal of species, indicate that the network is not yet ecologically coherent (Figure 12.2).

Improving connectivity requires joint efforts from all HELCOM countries when planning and nominating new sites to the HELCOM MPA network. The next coherence assessment will be ready by 2027.

Effectiveness of management

Many existing MPAs are, however, not implemented in fact and only exist as "paper parks" where legislation is not enforced, the necessary surveillance is not present, management resources are lacking, and management plans are inactive or deficient, or do not comply with the regulations in place.

HELCOM is working towards the development of a method to assess the management effectiveness of HELCOM marine protected areas and the network. Such an assessment will be important to corroborate environmental positive effects and the marine protected area management. It can also function as form of gap analysis, providing a basis for prioritization of management improvement efforts and resource allocation.

12.2.2 OECMs

With OECMs being a relatively new concept within the Baltic Sea there are currently no recognised OECMs in the region, although several countries are exploring the possibility to recognize measures as OECMs. In 2022 HELCOM produced a common understanding of how to interpret the OECM criteria and developed a decision tree to support countries in their efforts to identify potential OECMs. As part of the regional level work on OECMs HELCOM has emphasised that a more in-depth analysis and/or assessment, targeting the Baltic Sea and the Baltic Sea MPA network specifically, will be needed in the future. The aim of such an analysis would be to obtain an ecologically relevant understanding of the role and contribution of OECMs in relation to the MPA network and achieving positive biodiversity outcomes.

Main criterion	Score	Likelihood of the network achieving coherence	Integrated result for ecological coherence
Representativity	1.1	Likely	It is unlikely that ecological coherence is reached for the Baltic Sea MPA network
Replication	1.2	Likely	
Adequacy	0.6	Unlikely	
Connectivity	0.2	Very unlikely	

Figure 12.2. Scores of the main criteria and final aggregated outcome of the ecological coherence assessment.

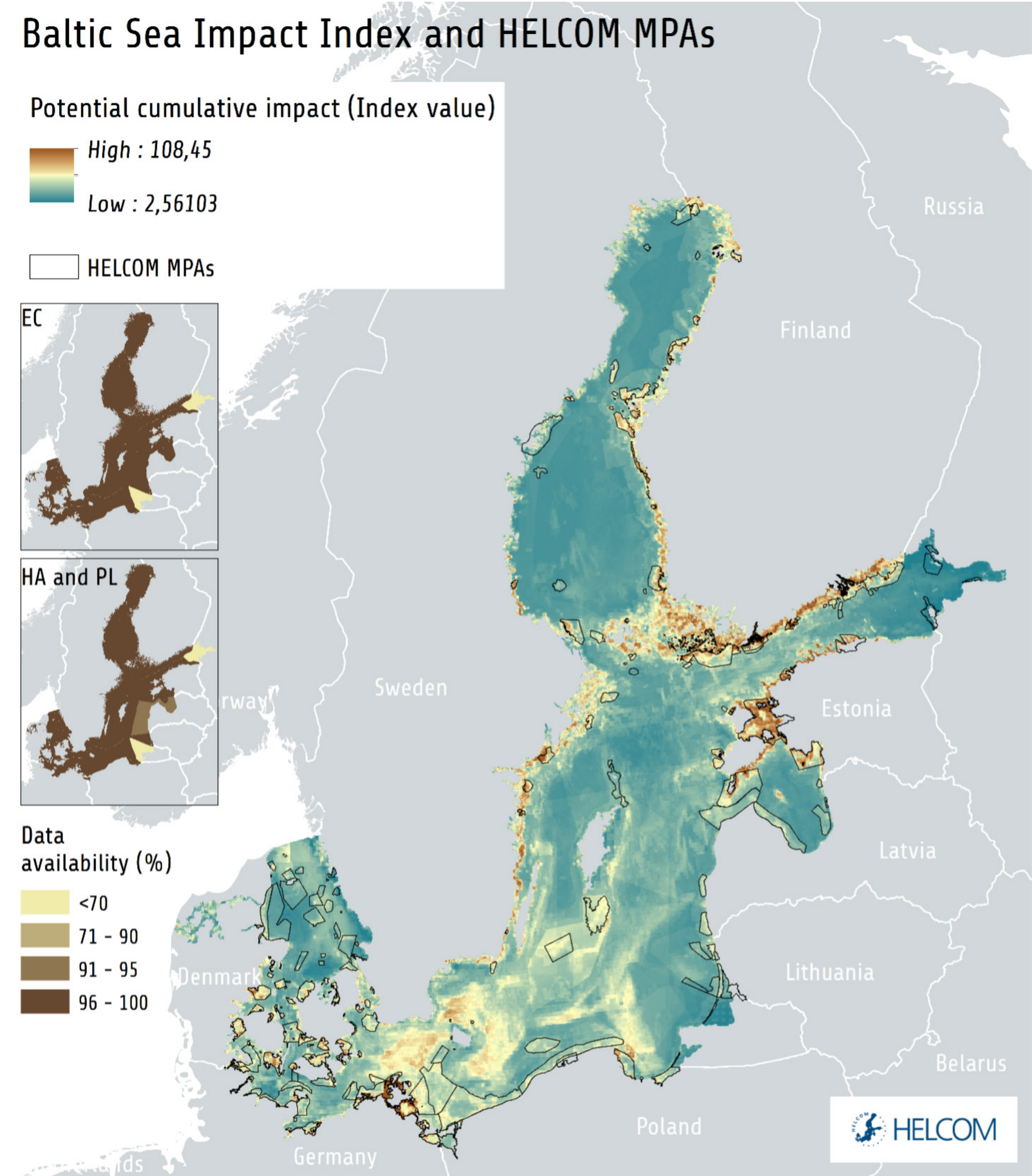

Figure 12.3. Distribution of cumulative impact from human activities on the Baltic Sea environment based on the Baltic Sea Impact Index (HELCOM 2023a) and the distribution of MPAs. The analysis is based on currently best available regional data, but spatial gaps may occur in some underlying datasets, as described by the data availability maps, showing available data for human activities/pressures and ecosystem components (EC=ecosystem component, HA=human activities, PL=pressure layers).

State of the Baltic Sea
Third HELCOM holistic assessment 2016-2021

Biodiversity
12. Spatial protection

12.3. Changes over time for spatial conservation

The designation of marine protected areas (MPAs) has been an instrument for protection of the Baltic Sea for more than 30 years and serves as an important measure in meeting the commitments of the EU Member States who are also Contracting Parties (CPs) to the Helsinki Convention. Since the designation of the first HELCOM MPAs in 1994, when all nine riparian states nominated 62 sites as HELCOM MPAs, there has been a substantial increase in the areal coverage of MPAs in the Baltic Sea: in 2004, the protected marine area was 3.9 percent, while in 2010, only 3 years after the adoption of the 2007 BSAP, this number had increased to 10.3 percent, making the Baltic Sea the first marine region in the world to reach the target of conserving at least 10 percent of coastal and marine areas, as set at the time by the UN Convention on Biological Diversity.

12.4. Relationship of spatial conservation to drivers and pressures

Pressures on marine ecosystems from human activities are already severe and the often competing demands for marine space and resources are projected to rise. On a global level marine ecosystems, from coastal to deep sea, now show the influence of human actions, with coastal marine ecosystems showing both large historical losses of extent and condition as well as rapid ongoing declines (IPBES 2019a).

As marine protected areas are a form of spatial measure, the type of activities and pressures affecting a given area can vary significantly and the vast majority of MPAs are subject to multiple pressures at any given time, many of which result in cumulative impact on the biodiversity of the protected areas (Figure 12.3). For more information on the spatial distribution of cumulative impacts in the Baltic Sea please see the HOLAS 3 Thematic Assessment report on Spatial distribution of pressures and impacts (HELCOM 2023a). The main aim of introducing spatial protection measures is to limit the pressures occurring within an area, or those that might potentially occur, for the benefit of the biodiversity there. Marine protected areas have on a global level shown the potential to address several of the pressures on marine biodiversity, in particular curbing over-fishing, exploitation, and habitat destruction (OECD 2017).

Protection, regulation and management activities represent long-term measures, and to ensure they are sufficient both now and in the future, strategic planning and implementation needs to account for changes in the environment, first and foremost climate change. Designing MPA networks without taking climate impacts into account could result in major efforts being made in areas which may not survive the next decades. While MPAs have, historically, been established to target a subset of rare and threatened species or habitats/biotopes, the ongoing dual global climate change and biodiversity crisis necessitate a broadening of the focus of spatial protection. In addition to species or biotopes under threat focus on identification and inclusion of key refuges (e.g. areas of high diversity and/or resilience), pathways of connectivity, and measures to build redundancy into the marine protected area networks, thereby ameliorating the risk that climate-change impacts will result in irrevocable biodiversity loss. To address the uncertainty associated with climate change MPAs would need to be identified in a variety of temperature regimes (McLeod *et al.* 2009). These recommendations, combined with existing biophysical principles, allow managers to design MPA networks that are more likely to survive, despite climate-change impacts.

12.5. Assessment methodological details

The assessments rely on data and information reported by the Baltic Sea countries.

The assessment of spatial extent was done by comparing the extent of spatial data layer for protected areas, removing terrestrial components extending more than XX onto land, with the full spatial extent of the Baltic Sea. The same assessment was performed per sub-basin, providing sub-basin specific results.

The methodology for each of the criteria and sub-criteria used in the coherence assessment is provided in respective chapter of the report Ecological coherence assessment of the Marine Protected Area network in the Baltic Sea (HELCOM 2016b).
The methodology for the proof of concept assessment of management effectiveness is provided in the report Methodology, test case and recommendations for assessing the management effectiveness of the Baltic Sea Marine Protected Area (MPA) network (HELCOM ACTION 2021c).

12.6. Follow up and needs for the future with regards to spatial conservation

12.6.1 HELCOM Actions

Lifting issues and challenges shared by several MS to a regional level, especially when making use of an existing platform and already established transboundary relationships, ensures efficient use of resources as solutions and strategies can be developed jointly, as opposed to each MS working in parallel (i.e. develop once, use many times). This also ensures comparative approaches and methods are available to be used across the marine biogeographical region.

The 2021 Baltic Sea Action Plan contains several actions which target spatial distribution, coherence and management of MPAs and OECMs. These include:

Code	Action
Theme: Spatial conservation measures	
B1	By 2030 at the latest, establish a resilient, regionally coherent, effectively and equitably managed, ecologically representative and well-connected system of HELCOM marine protected areas (MPAs), supported by those other spatial conservation measures, under alternative regimes for marine protection, which can contribute to the coherence of the network. Where scientifically justified, special attention should be given to offshore areas beyond territorial waters. The network of marine protected areas will: — cover at least 30% of the marine area of the Baltic Sea, of which at least 1/3 will be strictly protected. Other Effective Area-based Conservation Measures (OECMs) could be counted towards the 30% targets only if they, as a minimum, comply with the OECM criteria agreed by the Convention on Biological Diversity (CBD). — where scientifically justified, consider including no-use zones within marine protected areas, which can also serve as scientific reference areas. — expand conservation efforts to actively include areas of particular importance for biodiversity and ecosystem resilience, including important ecosystem elements such as species or areas recognized to be ecologically significant based on function for the ecosystem/provisioning of ecosystem services and broad habitat types, but which may not necessarily be rare or threatened.
B2	By 2022 come to a common understanding of the Other Effective Area-based Conservation Measures (OECMs) criteria and their use in HELCOM, based on definitions agreed in the Convention on Biological Diversity (CBD) and the EU, and define how OECMs can support the coherence of the Baltic Sea marine protected area (MPA) network. By 2025 identification of OECMs in the Baltic Sea region.
Topic: Spatial conservation management	
B3	By 2030 strengthen the management of the Baltic Sea marine protected area (MPA) network by introducing key elements into management efforts, including but not limited to those highlighted here, to increase effectiveness of protection, including by providing support to Baltic Sea MPA managers through capacity building e.g., through annual workshops. By 2023 update, and by 2025, apply HELCOM MPA management guidelines with focus on: a. Assessments and evaluation methodology and structures for management effectiveness; b. Setting quantitative conservation objectives; c. Effective conservation measures that reduce pressures; d. Establishment of indicators to monitor management performance and status of conservation features; e. Establishment of a common monitoring strategy and evaluation of conservation features and pressures; f. Adaptive management.
B4	By 2026 nationally ensure that marine protected area (MPA) management plans and/or measures are legally binding and ensure appropriate structures are in place to enforce compliance in order to achieve their conservation objectives.
B5	Develop, implement and share information on effective management measures, including measures to ensure compliance/control measures, to reduce the impact of fisheries inside marine protected areas (MPAs) in order to contribute to achieving their conservation objectives.
Topic: Coherence of the marine protected area (MPA) network	
B6	The coherence of the marine protected area (MPA) network will be periodically assessed at least every ten years, with the next such assessment to be carried out by 2025. By 2027 the results from the coherence assessment are to be used to take appropriate actions to ensure conservation and resilience of biodiversity, and to identify possible spatial conservation expansion needs to improve coherence.
B7	Ensure that by 2030 the HELCOM marine protected area (MPA) network amongst other things provides specific protection to species and biotopes listed as regionally threatened or near threatened in the HELCOM Red Lists.

These actions represent both actions that need to be taken jointly by all countries on a regional level, and also actions that need to be implemented by each country individually. In addition, HELCOM Recommendation 35/1 'System of coastal and marine Baltic Sea protected areas (HELCOM MPAs)' was adopted on 1 April 2014, superseding HELCOM Recommendation 15/5. It recommends that the Governments of the Contracting Parties to the Helsinki Convention take all appropriate measures to step up efforts to establish an ecologically coherent and effectively managed network of coastal and marine Baltic Sea protected areas (HELCOM MPAs) and to improve the protection effectiveness of existing HELCOM MPAs.

Specific targets of the Recommendation include to

- protect at least 10% of the marine area of each Baltic Sea sub-basin, when scientifically justified,
- designate new sites as HELCOM MPAs, where ecologically meaningful, especially in offshore areas beyond territorial waters,
- ensure that HELCOM MPAs provide specific protection to those species, habitats, biotopes and biotope complexes included in the HELCOM Red Lists,
- develop and apply management plans or measures for all existing HELCOM MPAs by 2015, and establish a management plan or measures for every new MPA within five years after its designation,
- assess the effectiveness of the management plans or measures of HELCOM MPAs by conducting monitoring, and, where feasible, scientific research programmes, which are directly connected to the conservation interests of HELCOM MPAs, including the placement of monitoring stations inside the MPAs,
- modernize the HELCOM MPA database, taking into account and harmonizing with other similar database

The latest reporting on the recommendation took place in 2022 and showed that the majority of the different objectives covered in the Recommendation have been implemented at least to some degree. A few have been fully implemented e.g. conducting reviews on new potential MPAs, whereas a few have not been implemented at all, such as the use of the latest coherence analysis when selecting new HELCOM MPAs. The reporting also clearly indicates that the main driver for most countries in the region when considering what species and habitats to designate areas for is the EU Habitats Directive. This means that in cases where regional marine habitats and species are not well represented under the Directive, or where the directive Annexes are outdated, the degree to which spatial protection measures provide protection to these species is unknown.

Starting in 2023 HELCOM will embark on a large scale, regional level project aiming to develop a comprehensive protection framework for the Baltic Sea, under the auspice of which several of the Recommendation targets will also be implemented.

12.6.2 Other international commitments

IPBES (2019) recognises the expansion and strengthening of ecologically representative, well-connected protected-area networks and of other effective area-based conservation measures as an effective policy measure for transformative change.

The EU Biodiversity Strategy 2030 aims to strengthen biodiversity, amongst other ways, through the establishment of a coherent network of protected areas and restoration. The BDS sets the objective to legally protect at least 30% of the sea in the EU area, of which at least one third, i.e. 10%, is to be under strict protection (European Commission 2020). This target is fully in line with BSAP Action B1. Within this, there should be specific focus on areas of very high biodiversity value or potential. The strategy identifies these as the most vulnerable to climate change and states that such areas should be granted special care in the form of strict protection, meaning that natural processes are left essentially undisturbed to respect the areas' ecological requirements. Subsequently the strategy calls for strict protection of 10% of EU seas (European Commission 2020). In the Baltic strict protection, as defined by the EU Commission under the EU Biodiversity strategy (European Commission 2022) and IUCN categories 1a and 1b (see Dudely 2008 and Day *et al.* 2012) is practically absent.

In Europe, the European Marine Strategy Framework Directive aims to establish a network of MPAs as one of the main protection measures to maintain and improve the sustainable use of European marine waters, the biodiversity and biological connectivity, the quality and occurrence of habitats and the distribution and abundance of species (European Commission, 2008).

Under both the Convention on Biological Diversity's (CBD) Aichi Target 11 and the Sustainable Development Goals, Parties agreed to conserve 10% of marine and coastal areas by 2020.As of December 2022, with the adoption of the global biodiversity framework under CBD, this ambition has been raised to protecting 30% of the world lands and seas by 2030.

The main MPA global policy targets aim to protect by 2030 at least 30% of coastal and marine areas, and the urgency of increasing the ocean area covered by ecologically representative and well-connected MPA systems to at least 30% by 2030 is underlined in the IUCN World Parks Congress of Sydney, Australia, 2014 (Charles *et al.*, 2016, Krueck *et al.*, 2017Charles *et al.*, 2016, Krueck *et al.*, 2017).

12.6.3 Needs for future assessments

It has taken the Baltic Sea region almost 30 years to achieve the current level of spatial coverage, and to reach the BSAP/EU Biodiversity Strategy/CBD Global Biodiversity target the countries will have to come together and protect approximately the same amount, ~15% of the Baltic Sea area in just 8 years. However, it is vital to recall that the ultimate aim of all the initiatives is not only to reach the percentual target, but to strengthen biodiversity. In order for spatial protection to be effective, it must account for what happens both within and outside of the immediate area of implementation, as well as account for both societal and ecological aspects. Therefore, to fully capitalize on the added value contributed by the increase in spatial protection towards the 30%/10% target designation should be done in a strategic way with respect to what is protected, for what purpose, in what way and where, all effort should be done at the ecologically relevant scale, be supported by functional governance, by effective and efficient measures as well as adaptive management including fit for purpose monitoring.

Currently the framework and necessary prerequisites for such strategic decision making at the regional level are missing. Without effective policy and management on a broad scale, MPAs serve as isolated islands of protection in a larger sea of degradation. While there already exists governance bodies and institutions with necessary mandates and aspirations for protection of the marine environment, the challenge lies in the implementation and the spatial scope at which protection of the marine environment is currently done. Most existing entities only focus on addressing a subset of the marine area (local or national). This fragmentation hinders the current network to reach its full potential and to secure positive biodiversity outcomes from existing protection measures. Past experiences have showed that the lack of regional coordination results in limited progress and sub-optimal development. A regime shift in how we consider marine protection is needed, including improved interaction between actors across the marine biogeographical region.

Known barriers include:

- Incomplete knowledge base for decision making and designation, including: distribution of biodiversity across the Baltic Sea, the function and role of biodiversity elements in increasing resilience, supply of ecosystem services and ecosystem function and the effect of pressures and human activities on biodiversity.
- Gaps in governance, including too narrow scope of protection, lack of strict protection, inconsistent use, or lack, of identified nature values, protection objectives and targets. Differing and inconsistent legislation and interpretations. Lack of a concrete network approach and gaps in coherence of the existing MPA network. Unclear implementation processes of OECMs in spatial protection.
- Insufficient use of adaptive management, including insufficient capacity of managers, lack of, or ineffective, management plans, insufficient measures, insufficient enforcement and lack of compliance assurance and insufficient monitoring.
- Lack of tracking progress and inadequate measuring the level of success across each aspect of the protection cycle.

The need to address the above on a Baltic wide scale to ensure comparability and compatibility across countries and by extension improved ecological relevance of the results and the consequent national implementation.

13. HELCOM work on restoration in the Baltic Sea

Assessment results in short

— Restoration in and of the marine environment is an emerging topic in the Baltic Sea. It is likely to become increasingly important in the future, due to both ecological, management and policy related changes.

13.1. Introduction to restoration

Despite increasing efforts to conserve marine-coastal ecosystems, global analyses show unprecedented rates of loss and change at all levels of biological diversity (Butchart *et al.*, 2010, Cardinale *et al.*, 2012). To strive to reverse the trend additional efforts are therefore needed. Ecological restoration is the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed.

In some cases, restoration simply requires the removal of the source of the disturbance and allow sites to recover naturally through ecological succession. This process is called passive, or unassisted, restoration because restoration do not need to take much action. This approach requires comparatively few resources and can as such be done over large areas. However, once a source of impact has been removed, the return to pristine conditions can vary from decades to centuries (Lotze *et al.*, 2011) as this is based on both intrinsic (e.g., life-histories traits, ecosystem-specific features) and extrinsic (e.g., type and magnitude of disturbance) factors (Worm *et al.*, 2006).

In other cases, the ecosystem has passed a threshold of degradation, and disturbed sites within it are not able to recover on their own or can only recover very slowly. In such cases passive restoration can prove insufficient within a time frame that is acceptable from an anthropogenic/societal perspective (Dobson *et al.*, 1997, Lotze *et al.*, 2006). To restore such highly disturbed sites, the removal or cessation of the disturbance is only the first step and passive restoration can be insufficient to halt or reverse impact and its consequences (Perrow and Davy, 2002, McCrackin *et al.*, 2017, Jones *et al.*, 2018, Lindegren *et al.*, 2018). To this end, there is a need to actively assist the recovery of an ecosystem that has been degraded, damaged, or destroyed (Society for Ecological Restoration International Science Policy Working Group, 2004). This process starts or accelerates the recovery process or attempts to change the site's ecological succession and is referred to as active restoration. Active restoration is considered an effective strategy to supplement conservation and management actions when the natural recovery of ecosystems is precluded (Perrow and Davy, 2002, Perring *et al.*, 2015, Jones *et al.*, 2018) but is, by its nature, localized and often comparatively small scale as it requires direct intervention, which is resource intensive.

13.1.1 Importance of restoration for the ecosystem and ecosystem health

Primary goals of restoration are often to re-establish ecological functions and ecosystem services that are important for humans and to reinstall the system to a previous historical condition that is self-sustaining and resistant towards disturbance. The ultimate aim is to bring diverse and resilient nature back to marine ecosystems (HELCOM ACTION 2021a). This means reducing pressures on habitats and species, and ensuring all use of ecosystems is sustainable. It also means supporting the recovery of ecosystems, tackling pollution and invasive alien species (European Commission 2020).

13.1.2 Importance of restoration for Baltic Sea environmental management

Restoration is considered an effective strategy to accelerate the recovery of biological communities at local scale and can improve the health of existing and new protected areas, ensuring that biodiversity benefits are secured in a shorter timeframe. When successful, restoration of marine-coastal systems can provide a myriad of benefits, relating to climate, biodiversity, economic growth, and physical and mental well-being (Aronson and Alexander, 2013). Increased restoration efforts across Europe are expected to create jobs, reconcile economic activities with nature growth and help ensure the long-term productivity and value of the natural capital of European Seas, including the Baltic Sea (European Commission 2020).

However, the effects of restoration can be unpredictable in the marine realm (Bayraktarov *et al.*, 2016, Fraschetti *et al.* 2021). As restoration is a costly activity, it is vital that limited conservation funds are spent effectively and the potential is realized in practice to obtain the intended outcomes and galvanize further action.

13.2. Status of restoration efforts in the Baltic Sea

Marine restoration is still in its early developmental stages in the Baltic Sea, and focuses primarily on coastal areas. Restoring coastal systems and areas in the Baltic Sea have so far tended to fall under one, or several, of four broad categories: transplanting fauna and flora from one site to another, creating artificial habitat to promote range expansion and recolonization, inducing changes in hydrological and physical settings each with their own cost and probability of success (Fraschetti *et al.* 2021). The method of restoration is however only one aspect that needs to be taken into account when planning for successful restoration. The focal species/ecosystem (Montero-Serra *et al.*, 2018), duration of the restoration activity (Bayraktarov *et al.*, 2016), geographical location (Darwiche-Criado *et al.*, 2017), and local factors such as pressures present and conservation level have been identified as relevant in restoration (Keenleyside *et al.*, 2012).

Recent scientific reviews have highlighted several challenges and broadened the perspectives in marine restoration (e.g., Bayraktarov *et al.*, 2016, Swan *et al.*, 2016, Jacob *et al.*, 2018), starting from a revision of concepts and definitions (Elliott *et al.*, 2007, Abelson *et al.*, 2016).

While no specific assessment on restoration in the Baltic Sea was possible for the holistic assessment, in 2021 the EU co-financed HELCOM ACTION project prepared an overview of restoration measures for coastal habitats in the Baltic Sea which, in addition to exploring cost-efficiency, also looked at areas of highest significance and need (HELCOM ACTION 2021a).

13.3. Changes over time for restoration efforts

As restoration in the Baltic Sea is largely in its infancy, experiences of marine restoration measures are still very restricted (Naturvårdsverket 2016, Kraufvelin *et al.* 2020b) and there is no consistent source of information on effort, success rates or trends of restoration in the region. The evaluation of restoration outcomes is also not an easy task (Wortley *et al.*, 2013) and there is no standardized definition of success against which to measure. It is therefore important to evaluate the restoration measures and their success through quantitative follow-up studies.

Since a restoration process is ongoing/continuous, while ecological responses to different restoration measures are seldom linear, it can be challenging to judge if a restoration measure is successful or not. This can be done for example by following the development of the target features in a restored area over time. To be able to assess the success of restoration efforts, it is important to establish reference conditions, to specify and clarify the goals of the restoration activities, and agree upon what level of restored condition is the aim. These aspects are very important but are often overlooked. The reference conditions should describe both habitat structures and functions, but also the biological, chemical and physical processes that are creating and maintaining the structures and systems (Kraufvelin *et al.* 2020b). These kinds of monitoring investigations can be done through a before/after-design, which means that there are data available both before and after the restoration measures. The end result can also be compared with the conditions in unrestored reference systems using a control/impact-design, which means that there are data from the restored area as well as from an unrestored reference area. More comprehensive follow-up programs, where the aim is to establish cause-effect relationship and allow for scientific analyses, before after-control-impact design (see Stewart-Oaten *et al.* 1986, Underwood 1994, Schmitt & Osenberg 1996) in order to cover all relevant dimensions. These investigations include multiple measurements before and after the restoration measures, both in the target water area as well as in similar reference areas (preferably there are more than one reference area) where the restoration measures have not been carried out (HELCOM 2021a).

A central goal for a restoration measure thus needs to be that the ecosystem can develop in an unrestricted positive direction after the measure has been implemented (Bradshaw 1996). In many cases ascertaining the success of restoration efforts requires many years, or even decades, depending on the generation length of the species in question.

13.4. Relationship of restoration to drivers and pressures

A fundamental prerequisite for a successful restoration is that the factors initially causing the damage on the habitat or ecosystem have disappeared or can be kept at a level which is known not to cause detrimental impact.

During the past decades, many shallow coastal ecosystems have faced increased disturbance, which has led to their rapid deterioration (Crain *et al.* 2008, Halpern *et al.* 2008, Andersen *et al.* 2015, HELCOM 2018a). In temperate areas, such as in the Baltic Sea, recruitment areas for fish, biogenic reefs and vegetated bottoms are especially threatened by many human activities (Kraufvelin *et al.* 2018, 2020a). Impact in the coastal zone are often caused by several activities and pressures acting simultaneously, for instance different kinds of coastal construction and recreation, increased input of nutrients and other pollutants, selective harvesting of species, introduction of non-indigenous species, and climate change (Elliott 2004, Korpinen *et al.* 2012, Andersen *et al.* 2015, Worm 2016). Typical effects, seen globally, are that biological communities are becoming more and more similar (homogenisation), important top predators are decreasing in abundance and size, habitat-forming species are decreasing and the structural diversity, connectivity and process dynamics within biological communities is being disturbed (Geist & Hawkins 2016).

A particular challenge in relation to restoration is to understand the relationship between human pressures and their effects on ecosystems (e.g. Borja 2014). In the Baltic this has been explored for example in a Swedish national report by Kraufvelin *et al.* (2020) focusing on physical pressures and biological effects. While this interaction is important when mitigating pressures, it is also important when planning which restoration measures to implement, where to implement them and in what way, since if they are wrongly applied, some such measures themselves can impose pressures on the environment, rather than contribute to an improvement (Kraufvelin *et al.* 2020bc). Measures should also be undertaken with the perspective of climate change in such a way that it is evaluated if the restored systems are resilient enough to changing conditions, as well as if the restored systems even can be adapted to assist with the mitigation and dampening of the negative effects of climate change.

13.5. Assessment methodological details

Due to restoration representing an emerging topic in the Baltic Sea no assessment has been carried out for restoration specifically for HOLAS 3.

13.6. Follow up and needs for the future with regards to restoration

13.6.1 HELCOM actions

Interest in marine restoration in the Baltic Sea area is highly likely to increase in coming years. This is partly because the Baltic Sea has many areas which have suffered impact and not yet recovered, partly due to increased global environmental threats such as climate change and partly due to the fact that restoration has only recently become a part of the the political agenda. Demands for restoration activities are included within European environmental directives and of central interest for actions to recover environmental status in the Baltic Sea.

The 2021 Baltic Sea Action Plan contains concrete actions that directly target restoration, as well as a number of actions for which restoration is of relevance. These include the development of a regional HELCOM Action Plan for Restoration and identifying suitable measures and habitat types for restoration efforts.

Code	Action
B25	Map ecosystem services and the present and potential spatial distribution of key ecosystem components, including habitat forming species such as bladder wrack, eelgrass, blue mussel and stoneworts Baltic-wide, by 2025.
B26	Protect key ecosystem components including habitat forming species by 2030, by: — assessing the state of, and threats to these key ecosystem components by 2023 — implement effective and relevant threat mitigation measures based on the threat and state assessments, including restricting human activities associated with causing physical loss or disturbance, by 2030 — identifying suitable measures and types of habitats, biotopes and key ecosystem components for passive or active restoration by 2025 and implementing programmes for restoration as outlined in the HELCOM Restoration Action plan by 2030.
B27	By 2025 develop and by 2026 start implementing a HELCOM Action Plan for habitat and biotope restoration, including qualitative and quantitative regional targets, a prioritized list of actions, and an associated implementation toolbox outlining best practices and methods for restoration in the Baltic Sea region.
B15	Develop and coordinate monitoring and assessment methods, where ecologically relevant, for specified representative coastal fish species, populations and communities, by 2023. Based on these assessment methods, to regularly assess the state of the coastal fish community through selected coastal fish species and groups, including threatened species, by at latest 2023. Based on the results of the assessment, develop and implement management measures with the ambition to maintain or improve the status of coastal fish species, including migratory species by 2027.
B16	To strengthen native strains and to reinstate migratory fish species: — By 2023 identify rivers where management measures for migratory fish species, including eel, would have the greatest positive impact. — Starting from 2023, in line with relevant international commitments, iteratively review and prioritize effective mitigation measures in the identified rivers and/or dams, including removal of dams and migration barriers where relevant and possible, especially in small waterways. — Develop and implement habitat restoration plans of spawning sites for anadromous species in relevant rivers by 2025.
B23	By 2025 develop, and by 2027 implement, and enforce compliance with ecologically relevant conservation plans or other relevant programmes or measures, limiting direct and indirect pressures stemming from human activities for threatened and declining species. These will include joint or regionally agreed conservation measures for migrating species.
B29	By 2025 develop, and by 2027 implement, and ensure compliance with, ecologically relevant conservation plans or other relevant programmes or measures, limiting direct and indirect pressures stemming from human activities for threatened and declining biotopes and habitats.

Restoration can also function as a key component of other protection efforts, both spatial and targeting individual species, directly through e.g. the restoration of breeding habitat or indirectly through restoration efforts improving status for other compartments of the foodweb which in turn provides more prey.

While there is no HELCOM Recommendations which target restoration, the recommendations for threatened species and habitats (HELCOM Recommendation 37/2 Conservation of Baltic Sea species categorized as threatened according to the the 2013 HELCOM Red List, and HELCOM Recommendation 40/1 Conservation and protection of marine and coastal biotopes, habitats and biotope complexes, as well as that for marine protected areas (HELCOM Recommendation 35/1 'System of coastal and marine Baltic Sea protected areas (HELCOM MPAs)) all have relevance for restoration, and vice versa.

13.6.2 Other international commitments

Recognizing the potential of restoration, the Convention on Biological Diversity and the European Union have dedicated restoration targets (EU, 2011, CBD, 2014), and in 2019 the "United Nation Decade on ecosystem restoration 2021–2030" has been declared (Waltham *et al.*, 2020)

Nature restoration is already partially required from the Member States in existing EU legislation (Notably the EU Birds Directive (2009/147/EC), Habitats Directive (92/43/EEC), Water Framework Directive (2000/60/EC), Floods Directive (2007/60/EC) and Marine Strategy Framework Directive (2008/56/EC).

However, the EU Commission has identified significant implementation and regulatory gaps hinder progress. For instance, there is no requirement for Member States to have biodiversity restoration plans. There are not always clear or binding targets and timelines and no definition or criteria on restoration or on the sustainable use of ecosystems. There is also no requirement to comprehensively map, monitor or assess ecosystem services, health or restoration efforts. These issues are exacerbated by the gaps in implementation that prevent the existing legislation from achieving its objectives (See Fitness Check of the EU Nature Legislation (European Commission SWD(2016) 472) and Fitness Check of the EU Water Legislation (European Commission SWD(2019) 439)). To ensure that nature restoration across land and sea picks up, increases the resilience, and contributes to climate change mitigation and adaptation as a key nature-based solution, the EU Biodiversity Strategy set a target for EU countries to ensure 20% of land and sea areas are restored by 2030, and all ecosystems in need of restoration are restored by 2050. To support these efforts the European Commission has presented a proposal for an EU restoration regulation which is currently being considered. The proposal aims to restore ecosystems, habitats and species across the EU's land and sea areas in order to enable the long-term and sustained recovery of biodiverse and resilient nature, contribute to achieving the EU's climate mitigation and climate adaptation objectives and meet international commitments. It also functions as a key element of the EU Biodiversity Strategy, which calls for binding targets to restore degraded ecosystems, in particular those with the most potential to capture and store carbon.

As part of the Convention on Biodiversity Global Biodiversity Framework, adopted in December 2022, the ambition level was further increases by setting a target of restoring 30% of terrestrial and marine ecosystems by 2030.

13.6.3 Needs for future assessments

With regard to marine restoration, there is a great need for a toolbox for active measures that can be applied broadly in various marine and brackish water areas. This is partly due to the current deteriorated environmental state in many coastal areas. It is also due to the fact that natural processes of recovery (passive restoration) and targeted measures within management, such as formal protection (see Knowlton *et al.* 2012, De'ath *et al.* 2012, Abelson *et al.* 2016), are often insufficient to return ecosystems to pre-disturbed conditions.

Even though there is a growing body of knowledge of marine restoration activities, especially in coastal ecosystems, marine restoration as a scientific or management area is still emerging. Our knowledge is especially scarce when it comes to restoration of open marine systems (Elliott *et al.* 2007, 2016). The main reasons behind this lack of knowledge are that many natural physical processes in the sea are still quite poorly understood. Furthermore, our knowledge about how human activities are affecting these processes, as well as how resistant and resilient marine ecosystems are, is also a clear gap (Carter 1989, Elliott *et al.* 2016, Ounanian *et al.* 2018). Similarly, we lack a lot of knowledge about the connectivity and openness of different marine ecosystems, i.e. fundamental information to achieve marine green infrastructures. The challenges within marine restoration are further complicated by different sources of uncertainty such as incomplete knowledge, unpredictability and ambiguity, all of which are factors that must be dealt with by the practical restorers (Ounanian *et al.* 2018).

In order to be able to apply the most relevant and cost efficient measures possible, functioning methods of restoration need to be developed, described, tested in practice, and thoroughly evaluated.

Both from a scientific and a legal perspective it is important to define what the purposes are of the different types of applied restoration measures and to clearly establish the goals (Moksnes *et al.* 2016). Many restoration attempts are carried out without clearly established goals, with the possible exception of a few individual target species for which the post-restoration conditions may have been defined beforehand. In order to make the restoration efforts effective and successful, it is necessary to involve people with ecological competence and a broad understanding about how different habitats or ecosystems function. Additionally, it is also important to include people with the knowledge and background in supporting processes, all the way from the planning and funding stages to execution, monitoring and evaluation (Moksnes *et al.* 2016a). In order to understand how physical processes that are formative for the habitats and how they operate, it is also important to involve oceanographers and people with broad hydromorphological competence (Kraufvelin *et al.* 2020b).

14. Conclusions and future perspectives

Implications of the results for the Baltic Sea ecosystem

Biodiversity is critical for maintaining ecosystem health. Declining biodiversity and deteriorating biodiversity status threatens the structure and proper functioning of the ecosystem and lowers its productivity and resilience. Although all systems are able to adapt to and cope with external stressors to some degree, biodiversity degradation reduces for example the complexity of food webs and the connectivity between ecosystem components, due to the lost roles of multiple interacting species or individuals. Along with such degradation, the ecosystem loses its ability to recover from disturbance, and becomes critically senstive to destabilization and collapse.

The current assessment shows that there are cases of inadequate status in biodiversity indicators across the full spatial extent of the Baltic Sea and in all parts of the foodweb. Only a few core indicators have acceptable levels in part of the Baltic Sea, and none in all assessed areas. Although the deteriorated status is first noted for the species or components where the impact is immediate, the effects spread into the whole ecosystem through links within the food web. The overall results suggest that the environmental impact of reduced biodiversity status in the Baltic Sea are far-reaching and not restricted to certain geographic areas or certain species groups. Persistent negative trends in status eventually threaten the perstistence of populations, suitable habitats, and the long-term survival of species and, importantly, increases risks for further degradation.

However, we should also recall what the state of the Baltic Sea environment could have looked like without the work that has been done so far to protect the Baltic Sea. Several long-term pressures, such as inputs of nutrients and several hazardous substances, are decreasing today, several previously prevailing pollution hot spots have been removed and the share of marine protected areas in the regions has increased. For most ecosystem components (but not all), the assessment period of six years applied here is not sufficiently long to encompass the time needed for achieving an improved status, as recovery and restoration can be long term processes. Many pressures have been acting on the Baltic Sea for a long time and legacies such as nutrients and contaminants will still show unacceptable levels in the marine environment long after their inputs have ceased. For example, ecosystem models show that responses to nutrient reductions act on the time scale of decades. Still, the current assessment results suggest that the recovery rate for biodiversity today is too slow or missing.

However, if we limit the amount of human pressures on the environment, it can be anticipated that biodiversity will show signs of improvement in the future, and continued efforts to improve the environmental status of biodiversity are of key importance. The results presented in this report clearly show that, in order to ensure the Baltic Sea ecosystem maintains and improved its functions, we need to improve management to limit the extent and intensity of pressures on biodiversity, and enhance the resilience of the natural ecosystem.

Implications of the results for society and management

Degradation of the marine environment and biodiversity reduces the ecosystem's ability to produce goods and services to society, known as ecosystem services (Millennium Ecosystem Assessment 2005). The ecosystem services supplied by marine environments affect the supply of benefits to society, which in turn result in changes in human well-being (Fisher et al. 2008). The evaluations and integrated assessments presented in this report constitute an integral part of the adaptive management cycle, enabling learning from previous experiences and planning for future action through the evaluation and assessment of status and, by extension, management (Figure 14.1).

Having a marine environment in good status brings several benefits that are currently not fully provided across the Baltic Sea, such as clear and oxygen-rich waters, healthy fish stocks, safe fish and seafood for human consumption, good quality coasts and beaches, and healthy marine biodiversity. Reaching good environmental status in national marine waters by 2040 is collectively estimated to be worth 5.6 billion euros per year to the region's population (HELCOM 2023b). Not achieving good status of the marine environment affects different groups of society, through for example decreased opportunities for recreation, reduction of fish stocks and adverse human health impacts, including future generations (HELCOM 2023b).

State of the Baltic Sea
Third HELCOM holistic assessment 2016-2021

Biodiversity
14. Conclusions

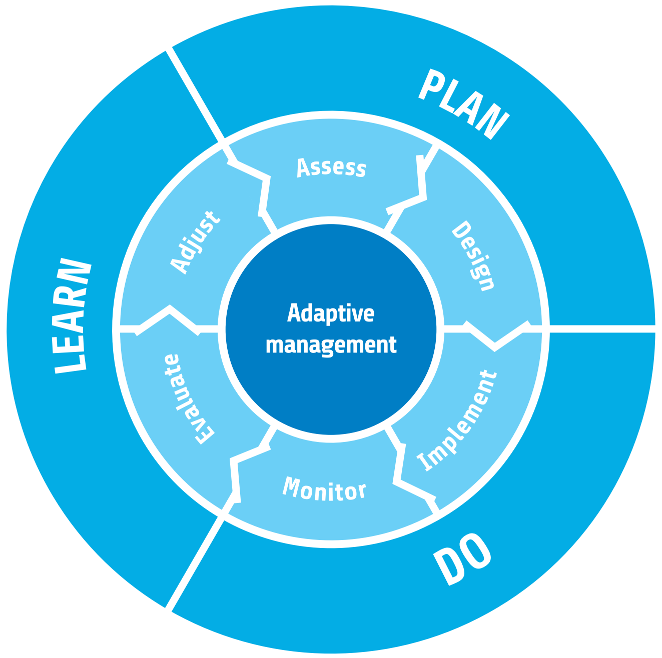

Figure 14.1. Steps and components of the adaptive management cycle directly supported by the thematic assessment of biodiversity, presented in bold. These steps then enable the other parts of the cycle.

Changes in the 2016-2021 assessment compared to 2011-2016

The 2016-2021 assessment of biodiversity has a broad range of improvements compared to previous assessments. Data availability has been improved through the improvement of data flows, monitoring and data reporting by HELCOM Contracting Parties, but also due to methodological developments which enable a broader set of data to be included in the indicator evaluations and, subsequently, in the integrated assessment. New integrated assessment methodology has been included for both pelagic and benthic habitats, enabling a more ecologically relevant assessment. This progress has improved the reliability and robustness of evaluations and assessments, as can also be seen in the confidence evaluations which accompany the results.

Several new topics have also been introduced into the thematic assessment report, e.g. harbour porpoise, foodwebs and bycatch, as well as chapters on spatial conservation, threatened species and restoration, the latter to more closely align the thematic assessment report with the Baltic Sea Action Plan. For the assessment of waterbirds integrated assessment results are presented for the first time, both for the species group overall and for the individual functional groups. Examples of new indicators that have been introduced are the Cumulative impacts on benthic habitats and Shallow water bottom oxygen, and several existing indicators have expanded their spatial scope to include additional areas (e.g. Zooplankton mean size and total stock, Seasonal succession of dominating phytoplankton groups, Diatom-dinoflagellate index, Abundance of waterbirds in the breeding season), all contributing to a more holistic assessment.

Although intersessional development for several indicators means that the one to one comparisons may not yet be possible, for the first time it is possible to qualitatively compare trends for indicator and assessment results across assessment periods, enabling exploring indicated changes in more detail to establish whether they represent genuine change and indentifying underlying causes.

The further development of the spatial pressures and impacts assessment tool has also enable the inclusion in the report of maps illustrating the distribution of ecosystem components, as well as of activities and pressures affecting the various ecosystem components. This provides valuable contextual information for the assessments and improves the explanatory value. Climate change effects and impacts has for the first time been directly included in both the biodiversity indicator reports and in the thematic assessment.

Future perspectives

The deteriorated status presented in this report can all be linked to the activites and priorities of us as a society. Subseqently, the recovery of Baltic Sea biodiversity is entirely dependent on how well we can manage our activities to ensure that they are truly sustainable, both in the near future and long term. As also called for in the EU Biodiversity strategy, the Sustainable Development Goals, and in the CBD Global Biodiversity Framework recently adopted in December 2022, transformative change is needed to ensure that our activities are within the tolerance of the ecosystem in which they take place. The assessment results and information presented in this Thematic Assessment report on biodiversity functions as one important basis to inform the Third State of the Baltic Sea report, and will underpin national and regional policy in the Baltic Sea region the coming years. At the core it functions as an integral part of the tracking of progress in the implementation of the Baltic Sea Action Plan, and can help identify areas where the commitments in the Plan needs to be further elaborated and supported by additional actions.

State of the Baltic Sea
Third HELCOM holistic assessment 2016–2021
Biodiversity
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State of the Baltic Sea
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State of the Baltic Sea
Third HELCOM holistic assessment 2016–2021

Biodiversity
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