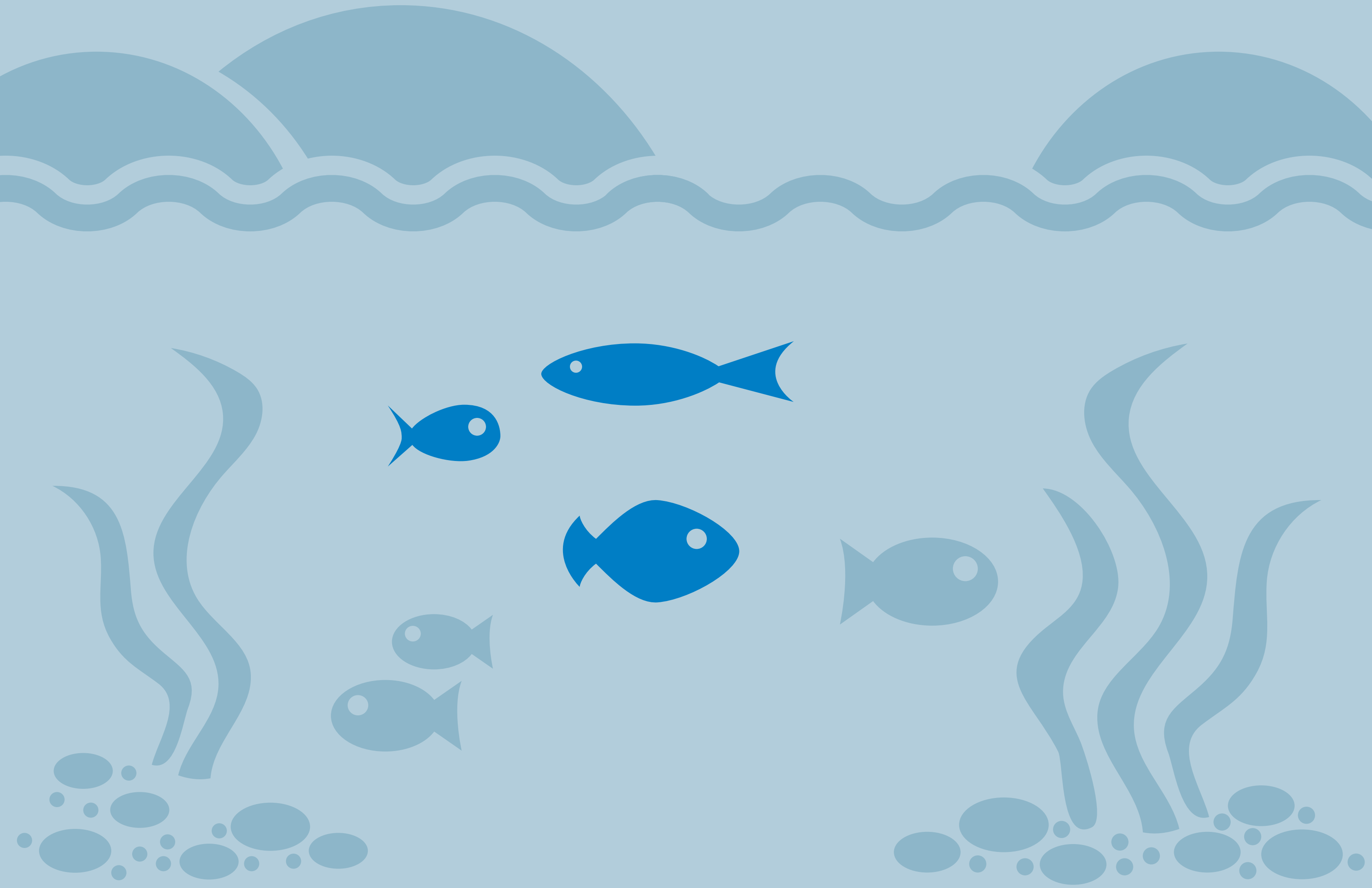
FISH PRO III

Status of coastal fish communities in the Baltic Sea 2016–2020 – the fourth thematic assessment

Baltic Marine Environment Protection Commission

Monitoring and assessment

Baltic Sea Environment Proceedings n°199



helcom.fi

Published by:

Helsinki Commission – HELCOM
Katajanokanlaituri 6 B
00160 Helsinki, Finland

www.helcom.fi

For bibliographic purposes this document should be cited as:
“Status of coastal fish communities in the Baltic Sea 2016-2020 - the fourth thematic assessment. Baltic Sea Environment Proceedings n°199. HELCOM (2024)”

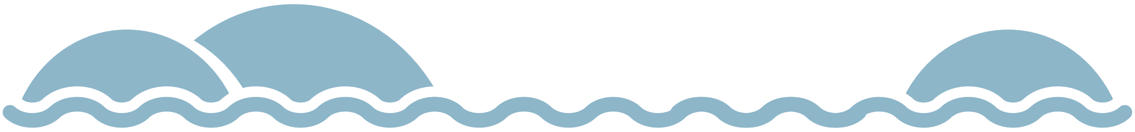
Authors: Elisabeth Bolund, Matilda Andersson, Lena Bergström, Örjan Östman, Jens Olsson (SLU, Sweden), Mikko Olin, Antti Lappalainen (LUKE, Finland), Lauri Saks, Roland Svirgsden (University of Tartu, Estonia), Laura Briekmane, Eriks Kruze (BIOR, Latvia), Justas Dainys, Linas Lozys (Nature Research Center, Lithuania), Tomas Zolubas (Klaipeda University, Lithuania), Adam Lejk, Lukasz Dziemian (National Marine Fisheries Research Institute, Poland), Elliot J. Brown (DTU, Denmark).

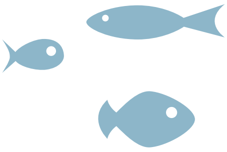
Layout: Laura Ramos Tirado

ISSN: 0357-2994

Contents

Executive summary





This report summarizes the most recent advances in the HELCOM regional collaboration on Baltic Sea coastal fish communities by reviewing the current state of knowledge on important pressures impacting coastal fish communities and available measures to restore and sustain the status of this essential ecosystem component. A significant part of the report also includes a presentation of the latest status assessment (pertaining to the years 2016-2020) of coastal fish as included in the HOLAS 3 assessment using three HELCOM agreed upon core indicators; *Abundance of key coastal fish species*, *Size structure of coastal fish*, and *Abundance of coastal fish key functional groups*. The rationale for producing the report is to complement the assessment of coastal fish within HOLAS 3 with reviews on impacting pressures on coastal fish and measures to support the fish communities. In addition, future development needs for status- and impact assessments, as well as effective restoration and conservation measures are included. The report also marks the finalization of the HELCOM FISH PRO III-project running between the years 2018-2023 and will hopefully be of use for managers, stakeholder and the wider scientific community.

The status assessment as presented in this report includes data from Finland, Estonia, Latvia, Lithuania, Poland, Denmark and Sweden, and updates the previous assessment published in 2018 covering the years 2011-2016. Overall, the status of coastal fish communities is poor and has worsened between the previous abd the current assessment. For the indicator *Abundance of key coastal fish species* including the species perch, flounder, eelpout, pike, pikeperch and whitefish, only 32% of the considered assessment units reached the threshold for good status compared to 62% of the assessment units in 2011-2016. The current assessment of the indicator *Abundance of coastal fish key functional groups* only considered cyprinids and mesopredators, and only 29% of the assessment units considered reached the threshold for good status. Reasons for the low and deteriorated state includes the fact that additional key species (pike, pikeperch, whitefish, and eelpout) and monitoring areas were considered in the current compared to the previous assessment, and that several of these are not in a state characterized by good status. The aggregation and integration rules applied in the current assessment are also stricter compared to the previous assessment in turn making the current one more conservative. But the observed deterioration in status cannot be attributed to methodological differences alone. For example, the status of perch and flounder, which is more comparable between previous and current assessments, do show rather small differences in status but with no clear signs of improvement over time. The newly introduced indicator *Size structure of coastal fish*, evaluated as the size of the largest fish in the population compared to a size threshold, was used for the key species perch. The results show that only 27 % of the assessment units considered achieved good status.

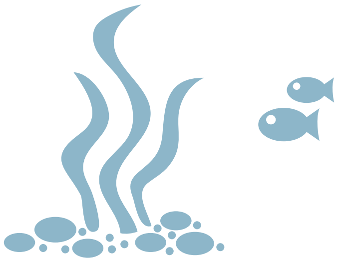
As highlighted above, the overall status of coastal fish as derived from the three core indicators evaluated is far from good. There are, however, differences between some areas, regions and indicators. For the indicator *Abundance of key coastal fish species*, the status appears to be better along the coasts of the Bothnian Bay, parts of the central Finnish coasts, and in the one Estonian and two Latvian monitoring areas. The spatial coverage for the assessment of the indicator *Size structure of coastal fish* is poorer compared to that of the abundance-based indicator, but variation in the assessment results are similar across coastal areas. There is a tendency for better status in more northern areas in the Gulf of Bothnia, with the exception of the Northern

Quark, for the indicator *Abundance of coastal fish key functional groups*. In the areas characterized as being in poor status for this indicator, it is foremost the high abundance of cyprinid fishes that is preventing the indicator from reaching the threshold for good status. The confidence in the assessment is low to intermediate in most areas for *Abundance of coastal fish key functional groups*, and intermediate to high for most areas considered for *Abundance of key coastal fish species* and *Size structure of coastal fish*.

The observed poor status of coastal fish communities in the Baltic Sea is likely the result of impacts from a multitude of natural and anthropogenic pressures acting simultaneously and potentially also synergistically and cumulatively. From the review included in this report, the poor status likely reflects unfavorable environmental conditions related to the impacts of habitat loss and degradation, fishing (including commercial and recreational fisheries), eutrophication, climate change, and food web interactions such as predation from apex predators. As coastal fish communities have rather local population structures and the extent to which different factors affect the communities likely varies substantially across coastal areas, the potential for generalizations across areas is limited. Some factors may have strong effects locally and thereby explain a large proportion of the variation in fish abundance and size structure, whereas others could have comparatively smaller effects or may be apparent only under certain environmental conditions. In order to address the extent of impacts from human activities on coastal fish communities, one must therefore take a full set of potential human-induced pressures into account and assess them within the context of food web interactions and ambient environmental conditions of the specific area.

Given the overall poor status of coastal fish in many areas of the Baltic Sea, as presented in this report, there is an urgent need for additional measures to be taken to support and restore the impacted populations and communities. As the key factors influencing the status of coastal fish likely vary across areas, the recommended plan of action will likely differ between areas, and should hence be developed while accounting for the specific environmental setting, the range of current anthropogenic pressures, and the structure of the fish community and food web in focus. Of all the available potential measures, our literature review shows that only a few, primarily those aiming at reducing the fishing mortality of the fish, have sufficient scientific support for being effective. The strongest support is found for permanent fishing closures (no-take areas). Partial fisheries closures and regulations of fishing gears and catch might also be effective, but these have all weaker support in the literature. Among the measures aiming to support the recruitment and growth of fish, those focusing on protecting existing habitats have gained the strongest scientific support for being effective. Habitat restoration and nutrient reductions might also be effective but have rarely been evaluated and henced recieved relatively little scientific support. Despite public support, there is to date also no general scientific support for measures related to biomanipulation including stocking of hatchery-reared fish, regulation of top predators, or intensively fishing unwanted species. To gain stronger support for the effectiveness of individual measures, it is of utmost importance that ongoing and past measures to support coastal fish are scientifically evaluated to a far greater extent than what is currently done. More in-depth reviews and detailed meta-analyses of the existing literature on measures could also help in the development of appropriate measures for restoring and supporting coastal fish. Moreover, an adaptive ecosystem-based approach to management where fisheries and environmental management, as for example fisheries closures and habitat protection, are considered jointly is likely to be most effective since coastal fish are at the center of coastal food webs and are hence impacted by both top-down and bottom-up processes. Given the regulatory roles of fish in marine food webs, carefully designed measures with an integrated and ecosystem-based management strategy are also likely to result in both direct and indirect positive effects for the coastal food web structure and functioning.

To that end, the results and conclusions as presented in this report should serve as the basis for future follow-up actions within the context of the Baltic Sea Action Plan, the national implementation of the Marine Strategy Framework Directive, as well as for local management measures and assessments for coastal fish communities in the Baltic Sea. The work presented in this report has been facilitated by co-operation between HELCOM Contracting Parties within the HELCOM FISH PRO III project and HOLAS 3 process, and by nationally funded development work and research projects. Despite the recent advances in the Baltic-wide cooperation on coastal fish communities there are still several knowledge gaps and development needs to fill, which should be considered in the future. One often neglected aspect that should be stressed is an expanded potential use of coastal fish data to for example further study the expansion and effects of invasive species like the round goby. Finally, besides the issues already considered above, perhaps the most important is that future efforts should include safeguarding and expanding the spatial coverage of coastal fish monitoring programs while also considering additional data sources for status assessments besides fisheries independent surveys, as well as further refinement and development of the currently used indicators, assessment methods and associated thresholds.



1. Background

1.1. Coastal fish in the Baltic Sea

The Baltic Sea with its brackish water exhibits strong environmental gradients in salinity, temperature and nutrient conditions (HELCOM 2018a). Fish inhabiting the Baltic Sea represent a mixture of species with a marine and freshwater origin, where some are favored by warmer waters and eutrophic conditions while others are not (Koehler *et al.* 2022). "Coastal fish communities" here refers to the fish assemblages in relatively near-shore and shallow (< 20 m depth) coastal areas, and often harbor a mixture of species of marine and freshwater origin (Ojaveer *et al.* 2010; Olsson *et al.* 2012a; Koehler *et al.* 2022). Typical coastal freshwater species are perch (*Perca fluviatilis*), ruffe (*Gymnocephalus cernua*), pikeperch (*Sander lucioperca*), pike (*Esox lucius*), whitefish (*Coregonus maraena*) and species from the carp family (*Cyprinidae*), such as roach (*Rutilus rutilus*), breams (*Abramis sp.*) and bleak (*Alburnus alburnus*). Common marine species found in coastal areas are herring (*Clupea harengus*), flounder species (*Platichthys flesus* and *Platichthys solemdali*), cod (*Gadus morhua*), turbot (*Scophthalmus maximus*), sticklebacks (*Gasterosteidae)*, gobies (*Gobiidae*), eelpout (*Zoarces viviparous)* and eel (*Anguilla anguillla)* (HELCOM 2012; Olsson *et al.* 2012a; Bergström *et al.* 2016b). In the eastern and northern parts of the Baltic Sea, with lower salinity, species of freshwater origin dominate, whereas an increased segment of marine species is commonly found in the more saline southern and western parts (HELCOM 2012). There are also seasonal and small-scale spatial variations in species composition. During the warmer parts of the year, coastal fish communities are often dominated by freshwater species and those preferring higher water temperatures (Olsson *et al.* 2012a), especially in more sheltered areas. In contrast, more exposed areas can be relatively more dominated by species of marine origin and those preferring lower water temperatures during the colder parts of the year.

Hence, due to the influence of environmental gradients and seasonality in community composition, the predominating coastal fish species in the Baltic Sea vary both spatially and temporally. Still, a key feature of coastal fish communities in the Baltic Sea region is their relatively restricted dispersal pattern, compared to fully marine regions. Many coastal species of freshwater origin have a clear local population structure (Laikre *et al.* 2005; Östman *et al.* 2017b). Freshwater species in the Baltic Sea, such as perch, pike, whitefish, pikeperch, and cyprinids, exhibit rather strong genetic population subdivision on a small scale and restricted migration across coastal areas (Laikre *et al.* 2005; Olsson *et al.* 2011, 2012b; Östman *et al.* 2017b). Populations of marine species like cod and herring, on the other hand, migrate across vast areas and are typically characterized by substantial gene flow and relatively weak population sub-structuring (Nielsen *et al.* 2003; Jørgensen *et al.* 2005; Florin & Höglund 2007; Östman *et al.* 2017b). There are also examples of ecological adaptation of fish in the Baltic Sea in response to the brackish conditions. Recent studies on flounder have shown that flounder populations in the Baltic harbors two distinct species, the Baltic flounder (*Platichtys solemdali*) and European flounder (*Platichthys flesus*; (Momigliano *et al.* 2018).

As a result, coastal fish communities are also local in how they may respond to environmental conditions and pressures (see for example (Bergström *et al.* 2016b; Östman *et al.* 2017b). Combined, the local population structure and spatial variability in community composition along environmental gradients imply that assessments of coastal fish communities need to consider a small geographic scale, preferably relating to the migration distance of the most common species in the communities (Bergström *et al.* 2016a; Östman *et al.* 2017b; a). This also implies that management measures to restore and/or strengthen coastal fish communities should consider local preconditions.

1.2. Ecological role and societal relevance of coastal fish

Coastal fish are important both for the Baltic Sea ecosystem and for humans with respect to socio-economic and cultural values (Blenckner *et al.* 2021). Fish constitute a central part of the food web and hence have a key role in linking different

Perch is on of the key target species in recreational fisheries in the Baltic Sea. © Jens Olsson.

processes, meaning the status of coastal fish communities influences the larger ecosystem structure and functioning (Östman *et al.* 2016; Olsson 2019). As such, the status of coastal fish conveys information on the general status of coastal ecosystems in the Baltic Sea (HELCOM 2006, 2012, 2018b). The ecosystem services concept captures the various direct and indirect ways in which the ecosystem and its organisms, including coastal fish, contribute to human well-being (IPBES 2019; Daily & Ruckelshaus 2022). A key regulating service that coastal predatory fish provide is the natural control of nuisance, opportunistic and invasive species (Ljunggren *et al.* 2010; Sieben *et al.* 2011; Eklöf *et al.* 2020). Coastal fish also contribute to the binding of carbon, nutrients and harmful substances, as these components are taken up in the bodies of fish via their food and subsequently decomposed and buried in sediments (or in some cases fished or consumed by predators) (Hjerne & Hansson 2002; Vanni *et al.* 2013; Dabrowska *et al.* 2017; Mariani *et al.* 2020; Bianchi *et al.* 2021; Scotti *et al.* 2022). Such regulating services can provide benefits to humans by buffering excess levels and fluctuations resulting from human activities, enabling human activities to be carried out in an ecologically sustainable way and reducing costs for restoration measures. Further, the maintenance of living environments that support coastal fish provides direct benefits in the form of nutrition for both humans and wild animals, including other fish, sea birds and marine mammals. Ensuring a diversity of coastal fish habitats also contributes to ensuring genetic resources that can be utilized to secure the resilience of coastal fish against environmental perturbations (Wennerström *et al.* 2017) and potentially support aquaculture and restocking (Ben Khadher *et al.* 2016; Baer *et al.* 2021). For humans, further, both coastal fish and their habitats also contribute to recreational activities, where recreational fishing, snorkeling and photography are some examples (HELCOM 2015; Jernberg *et al.* 2024). Ensuring the availability of these habitats and species also enables aesthetic experiences for entertainment or representation, scientific investigation or the creation of traditional ecological knowledge or enable education and training. Several coastal species are, further, highly valued by humans for their contribution to culture, heritage or for their existence value (Nieminen *et al.* 2019).

Table 1. Example of key ecosystem services provided by coastal fish. The second column indicates the most closely corresponding classification code according to (Haines-Young & Potschin-Young 2018).

Ecosystem service	Code
Regulating	
Nutrient fixing and storage in fish	2.1.1.2
Control of nuisance, opportunistic and invasive species	2.2.3.1
Binding of carbon in fish	2.2.4.2
Binding of harmful substances in fish	2.2.5.2
Provisioning services provided by essential fish habitats	2.2.2.3
- Species for nutritional purposes for humans	
- Species for replenishing stocks or breeding	
- Species contributing with genetic material for further use	
Cultural	
Species supporting recreational fishing	3.1.1.2
Species supporting aesthetic experiences	3.2.1.3
Species enabling scientific investigation	3.1.2.1
Species important for culture or heritage	3.2.1.2
Species with an existence value	3.2.2.2

The many connection points between coastal fish and ecosystem services highlight the importance of achieving a good status of coastal fish communities, as described for example in the environmental objectives of the Baltic Sea Action Plan (HELCOM 2007) and the Marine Strategy Framework Directive (MSFD, European Commission 2008), for example.

1.3. HELCOM FISH-PRO and earlier coastal fish assessments

Coastal fish monitoring in the Baltic Sea region date back to the early 1970s in some areas (Olsson *et al.* 2012a). Since 2023, HELCOM has coordinated coastal fish monitoring and assessments in the Baltic Seaunder dedicated projects (HELCOM FISH, HELCOM FISH-PRO I-III. This work will be continued from 2024 and onwards in the newly established Expert group on coastal fish (EG Coastal Fish).

Three thematic assessments describing the status of coastal fish communities in the Baltic Sea based on indicators have previously been produced (HELCOM 2006, 2012, 2018b). The Baltic Sea Action Plan (HELCOM 2007) and the implementation of the EU Marine Strategy Framework Directive (European Commission 2008, 2017) have led to an increased focus on regional harmonization of assessment methods and monitoring programs also for coastal fish (HELCOM 2013).

1.4. Objectives of the report

This fourth thematic assessment of coastal fish in the Baltic Sea advances previous status assessments (HELCOM 2006, 2012, 2018b) by expanding the spatial coverage of the assessment, including additional monitoring sites, and also by considering additional aspects of coastal fish communities, assessing more species and the size structure of some key species. With these improvements, the report gives an update on the status of coastal fish communities in the Baltic Sea until year 2020 (Chapter 3). To that end, the report also reviews the current knowledge base about factors influencing the state and temporal development of coastal fish (Chapter 2), measures to strengthen and restore coastal fish communities (Chapter 4), and recommendations for future work to advance the monitoring and management of coastal fish in the Baltic Sea (Chapter 5).

2. Factors impacting coastal fish communities

Coastal areas are among the most productive environments worldwide, but also the most heavily impacted by human activities (Lindeboom 2002; Airoldi & Beck 2007). Several human-induced pressures may impact coastal ecosystems, including fishing, habitat exploitation, climate change, eutrophication and exposure to hazardous substances (Collie *et al.* 2008; Brown *et al.* 2018; HELCOM 2018a; Reusch *et al.* 2018; Viitasalo & Bonsdorff 2022). Due to their central position in the food web, fish are also influenced by species interactions and internal population processes (Persson *et al.* 2000; Harvey *et al.* 2003). Hence, coastal fish communities may be subject to a plethora of pressures, which are likely to differ among areas and between seasons, due to the local population structure of most coastal fish species and due to different combinations of pressures in space and time (Olsson *et al.* 2012a; Östman *et al.* 2017a). This chapter aims to review the main potential drivers of change in coastal fish communities in the Baltic Sea and to increase the understanding of which drivers mitigation measures should focus on.

2.1. Fishing

Fishing can exert different types of pressures on fish communities. One main distinction is between direct effects from the extraction of species, and the indirect effects of trophic cascades triggered by species extraction, (Airoldi & Beck 2007).

Both commercial and recreational fisheries target coastal fish populations, but the main focal species differ between activities and sub-regions. For coastal resident species such as perch, pikeperch, pike, and whitefish the outtake by recreational fisheries greatly exceeds that of the commercial fishery in many countries (Karlsson *et al.* 2014; Hansson *et al.* 2018; Bergström *et al.* 2022b; Dainys *et al.* 2022). In coastal areas of the southern and western Baltic Sea, relatively large recreational catches have also been seen for marine species like cod and flounder, and the migrating species eel (Sparrevohn & Storr-Paulsen 2012; Ferter *et al.* 2013; Eero *et al.* 2015; Hyder *et al.* 2018). With the ongoing decrease in commercial fishers it is likely that the proportion of total catch attributable to recreational fishers will only increase in the future (Lewin *et al.* 2023). The exception to this trend may be eel and cod, which ICES has suggested should no longer be targeted by either fishery (European Commission 2022; ICES 2023).

While the commercial fishery is obliged to report catches and effort to the authorities, reporting of catches from the recreational fishery (in some form) do not occur regularly in all countries around the Baltic Sea (Karlsson *et al.* 2014; HELCOM 2015; ICES 2022b). Due to the general poor reporting by the sector, and likely high take, the effect of recreational fishing on coastal fish communities is certainly underestimated (Dainys *et al.* 2022). However, coastal member states of the European Union shall in the nearest future ensure that citizens engaged in recreational fisheries are registered and that they record and report their catches through an electronic system (European Commission 2023).

Fishing can have strong effects on coastal fish populations and their broader communities. This is mainly the outcome of direct fishery induced mortality reducing the abundance and mean size of targeted species (Florin *et al.* 2013). High fishing pressures has been linked to declines in abundance and size of flatfish and pike

Fishing is one of the human activities impacting coastal fish communities. © Jens Olsson

(Berggren *et al.* 2022; Tomczak *et al.* 2022), and, correspondingly, using no take zones (NTZs) to decrease fishing pressure has proven effective for increasing monitoring catches within the NTZs for, among other species, pike, perch, and whitefish (Berkström *et al.* 2021; Bergström *et al.* 2022a). Coastal commercial fisheries as well as recreational fishers, target large piscivores such as perch and pikeperch (Olsson *et al.* 2015; Bergström *et al.* 2016a), and the share of large perch and pike in a population are affected by the fishing pressure in an area (Bergström *et al.* 2016b, 2022b; Lappalainen *et al.* 2016; Berggren *et al.* 2022). The large individuals in a population also contribute disproportionally to reproduction and are therefore highly important for the sustainability of fish populations (Birkeland & Dayton 2005; Olin *et al.* 2012; Barneche *et al.* 2018). Thus, the size distribution of a population gives an indication of the local fishing pressure and the health of the population. The indirect effects of fishing are diverse and vary from changes in individual species' life-history traits caused by fisheries induced selection (Cardinale *et al.* 2009), to changes in trophic regulation leading to trophic cascades within and across communities (Baden *et al.* 2003; Österblom *et al.* 2007; Eriksson *et al.* 2011; Casini *et al.* 2012).

2.2. Temperature

Temperature regulates the productivity of several species in coastal ecosystems, and hence influences food and energy availability for coastal fish. Temperature also directly affects ectothermic organisms, such as fish, for which increasing temperatures increase both activity and growth rate, until they reach their species or population-specific upper tolerance (Biro *et al.* 2009; Lindmark *et al.* 2022). For warm-adapted species such as perch, pikeperch, and roach, higher temperatures have led to strong recruitment, and faster growth (Böhling *et al.* 1991; Karås & Thoresson 1992; Lehtonen & Lappalainen 1995; Tarkan & Vilizzi 2015; Fey & Greszkiewicz 2021; Lindmark *et al.* 2023). Some studies show that increased growth rate is restricted to younger age classes, and that the positive effects of increasing temperatures on growth decrease or vanish for larger pike and perch (Huss *et al.* 2019; van Dorst *et al.* 2019; Berggren *et al.* 2022) (but see Lindmark *et al.* 2023).

Warmer waters have also been linked to increased mortality rates which can be due to shifts in activity increasing risk of capture by predators or fishers or simply due to a shift in pace-of-life (Berggren *et al.* 2022; Lindmark *et al.* 2023). All increases in growth for warm-adapted species are dependent on fish being able to access sufficient resources and temperatures remaining under their thermal optima.

For cold-adapted species, the temperatures in shallow coastal systems can exceed their physiological limits, periodically excluding them from particular habitats (Tunney *et al.* 2014; Guzzo *et al.* 2017), increasing mortality (ICES 2020) and decreasing recruitment (Östman, et al. in rev). As temperatures increase, these cold-adapted species can be outcompeted by freshwater species such as percids and cyprinids which have higher optimum temperatures, leading to a decrease of cold-water adapted species (Olsson *et al.* 2012a; Östman *et al.* 2017a; Olin *et al.* 2023). In the Baltic, the cold-water fishes most at risk due to warming include salmonids, sculpins, and species of marine origin (e.g. herring, flatfish, and cod) (Karås & Thoresson 1992); Östman et al. in rev).

The abundance of adult flounder is, somewhat favoured by increasing water temperatures (Olsson *et al.* 2012a) but see (Orio *et al.* 2017). However, different life stages and individual populations may show contradictory responses to coastal temperature increases, with responses depending heavily on the overlap of environmental temperatures with the species' thermal maxima. For example, European whitefish, a cold-adapted freshwater species found in northern coastal fish communities, show mixed responses to increased temperatures depending on life stage. Like many fish species, young whitefish show higher growth rates as temperatures increase, but they reach maturity earlier allocating resources to reproduction instead of growth, likely reducing the reproductive capacity of the stock (Veneranta *et al.* 2021). The high temperatures and reduction in ice cover can also reduce the reproductive success of whitefish by impairing fertilization and increasing embryo mortality (Cingi *et al.* 2010; Veneranta *et al.* 2013).

Changes in water temperature, caused by weather conditions and currents, also impact the activity of coastal fish, directly affecting their catchability in passive gears such as gill nets and fyke nets, making it important to consider the effect of temperature during sampling when assessing the status of coastal fish communities (Bergström *et al.* 2016a; Östman *et al.* 2017a; Naddafi *et al.* 2022). Given that the water temperature of the Baltic Sea reflects global warming trends and that local thermal conditions are unlikely to be influenced by management actions in the short-term, it is important to consider the effect of climate-related changes in temperature on coastal fish in their general management including for example the potential for species ranges shifts and increased vulnerability of certain populations and species to other pressures when already under "temperature stress".

2.3. Salinity

Being a brackish water system, the salinity in the Baltic Sea has a substantial impact on the distribution patterns of organisms (Johannesson & André 2006; Wennerström *et al.* 2013; Uspenskiy *et al.* 2022). The prevailing salinity can affect the survival of fish eggs, larvae and juveniles, as well as prevent adults from utilizing certain habitats, e.g. potential feeding or spawning areas (DeFaveri & Merilä 2014; Lehtonen & Kvarnemo 2015; Illing *et al.* 2016). The variability of salinity observed in parts of the Baltic Sea creates overlaps in the distribution of different fish species, and in many coastal areas a co-occurrence of marine species, like cod, and freshwater species, such as perch or roach, are observed. Generally, however, the fraction of marine species decreases with increasing latitude in the Baltic Sea (HELCOM 2012). The abundances of species of freshwater origin drastically decrease in the more southern and western parts of the Baltic Sea as the salinity exceeds 10 psu.

The salinity gradient though is not fixed and is characterized by regional climate-driven inflow events and the mixing of saline North Sea water with the brackish Baltic water (Bendtsen *et al.* 2009). This mixing of water masses of different densities affects the dispersal patterns of passively drifting eggs and larvae from deepwater spawning species to coastal juvenile growth areas and may influence the survival of larvae (Hinrichsen *et al.* 2012; Petereit *et al.* 2014). Marine inflows also vary in strength from year-to-year influencing the recruitment and temporal distribution of marine species (Miethe *et al.* 2014; Hinrichsen *et al.* 2016).

Salinity might also act as a driver of ecological adaptation and differences in salinity between areas could be a barrier to gene flow. The presence of divergent populations of the same species in the Baltic Sea is exemplified by the differential in salinity tolerances of geographically separated cod stocks (Kijewska *et al.* 2016), and different reproductive strategies of non-isolated flounder species and pike populations (Nissling & Dahlman 2010; Momigliano *et al.* 2018; Sunde *et al.* 2018).

Changes in salinity levels, in parallel with temperature, could also be linked to changes in the long-term development and structure of coastal fish communities. During the last decades, the salinity of surface waters in the Baltic Sea has decreased, in parallel with a shift in coastal fish community composition in favour of freshwater species over those of marine origin (Olsson *et al.* 2012a, 2015). If salinity in the Baltic Sea continues to decrease, the proportion of freshwater species such as percids and cyprinids is expected to increase, whereas the abundances of marine species like herring, cod, and flounder are expected to decrease. However, there is also high uncertainty around the magnitude and direction of future changes in salinity in the Baltic Sea, so any predictions about future fish abundances or communities as they relate to changes in salinity should be interpreted with caution (Saraiva *et al.* 2019).

Similar to temperature, salinity is not a factor that can be controlled via management actions and should instead be accounted for when assessing the status of coastal fish communities (Bergström *et al.* 2016a; Östman *et al.* 2017a), similarly as highlighted for temperature above.

2.4. Eutrophication

The Baltic Sea has historically been subject to high input of nutrients, which, combined with long water-residence time, makes it one of the world's most eutrophied seas (HELCOM 2010; Fleming-Lehtinen *et al.* 2015; Reusch *et al.* 2018). Though the input of nutrients from land-based sources have decreased in recent years, due to the large amount of stored nutrients in both the sediments and the water column, along with high rates of nitrogen fixation by cyanobacteria, eutrophic conditions are expected to persist and should be accounted for in management plans (HELCOM 2018a). Under the current nutrient regime, the exchange of water masses between coastal and offshore areas in the Baltic Sea also has a large influence on nutrient concentrations in the coastal areas, and hence their eutrophication status (Bryhn *et al.* 2017).

The trophic conditions are decisive for the productivity of the coastal ecosystem and hence ultimately for the energy intake, growth, and reproduction of fish. Eutrophication may, for example, influence the balance between lower trophic groups of organisms, which in turn affects the food type and quality for fish. While slight eutrophication, shifting a system from oligotrophic to mesotrophic, often increases resources and thereby could increase fish biomass, excessive eutrophication is linked to oxygen deficiency, reduced habitat quality and water clarity, ultimately affecting species' behaviour, physiology, and abundance in different ways (Tomczak *et al.* 2022).

Eutrophication has a substantial impact on the distribution and occurrence of organisms in the Baltic Sea and also impacts the structure and function of coastal fish communities (Lappalainen 2002; Bergström *et al.* 2016a; Östman *et al.* 2017a). A common observation is an increased abundance of cyprinid species with increasing nutrient levels (Bonsdorff *et al.* 1997; Lappalainen 2002; Ådjers *et al.* 2006; Härmä *et al.* 2008; Snickars *et al.* 2015; Bergström *et al.* 2016a, 2019). Pikeperch, which are adapted to hunting in turbid conditions, are also comparatively abundant in eutrophic coastal areas (Bergström *et al.* 2019; Sundblad *et al.* 2020), along with sticklebacks which benefit from coastal eutrophication (Olin *et al.* 2022).

Perch, one of the most abundant predators in coastal fish assemblages, as well as pike, are often negatively affected by eutrophication, due to the decreased water transparency which decreases their foraging efficiency (Ljunggren & Sandström 2007; Bergström *et al.* 2019). The suitability of nursery habitats for various coastal fish species can also be decreased by lowered water transparency (Bergström *et al.* 2013), along with the increased presence of ephemeral macroalgae which reduces availability of suitable spawning areas through overgrowth and poorer oxygen conditions, all symptoms of eutrophication (Wennhage & Pihl 1994; Jokinen *et al.* 2015, 2016; Kraufvelin *et al.* 2018). These reductions in nursery habitat extent and quality have, for example, proven important for key species such as whitefish (Veneranta *et al.* 2013) and flounder (Carl *et al.* 2008). Some important coastal habitats may be lost altogether as a result of eutrophication impacting the species that depend on them (Vaher *et al.* 2022).

The symptoms of eutrophication can be mitigated in some cases by the regulatory functions of coastal fish communities, such as the top-down control by piscivorous fish that may lessen eutro-

Algal bloom during summer in a Swedish coastal bay. © Jens Olsson

phication symptoms in coastal areas (Eriksson *et al.* 2011; Sieben *et al.* 2011; Baden *et al.* 2012; Östman *et al.* 2016). The potential regulating effect of piscivorous fish on ephemeral algae might be as strong as the effects of nutrient additions, and the most pronounced effects are seen in already heavily eutrophied systems (Östman *et al.* 2016). Besides maintaining healthy and viable populations of coastal predatory fish to combat eutrophication symptoms, management should continue to take measures aiming at reducing nutrient input and concentrations in the Baltic Sea to conserve habitat qulatity and oxygen conditions for coastal fish communities as well to the balance and relative abundance of species within the communities.

2.5. Habitat availability and quality

Habitat availability can become a limiting factor for coastal fish populations when activities such as coastal development, resource extraction, dredging or filling of sand to combat erosion (so-called beach nourishment) take place on a

The quality of fish essential habitats is key for the recruitment of coastal fish species. © Jens Olsson

large scale (Kraufvelin *et al.* 2018). Coastal development includes, for example, the building of marinas, ports or coastal residences. The activities can physically cause displacement of fish by drastically altering the bathymetry, hydrography, seafloor type, and vegetation structure of coastal areas (Dafforn *et al.* 2015; Hansen *et al.* 2019).

Though there is a general consensus among fisheries biologists that coastal habitat availability and quality is a limiting factor for coastal fish production, to date, few studies have demonstrated this for coastal fish in the Baltic Sea (reviewed in (Kraufvelin *et al.* 2018) , but evidence is accumulating (Lefcheck *et al.* 2019). Although the effect may be very local in each individual case, the cumulative impacts of coastal development on fish habitat suitability have been shown to reduce the total available habitat for important life-history stages (Sundblad & Bergström 2014; Brown *et al.* 2018; Donadi *et al.* 2020), and impact the local productivity of the adult stage (Sundblad *et al.* 2014). Boat traffic and resource extraction in the coastal zone can also reduce the quality of available habitats by removing and affecting their structure and complexity (Sandström *et al.* 2005). This has been documented for the loss of coastal boulder reefs (Støttrup *et al.* 2014) and suggested for the removal of medium and large gravel (Christoffersen *et al.* 2018) along with other hard-bottom habitats more generally (Flávio *et al.* 2023). There is some evidence that the creation of sandbanks adjacent to dredged areas, increased diversity and fish biomass in the short-term, however, follow-up studies are needed (De Jong *et al.* 2014).

2.6. Changes in food web interactions

Coastal fish, especially piscivorous species, are important components of coastal food webs and affect ecosystem functioning (Eriksson *et al.* 2009; Baden *et al.* 2012; Olsson *et al.* 2012a; Östman *et al.* 2016; Olsson 2019). Large piscivores, such as perch, pike, and pikeperch, generally have a structuring role in the coastal ecosystem, mainly via top-down control on lower trophic levels (reviewed in Olsson 2019). The role of food-web processes such as internal dynamics

A cormorant colony along the Swedish Baltioc Sea coast. © Jens Olsson

and predation is, however, likely different between areas and communities (Vetemaa *et al.* 2010; Lehikoinen *et al.* 2011; Östman *et al.* 2012, 2016; Heikinheimo *et al.* 2016).

Coastal piscivorous fish populations are predated on by apex predators, foremost birds, such as cormorants, and seals (Veneranta *et al.* 2020). In some areas, the outtake of coastal fish by cormorants or seals exceeds, or is of a similar magnitude, to that of recreational or commercial fisheries (Vetemaa *et al.* 2010; Hansson *et al.* 2018; Berkström *et al.* 2021; Bergström *et al.* 2022b). Decreases in perch and pike abundance have been attributed to increases in cormorant populations in some areas (Vetemaa *et al.* 2010; Mustamäki *et al.* 2014; Veneranta *et al.* 2020; Bergström *et al.* 2022b), but other locations have found no relationship between coastal piscivorous fish abundance and cormorant colony size (Lehikoinen *et al.* 2017), suggesting that the effects are local. Ovegård *et al.*, (2021) concludes in a meta-analysis that percids and cyprinids are the most vulnerable to cormorant predation due to prey selection, so even local negative effects on one species should not be generalized to the broader local fish community.

Along the northern and western coast of the Baltic Sea, a small, abundant, mesopredator, the three-spine stickleback (*Gasterosteus aculeatus*, henceforth stickleback) is also responsible for substantial predation on coastal piscivorous fish, with negative effects from this predation observed along the Swedish coast (Byström *et al.* 2015; Olin *et al.* 2022). Stickleback migrate between the open sea and the coast where they spawn in the same bays used by coastal fish such as perch, pike and cyprinids. As adults, coastal predators feed heavily upon this small species, however, as juveniles, perch and pike are vulnerable to predation by sticklebacks (Donadi *et al.* 2017; Jakubavičiūtė *et al.* 2017; Jacobson *et al.* 2019; Nilsson *et al.* 2019). Sticklebacks can also consume perch and pike eggs, with field studies showing predation rates on pike eggs of up to 100% (Nilsson 2006). In recent years, predator fish populations along the central Swedish coast have been diminished to the point that they no longer exert sufficient top-down pressure to control stickleback populations, resulting in predator-prey reversals in which sticklebacks can suppress predator recruitment and bays previously dominated by perch and pike are now dominated by sticklebacks (Eriksson *et al.* 2011; Nilsson *et al.* 2019; Olin *et al.* 2022). These regime shifts are becoming more common and have been described as a "stickleback wave" in which bays closer and closer to the coast are becoming dominated by sticklebacks (Olin *et al.* 2022; Eklöf *et al.* 2023). It has been suggested that these patterns could be reversed locally by reducing fishing pressure or by restoring piscivore-spawning habitats, especially those with little connection to the sea, which sticklebacks have a harder time accessing (Eriksson *et al.* 2011; Donadi *et al.* 2020).

Similar to sticklebacks, populations of the invasive round goby have increased in recent years and show continuous northward range expansion (Puntila *et al.* 2018; Kruze *et al.* 2023). These gobies feed largely on bivalves and other benthic prey and show niche overlap with coastal species such as flatfish, ruffe, and large perch (Karlson *et al.* 2007; Rakauskas *et al.* 2013; Ustups *et al.* 2016; Herlevi *et al.* 2018). This resource competition is a proposed mechanism leading to local decreases in flatfish (Karlson *et al.* 2007; Ustups *et al.* 2016). A recent study has also shown that round gobies can prey on egg or larval stages of sticklebacks as well as important commercial species such as cod and herring, but the total impact on abundances is unknown (Wallin Kihlberg *et al.* 2023). Round gobies have also had positive effects on coastal species in some locations. There are local observations of round gobies creating new links in coastal foodwebs between molluscs and top predators (Almqvist *et al.* 2010) and increased consumption of round gobies has corresponded to increases in growth and condition of pikeperch (Hempel *et al.* 2016). Round gobies have also been incorporated into the diets of other predators such as cod, perch, and pike with the proportion of round gobies in the diet increasing as abundance increases and, in some cases, making up the majority of the diet (Rakauskas *et al.* 2013; Oesterwind *et al.* 2017; Herlevi *et al.* 2023).

2.7. Other important factors

Many other natural and human-induced pressures can also influence coastal fish. A non-exhaustive list of additional natural factors, acting more on the local scale, includes wind/wave exposure, the bathymetry and morphology of the coastal area, and interactions within the food web (other than those related to changes in the predation regime as discussed in section 2.6). These are part of the local abiotic settings of a coastal area that set the limits for the local abundance of coastal fish (HELCOM 2012; Bergström *et al.* 2016a; Naddafi *et al.* 2022).

The most widely studied consequences of human induced climate change, shifts in temperature and salinity, are discussed at length in the sections above but additional outcomes of climate change can also affect coastal fish. Some examples of these outcomes include shifts in the frequency and patterns of saltwater inflows, run-off from land, ice coverage, and shifts in overarching patterns of multi-annual and multidecadal weather patterns such as the North Atlantic Oscillation (Olsson *et al.* 2012a).

Other potential pressures related to human-activity include the pressures from marine transport (Sandström *et al.* 2005), the introduction of non-indigenous species (Kruze *et al.* 2023), and input of hazardous substances (Hanson *et al.* 2009; Bergek *et al.* 2012), and organic matter (humic substances).

2.8. Cumulative effects and long-term trends

The natural variability in temperature, salinity, trophic state, and bathymetry of the Baltic Sea set the initial boundaries that determine coastal fish community composition. On top of that, human-induced pressures and food web interactions interact with these conditions to structure the communities that we observe today. A few strong pressures often explain a large proportion of the variation in fish abundance and distribution, whilst the effects of others can only be observed locally or under certain conditions.

Decades of eutrophication have shifted coastal fish community composition in favour of cyprinids by altering resource availability, habitat quality, and visual conditions. Coastal fish abundance more generally though can suffer in areas where eutrophication has led to harmful algae or potentially cyanobacteria blooms. Increasing temperatures have also changed community composition during recent decades in favour of fish species benefitting from warmer waters, which show increased growth rates as temperatures increase and can outcompete cold-water species. Though temperature can increase fish growth in the short term, it is likely that higher temperatures will ultimately lead to smaller-sized fish, since it might increase mortality through increases in pace-of-life and vulnerability to predation and fishing. Lower resource availability in warmer waters can also contribute to decreasing fish size, and the lower reproductive output of smaller fish can decrease total fish abundance.

The impacts of habitat degradation are most visible on a local scale since many of the most abundant coastal species either have limited home ranges or return yearly to the same spawning grounds. However, if degradation is widespread, especially in habitats used by important life-history stages, the cumulative impacts on the abundance of certain species may be more widely viable.

Fishing intensity within the Baltic Sea also varies widely between areas, but it is occurring in the context of habitat degradation, eutrophication, and increasing temperatures, which have already altered community composition, population abundance, and average fish size. Fishing has been proven to have effects on the abundance of key coastal predatory fish in several areas. The impact of these decreases can be visible in the broader ecosystem often manifesting in the form of regime shifts, making restoration more difficult.

The recent shifts in food web structure in the Baltic Sea with sharp increases of mesopredatory fish as sticklebacks and apex predators as cormorants and seals have further impacted coastal fish species and communities. In all, there has been a chain of changes over time covering eutrophication, increased temperatures, deteriorated habitat conditions, fishing, and changes in food web structure and interactions in both the coastal and offshore Baltic that have had additive and cumulative effects on the structure and function of coastal fish communities.

To that end, the extent to which different pressures affect coastal fish varies substantially across coastal areas and among communities. The potential for generalizations across areas is limited and for each case, an individual evaluation should be performed. Furthermore, to address the extent of impacts from human activities on coastal fish populations, one must take a full set of potential human-induced pressures into initial account and assess them within the context of natural pressures and ambient environmental conditions of the specific area.

3. Status assessment

3.1. Monitoring of coastal fish in the Baltic Sea

To date, coastal fish monitoring is undertaken in some form by all countries around the Baltic Sea except Russia (HELCOM 2019), and regionally agreed upon indicator data are stored in a common database, COOL, hosted by the HELCOM secretariat (https://bio.helcom.fi/apex/f?p=108:5). The current assessment relies on time-series of indicator data (see below). Data from all countries except Germany was available for assessments at the time of production of this report. Although coastal fish monitoring in the Baltic Sea is coordinated by HELCOM, the exact methods used vary slightly between countries, due to different traditions in monitoring practice and varying ecological preconditions. Most countries carry out fisheries-independent monitoring programmes using passive gears, such as gill nets, fyke nets or trap nets (HELCOM 2019). Active gear types, for example, bottom trawls, are used in some areas to monitor demersal fish (HELCOM 2019). In Finland, fisheries-independent monitoring programs for coastal species are less developed and non-existant in Denmark. The status assessment for Finnish areas is therefore also based on data obtained from coastal commercial fisheries (HELCOM 2023b) and for Denmark the data is based on citizen science from recreational fishers (Støttrup *et al.* 2018). The indicators used in this assessment are developed in order to be generic and applicable in a similar way to data originating from all of the monitoring methods included in it (HELCOM 2023a).

Coastal fish monitoring during summer in Estonia. © Luari Saks

Monitoring of coastal fish is designed to primarily detect changes in the fish communities over time in relation to large-scale changes in the environment. For this reason, many of the monitoring areas are located in so-called reference areas, where the level of local human pressure is comparably low, i.e. with little to no physical development (or protection) or local sources of loading. However, fishing and small-scale boat traffic is typically allowed.

Figure 1. Map of coastal fish monitoring areas including delineation of the coastal zone (white areas) in the Baltic Sea. The areas denoted as "Assessed" are included in the latest status assessment of coastal fish as presented in Chapter 3 in this report and in HOLAS 3 (HELCOM 2023c). Areas denoted "Not assessed" are not included in the latest status assessment. In Finland data for status assessments are derived from commercial fisheries in the different ICES subdivisions (29, 30, 31 and 32, ie within the striped areas). In Germany there is no established coastal fish monitoring program, but pilot studies along the coast have been undertaken in recent years.

3.2. Methods for status assessment

The assessments presented in this report are based on the status of the three currently operational HELCOM core indicators for coastal fish (Box 1). The first indicator is *Abundance of coastal fish key species,* which describes the status of the key fish species perch (*Perca fluviatilis*), flounder (*Platichthys* spp.), pike (*Esox lucius*), pikeperch (*Sander lucioperca*), whitefish (*Coregonus maraena*), and/or eelpout (*Zoarces viviparus*), depending on the coastal area. The second indicator is *Abundance of coastal fish key functional groups*, which describes the state of important functional groups in the coastal fish communities, namely cyprinids or mesopredators. The third indicator is *Size structure of coastal fish*, which was assessed against a threshold for the key species perch, and evaluated using trends for pikeperch and flounder, using the new HELCOM indicator L90. L90 focuses on the size of fish at the relatively higher end of the observed size distribution, by looking at the proportion of fish in different length classes, and finding the fish length at the 90th percentile of the size distribution (Östman *et al.* 2023). The indicators estimate the relative abundance, biomass, or size distribution of key coastal fish species or species groups, derived from monitoring data and defined by each indicator, related to a site-specific threshold value or trend. The estimates are obtained from fishery-independent monitoring, citizen science and/or commercial catch statistics, as described further below. For more information on these indicators see below and (HELCOM 2023a; b; d).

Some general features of the assessment of coastal fish are of note:

- **First**, the indicators are evaluated in relation to conditions corresponding to sustainable use within prevailing environmental (climate and hydrography) conditions (European Commission 2008). For abundance indicators, time series data from the time period 2002-2015 (subject to availability) is evaluated as potential a reference period.
- **Second**, for abundance-based indicators, the approach for the assessments depends on the length of the time-series:
    - A threshold value (ASCETS approach) is used when the time-series covers more than 15 years (ten or more years potential reference period + five or more years assessment period (Figure 1a-c).
    - A trend-based approach is used when the time-series covers less than 15 years (Figure 1d-f).
- **Third**, for the size-based indicator:
    - The size structure is evaluated in relation to a threshold for good environ-

Box 1.
Indicators used

Coastal fish constitute important components of coastal foodwebs and reflect the ecological state of coastal ecosystems, because they are influenced by processes in different parts of the food-web, general environmental and hydrographical conditions, as well as anthropogenic pressures. Different aspects of this is reflected in the indicators *Abundance of coastal fish key species, Abundance of coastal fish key functional groups*, and *Size structure of coastal fish*.

Abundance of key coastal fish species is based on changes over time in typical key species of fish, such as perch (*Perca fluviatilis*), flounder (European flounder, *Platichthys flesus*, and Baltic flounder, *Platichthys solemdali*), pike (*Esox lucius*), pikeperch (*Sander lucioperca*), whitefish (*Coregonus maraena*) and eelpout (*Zoarces viviparous*), depending on the location, coastal area and sub-basin. Perch, pike, pikeperch, and whitefish are generally the key species in coastal fish communities in the less saline eastern and northern Baltic Sea (Sweden, Finland, Estonia, and Latvia), and in more sheltered coastal areas in Lithuania, Poland and Germany. In the more exposed coastal parts of the central Baltic Sea and in its western parts, the abundance of perch is generally lower and flounder and eelpout are used as key species. Perch and flounder are considered in most assessment units, but where data is available pike, pikeperch, whitefish, and eelpout are used as complementary species in the evaluation. Good status is achieved when the abundance is above a set site- and species-specific threshold value. Viable populations of key coastal fish species are generally considered to reflect an environmental status with few eutrophication symptoms and balanced food webs (Eriksson et al. 2009; Baden et al. 2012; Östman et al. 2016; Eklöf et al. 2020). Key coastal fish species are generally piscivores and/or benthivores species.

Abundance of coastal fish key functional groups evaluates the abundance of selected functional groups of coastal fish in the Baltic Sea. The functional groups used in this indicator are members of the cyprinid family. In areas where cyprinids do not exist naturally, mesopredatory fish species are used, i.e. any mid-trophic level species that are not piscivorous. The composition of cyprinid and mesopredator species differ along the coast. The most abundant species in the Cyprinid family (Cyprinidae) in the less saline eastern and northern parts of the Baltic Sea are for example roach (Rutilus rutilus) and bream (Abramis sp.), whereas mesopredatory fish such as wrasses (*Labridae*), sticklebacks (*Gasterosteidae*), flatfishes, clupeids and gobies (*Gobiidae*) are representative of the more exposed coastal parts of the central Baltic Sea and in its more saline western region. Good status is achieved when the abundance of cyprinids or mesopredators is within an acceptable range for the specific site. High abundances of cyprinids and mesopredatory fish are generally indicative of poorer environmental conditions in the coastal ecosystem and might reflect lack of top-down regulation, elevated eutrophication and increased water temperatures (Eriksson et al. 2009b; Baden et al. 2012; Bergström et al. 2016c, 2019; Östman et al. 2016)

Size structure of coastal fish evaluates the size distribution of typical key species of fish, such as perch, flounder, and pikeperch in the coastal areas of the Baltic Sea, to assess environmental status. As a rule, good status is achieved when the size of large fish (size at L90) is above a set gear- and species-specific threshold value. Large piscivores such as perch and pikeperch, are targeted by both the small-scale coastal commercial fishery as well as by recreational fishing (Olsson et al. 2015; Bergström et al. 2016a; c). Thus, the size distribution of a population gives an indication both regarding the fishing pressure in the area as well as the state of the coastal ecosystem.

mental status for perch.
- For pikeperch and flounder, the size structure is assessed with a trend-based approach.

For abundance-based indicators, threshold values for the status assessments are identified based on site-specific time-series data for each indicator. Site-specific values are used, because coastal fish generally have local population structures, limited migration, and show local responses to environmental change (see references in previous sections of the report). Furthermore, as the data supporting the indicators are derived from different types of monitoring programs, catch registration and data collection, the threshold values are not comparable across monitoring areas and data sources.

3.2.1 Threshold values

Abundance-based indicators

For **key species**, good status is achieved when the indicator of abundance or size distribution is above a specified threshold value. For **functional groups**, good status is achieved when the abundance is within a specific range of indicator values.

The quantitative threshold values for the *abundance-based indicators* of coastal fish are based on location-specific reference conditions where time series covering more than 15 years are available (ten or more years potential reference period + five or more years assessment period). In areas where shorter time series are available (<15 years), a trend-based approach is used. The specific approach used in the various monitoring locations is presented in the Results section.

A reference period needs to be defined for determining the threshold value. The period used to define the reference period needs to cover at least ten years in order to extend over more than twice the generation time of the typical species represented in the indicator and thus cater for natural variation in the indicator value, due for example to strong and weak year classes. For the period used to determine the reference to be relevant, it must also be carefully selected to reflect time periods with stationary environmental conditions, as stated within the MSFD (European Commission 2008). Substantial turnovers in ecosystem structure in the Baltic Sea were apparent in the late 1980s, leading to shifts in the baseline state (Möllmann *et al.* 2009), and for coastal fish communities, substantial shifts in community structure have been demonstrated in the late 1980s and early/mid 1990s (Olsson *et al.* 2012a; Bergström *et al.* 2016b). In some areas, there have also been minor shifts in fish community structure later. To account for this, the ASCETS method (Östman *et al.* 2020) is applied on time-series with more than 15 years of data. This method offers a refined approach to infer structural changes in indicator values over time and establish threshold values for the state during a reference period based on the observed variation in indicator values.

The assessment period applied when using the ASCETS methods should cover at least five years to cater for natural variability. Status is evaluated based on the deviation of the median value of the indicator during the assessment period in relation to the threshold value of the reference period (Figure 2a-c). When using the trend-based approach, environmental status is evaluated based on the direction and statistical significance of the linear trend towards good status, over the time period 2014-2020 (Figure 2d-f).

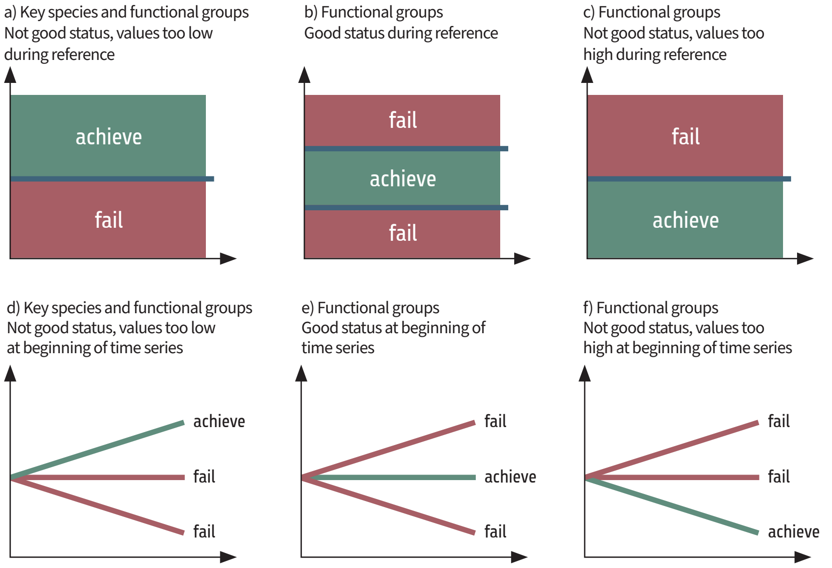


Figure 2. Threshold value (a–c) and trend-based (d–f) approaches to determine environmental status of the indicators Abundance of coastal fish key species and Abundance of coastal fish key functional groups. Figure headings denote which indicator(s) each figure pertains to and how the current status is determined in relation to the status during the reference period (a–c) or at the beginning of the time series (d–f). The threshold value approach is applied when the reference period spans a minimum of 10 years. The trend-based approach is used when the baseline approach cannot be applied, and it defines the status based on the direction of the trend of the indicator compared to the desired direction of the indicator over time.

Size-based indicator

For the *size-based indicator*, gear-specific threshold values for good status are implemented for perch. The thresholds were arrived at by analysing data on perch size distributions from 33 monitoring locations throughout the Baltic Sea coasts, using time series data of varying length from each location, ending at the year 2020 and with the longest time series starting in 1978 (Bolund in prep). The data was composed of annual survey data from Sweden, Estonia, Latvia, Lithuania, and Poland, and a combination of annual monitoring data and commercially collected data from Finland that fulfilled minimum data criteria (namely, a minimum of 50 measured individuals per year per location, and a minimum of six years of data from each location). Before calculating L90, a lower cut-off of 15 cm is applied to lower the influence of yearly fluctuations in recruitment. After accounting for the effects of gears, seasons, regions, and time on L90 in a linear mixed-effects model framework, implemented in R (R Core Team 2021), the mean L90 value was set as the threshold (Bolund in prep). There was relatively low amount of variation in L90 across regions and seasons, and also over time, but significant differences in the size distribution due to gears used necessitated gear-specific thresholds of 23 cm for net series and 25 cm for Nordic multimesh nets and fyke nets. The data used to map size structure of perch likely reflects a situation where the populations are not overfished (i.e. we see no strong negative trends over time), but still exploited at a level that the size structure is impacted (i.e. L90 is higher in no-take areas and MPAs; (Östman *et al.* 2023).

It is challenging to set a regional threshold value for L90 in flounder. This is because of substantial differences in L90 among regions, gears, seasons and ecotypes, and often there is a combination of these factors in different areas (Bolund in prep). Therefore, trends over time in L90 for flounder are addressed in the different monitoring areas. For pikeperch, data from commercial fisheries in Finland provide sample sizes that allow estimation of L90 and assessment of trends over time. The commercial data on pikeperch may allow the development of threshold values in future (Lappalainen *et al.* 2016).

3.2.2 Assessment protocol

Abundance/biomass-based indicators

ASCETS method

Coastal fish datasets must meet certain criteria in order to be able to apply an evaluation of status using the ASCETS method:

- The time period used to determine the reference period should cover a minimum number of years that is twice the generation time of the species most influential in the indicator assessment. This is to ensure that the influences of strong year classes are taken into account. For coastal fish, this is typically about ten years. In this evaluation, the time period used to determine the reference period against which good status is evaluated spans the years 1998-2015, with varying numbers of years depending on data availability for each time series.
- Before evaluating status, it should be decided whether the reference period reflects good status or not. If a previous status evaluation exists from HOLAS II, the reference period is assigned the same status as the assessment period in HOLAS II (2011-2016). When a previous status evaluation does not exist, this can be done by using historical data predating the start of the reference period, using additional information, or by expert judgment. For example, if available data from years preceding the current reference period have much higher indicator values, as determined by expert judgement, the reference might represent not good status (in case of an indicator where higher values are indicative of a good environmental state) or good status (in case of an indicator where higher values are indicative of an undesirable state).

The ASCETS method (Östman *et al.* 2020) offers a refined approach to infer structural changes in indicator values over time and establish threshold values for the state during a reference period based on the observed variation in indicator values. ASCETS also gives estimates on the confidence of an apparent change in state of indicator values between a reference period and an assessment period. Thus, by applying ASCETS to time series data, it is possible to derive threshold values for addressing structural changes in indicator values over time and to evaluate the confidence of the derived current indicator state relative to previous indicator values. To determine the status of the indicator, the ASCETS method first derives a bootstrapped distribution of median values from a time series of observed indicator values during a reference period. Specific threshold values for changes in indicator state is set based on the Xth and XXth percentile values of the bootstrapped distribution. The percentiles are 5 and 98 percent for key species and 5 and 95/98 percent (depending on the status of the reference period, see below) for functional groups. In both cases, the percentiles represent the confidence interval of median indicator values during the reference period. In this way, the derived boundaries of the confidence interval can function as threshold values for a change in state per assessment unit of each species/functional group. Because ASCETS bootstraps median indicator values during the reference period it is possible that one or several observed indicator values during the reference period will fall outside of the confidence interval, because the bootstrapping reduces the influence of what may be large sampling errors. Second, the bootstrapped median indicator value during the assessment period is evaluated in relation to the threshold values derived from the reference period depending on how much of the bootstrapped median distribution from the assessment period falls below, within, or above the Xth and XXth percentiles (see Figure 3).

For key species, this evaluation is done as follows:

— In situations where the reference conditions represent good status, the median of the years in the assessment period should be above the 5th percentile of the median distribution of the dataset used to determine the reference in order to reflect good status.
— In situations where the reference conditions represent not good status, the median of the years in the assessment period should be above the 98th percentile of the median distribution of the dataset used to determine the reference in order to reflect good status.

For functional groups, the evaluation proceeds as follows:

— In situations where the reference state reflects good status, the median of the years in the assessment period should be above the 5th percentile and below the 95th percentile to reflect good status.
— In situations where the reference state reflects not good status, in order to reflect good status, the median of the years in the assessment period should be above the 98th percentile if the reference status is indicative of too low abundances, and below the 5th percentile if the reference status is indicative of too high abundances.

Trend-based method

If the requirements for defining quantitative baseline conditions are not met (e.g. short time series), then a trend-based evaluation should be used. All available data starting from year 2014 is included in trend analyses.

In the trend-based approach, good status is defined based on the direction and significance of the trend of the indicator compared to the desired direction of the indicator over time (Figure 2d-f and 3).

For key species, this means that:

When the first years of the time series evaluated represent good status, the trend of the indicator over time should not be negative in order to represent good status. If the first years of the time series evaluated represent not good status, the trend in the indicator should be positive in order to represent good status. The level of significance for these trends should be p < 0.1.

For functional groups, this means that:

Where the first years in the evaluated time series represent good status, the trend of the indicator over time should not exhibit any direction in order to reflect good status. If, on the other hand, the first years of the evaluated time series represent not good status, the trend should be in the desired direction to reflect good status. The significance level for these trends should be p <0.1.

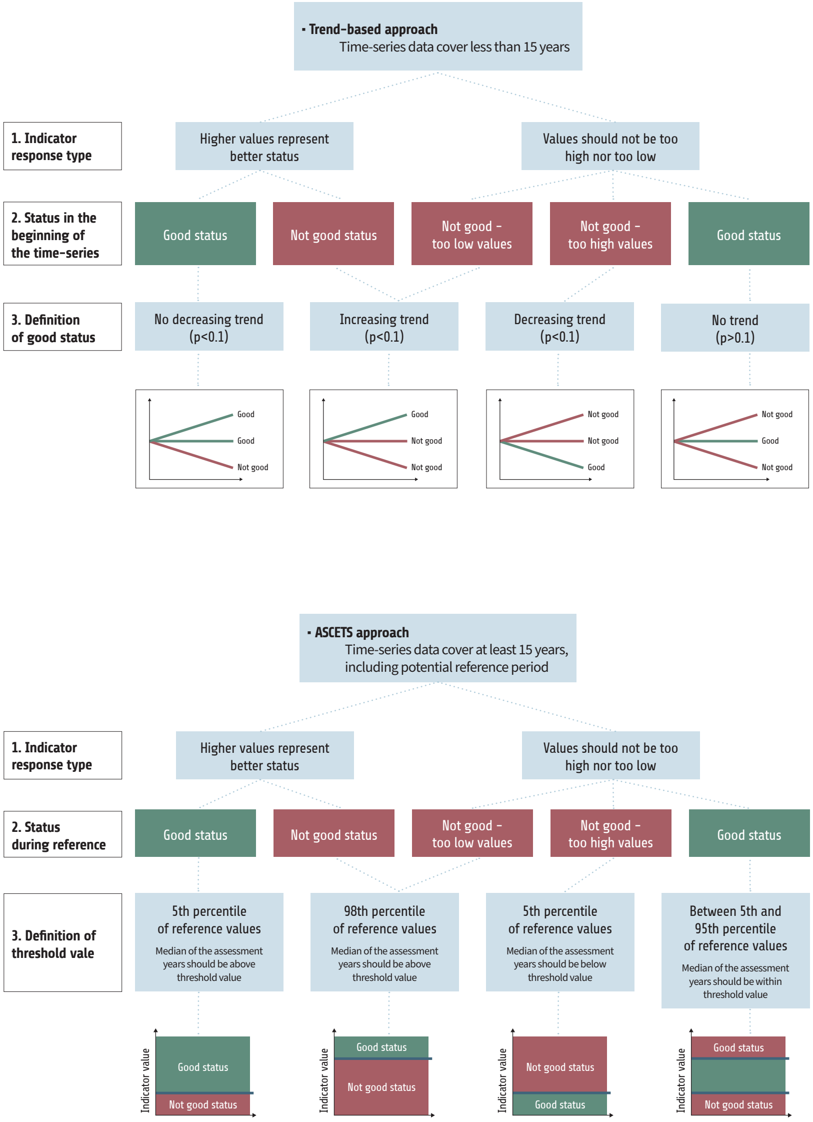


Figure 3. Decision tree for assessment of abundance-based indicator status. The ASCETS approach (top figure) and trend-based approach (bottom figure) are presented.

Size-based indicators

To assess environmental status of the size structure of perch, the median value of L90 during the assessment period was assessed in relation to the gear-specific threshold (analogous to figure 1a), and confidence in the status was determined by the number of years that fell above/below the threshold

Changes in L90 over time in flounder and pikeperch were assessed according to a trend-based approach, with a linear regression for year 2014-2020 and the significance threshold set to $p<0.1$ (Analogous to Figure 2d).

3.2.3 Assessment units and aggregation

Due to the local appearance of typical coastal fish populations, status assessments of coastal fish communities are representative for rather small geographical scales. In this evaluation the HELCOM assessment unit scale 3 'Open sub-basin and coastal waters' has been applied. The indicator is not evaluated for the open sea sub-basins since the species in focus are coastal.

For the integration of status across species and monitoring locations within assessment units, the One-Out-All-Out principle is applied (Dierschke *et al.* 2021).

The assessment units are defined in the Annex 4 of the HELCOM Monitoring and Assessment Strategy .

3.2.4 Data used in the assessment

The evaluations are based on data from fishery independent monitoring, citizen science and/or commercial fisheries catch statistics. For detailed information on the data and areas included in the assessment, see Appendix 1 results Table 1, 5 and 9.

Fishery independent monitoring

The evaluations are based on catch per unit effort (CPUE) data from annual averages of all sampling stations in each area. Individuals smaller than 12 cm (Nordic Coastal multimesh nets) or 14 cm (other net types) were excluded from the evaluation in order to only include species and size-groups suited for quantitative sampling by the method. Abundance is calculated as the number of individuals of the species included in the indicator per unit effort (CPUE).

Commercial catch data

Analyses were based on CPUE data in the form of kg/gillnet day, and each data point represents total annual CPUE per area. The gillnets used have mesh sizes between 36-60 mm (bar length) and hence target a somewhat different aspect of the fish community in the area, compared to the fisheries independent monitoring data. In addition, fishing is not performed at fixed stations nor with a constant effort across years. As a result, the estimates from the gillnet monitoring programmes and commercial catch data are not directly comparable, and only relative changes across data sources should be compared.

Citizen science

As for the other surveys, analyses were based on CPUE data (number of fish per effort) from monofilament gill nets or fyke nets. Voluntary recreational fishermen undertake fishing during the period April to November. For comparability only data from August was used in the current evaluation. The fishermen fish at fixed stations and during the first half of each month throughout the season. This mediates the comparability of the data with fisheries independent monitoring programs using gill nets or fyke nets.

3.3. Assessment results

3.3.1 Summary of status

The evaluation of coastal fish using core indicators shows that six out of twenty-two assessed coastal units achieved good status with regards to the indicator *Abundance of coastal fish key species*, and four out of fourteen assessed units with regards to the *Abundance of coastal fish key functional groups* (Figure 4, Appendix 1 results Table 2 and 6). Regarding *size structure of coastal fish*, four out of fifteen assessed units achieved good status (Figure 4, Appendix 1 results Table 10). Size structure was assessed for the key species perch using the new HELCOM indicator L90, which focuses on the size of fish at the relatively higher end of the observed size distribution, by looking at the proportion of fish in different length classes and finding the fish length at the 90th percentile of the size distribution (HELCOM 2023d).

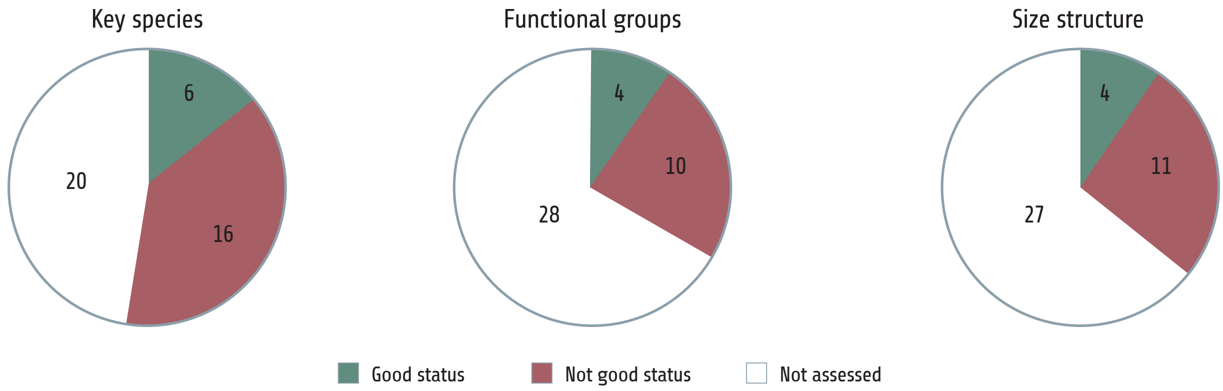


Figure 4. The status for coastal fish was assessed using three core indicators: Abundance of key coastal fish species, Abundance of coastal fish key functional groups, and Size structure of coastal fish. Pie charts indicate the shares of all relevant spatial assessment units, 42 in total, achieving good status (green), not good status (red) or which were not assessed due to lack of data (white). Numbers give the number of assessment units within each category. See also Core indicator reports: (HELCOM 2023a; b; d).

In all, the spatial coverage of the evaluation of coastal fish has expanded compared to the previous assessment in 2018 with data until 2016, as more monitoring locations and assessment units were included this time. In addition, more species have been included under the indicator Abundance of key coastal fish species and the new HELCOM indicator Size structure of coastal fish has been developed. Still, only 22 of in total 42 coastal assessment units were evaluated, and the indicator Abundance of key species was the only indicator that was evaluated in all 22 assessed units (Figure 4). Quantitative threshold values are lacking for all species included in the indicator Size structure of coastal fish, except perch.

The HELCOM indicator Abundance of key coastal fish species was evaluated based on data on the key species perch, flounder, pike, pikeperch, whitefish, and/or eelpout, depending on the coastal area. When combining the evaluation results across species and monitoring locations, using the One-Out-All-Out principle, the indicator achieved good status in six out of 22 assessment units (Bothnian Bay Finnish and Swedish coastal waters, Bothnian Sea Finnish coastal waters, and the coastal waters of Estonia, and Latvia; Figure 5, Appendix 1 results Table 2). Looking at results for different species and monitoring locations (HELCOM 2023b) and Figure 6), this reflects an overall good status for perch in 24 of 31 monitoring locations, and for flounder in eight of 26 locations. The other species were assessed at relatively fewer locations. For these, two of seven locations achieved good status for pike, six of nine for pikeperch, five of 11 for whitefish, and 10 of 14 for eelpout (Figure 6). In comparison to the previous assessment (HELCOM 2018b), the results indicate a deteriorating state. Only six out of 22 HELCOM assessment units achieved good status for the indicator Abundance of key coastal fish species in the current assessment, compared to 13 out of 21 assessment units in HOLAS II (Appendix 1 results Table 4). The decreased overall status partly reflects the inclusion of additional key species in the current assessment, namely pike, pikeperch, whitefish, and eelpout. Also, a stricter integration approach across monitoring locations was used this time (OOAO, while the majority rule was used in HOLAS II). Pike and whitefish did not achieve good status in most of the monitoring locations. For perch and flounder, which are more comparable between assessment periods, differences between this and the previous assessment are rather small.

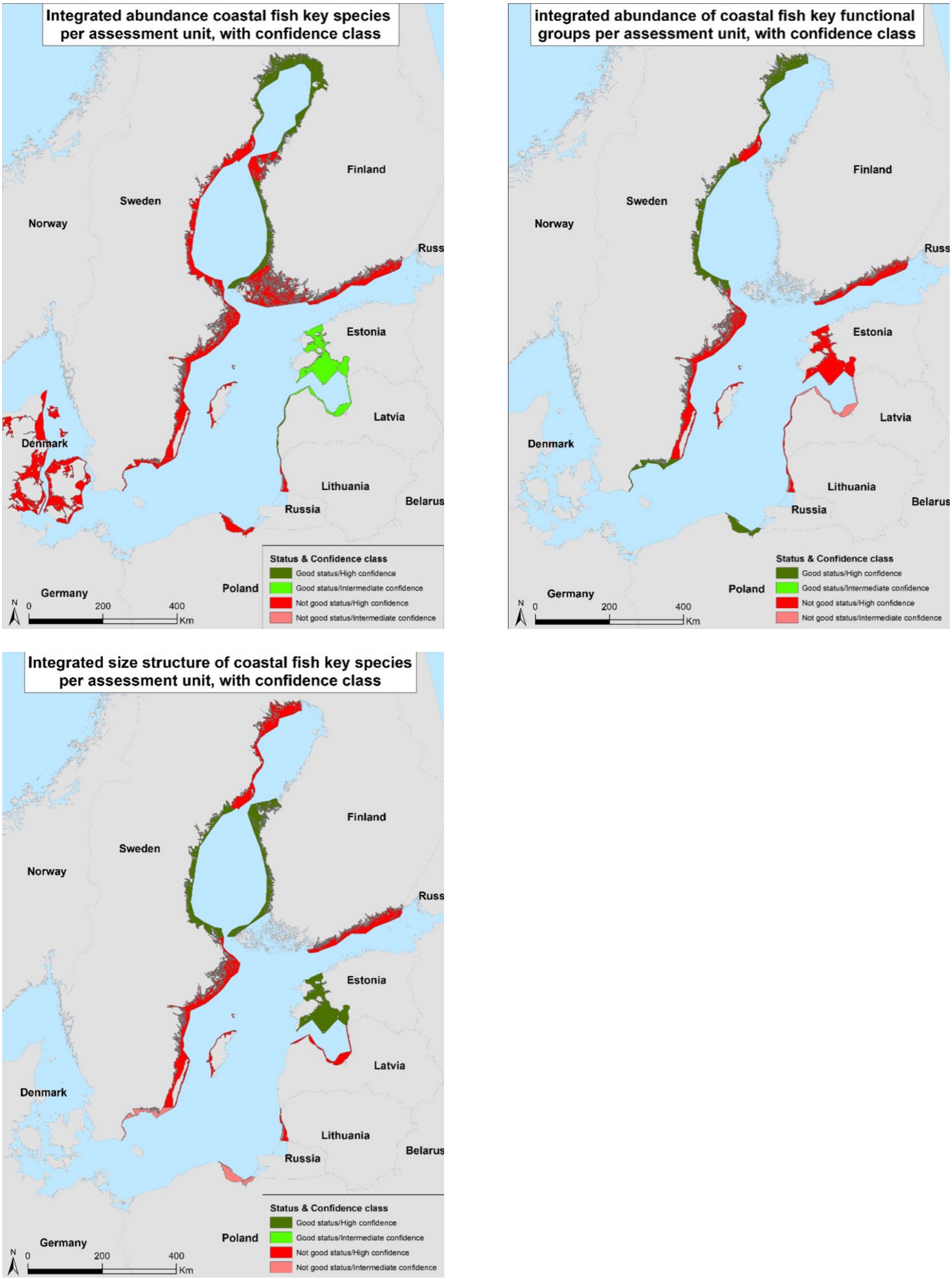


Figure 5. Aggregated status for the three indicators abundance coastal fish key species (a), abundance coastal fish functional groups (b), and size structure coastal fish key species perch (c) per assessment unit. Status is determined based on the one-out-all-out-approach in cases where assessment results from more than one indicator and/or monitoring area are available. Confidence in the assessment is shown in two classes (high and intermediate, no assessment unit had low confidence in the assessment).

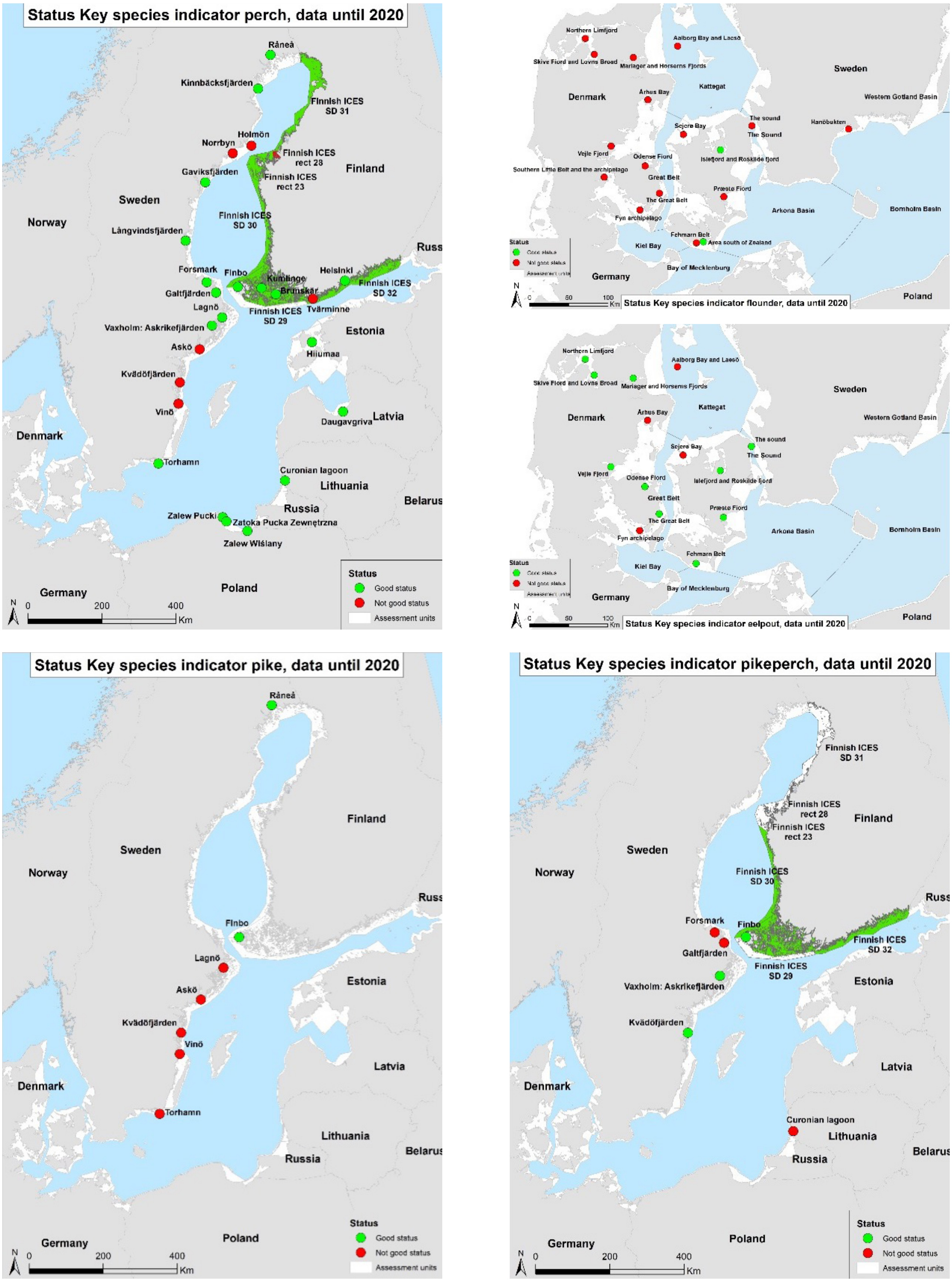


Figure 6. Status of coastal fish during 2016–2020 for the *Abundance of key coastal fish species*. Figures show the status per monitoring area and species (perch, flounder and eelpout in Danish waters, pike, pikeperch, whitefish, and flounder.

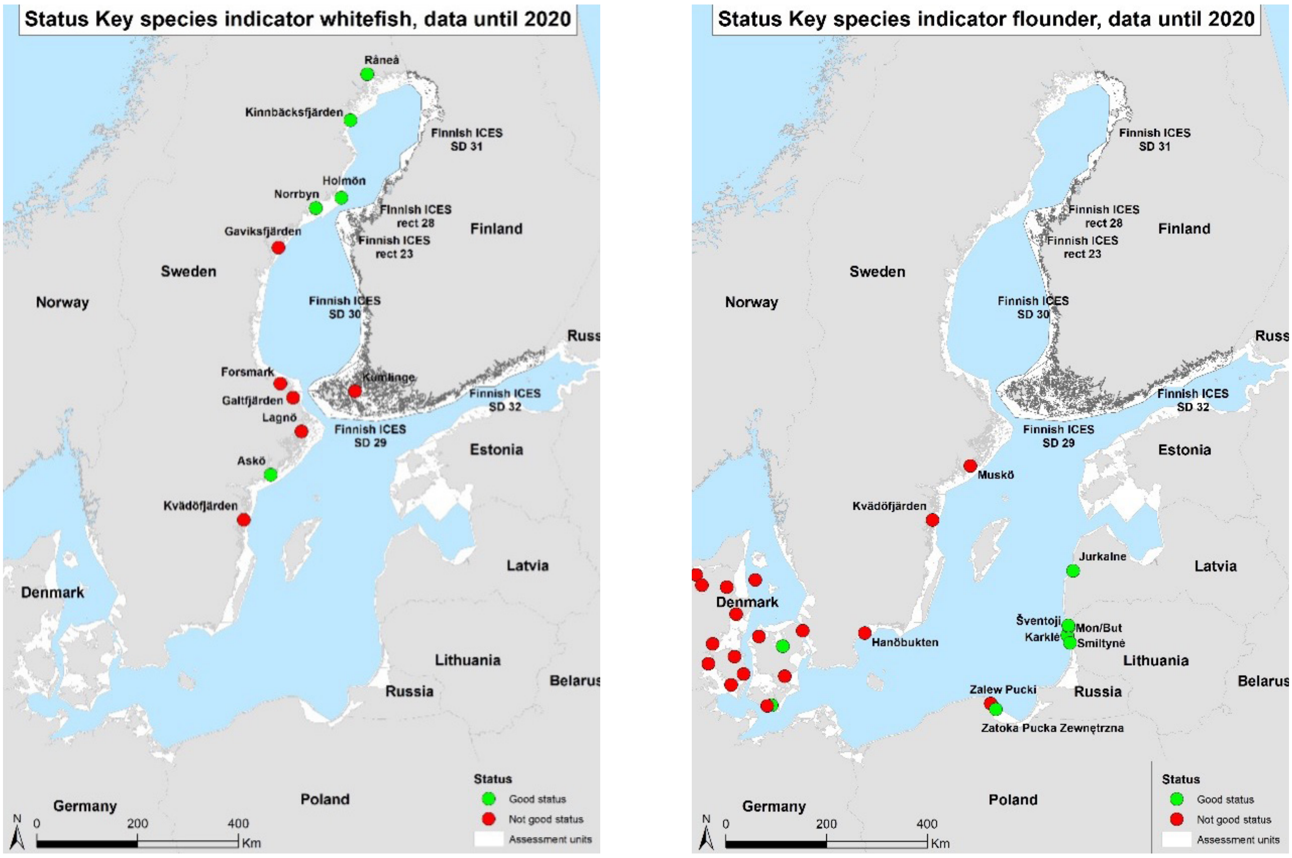


Figure 6. (Continued). Status of coastal fish during 2016–2020 for the *Abundance of key coastal fish species*. Figures show the status per monitoring area and species (perch, flounder and eelpout in Danish waters, pike, pikeperch, whitefish, and flounder.

The HELCOM indicator *Size structure of coastal fish* was only evaluated for the key species perch due to lack of quantitative threshold values for other species. Integration of monitoring results to the level of the spatial assessment unit showed that only four out of 15 assessed units achieved good status (The Quark Finnish coastal water, Bothnian Sea Finnish and Swedish coastal waters, and Gulf of Riga Estonian coastal waters; HELCOM 2023d and Figure 4 and 5, Appendix 1 results Table 10). In all, 28 monitoring locations were included, and half of these met the threshold value for good status (see HELCOM 2023d and Figure 7). The indicator was used for the first time in the current assessment.

The HELCOM indicator *Abundance of coastal fish key functional groups* was evaluated based on data on the groups of cyprinids and/or mesopredators, depending on the coastal area. The spatial coverage for this indicator was lower compared to that of the key species indicator. When combining the evaluation results across groups and locations, only four out of 14 assessment units fell between the upper and lower threshold values (Figure 4 and 5, Appendix 1 results Table 6). The indicator has both upper and lower threshold values because both very high and very low abundances of cyprinids and mesopredators may characterize an undesirable environmental state.

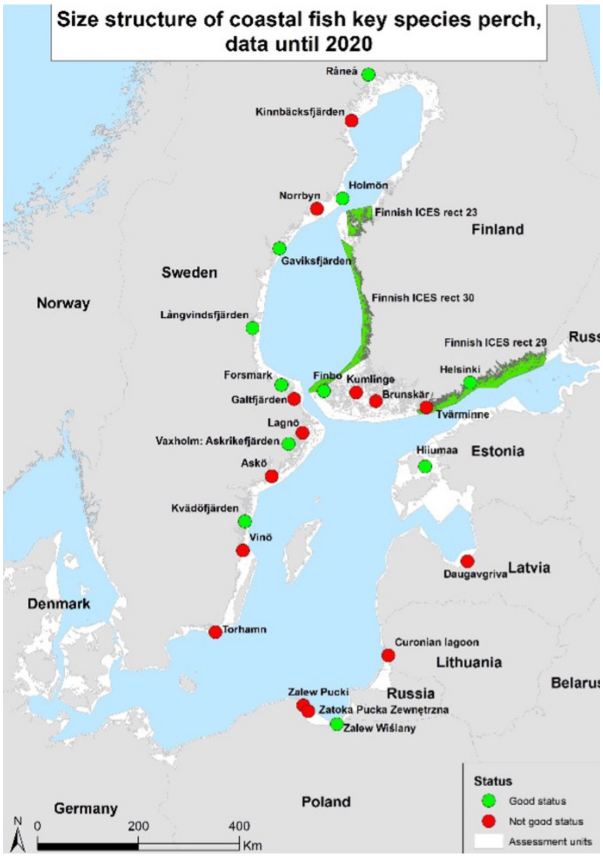


Figure 7. Status of coastal fish during 2016–2020 for the *Size structure of coastal fish* (perch) per monitoring area.

In cases when good status was not achieved, this was generally due to too high abundances. Good status was achieved in the Swedish coastal waters of the Bothnian Bay, Bothnian Sea, and Bornholm basin, and in the Polish coastal waters of the Gdansk basin. Looking at results for different monitoring locations, good status was achieved in 20 out of 32 monitoring locations (see (HELCOM 2023a) and Figure 8). In comparison to the previous assessment (HELCOM 2018b), there was a tendency for a slight decrease in the status of this indicator when considering cyprinids and mesopredators (Appendix 1 results Table 8). In three of the assessment units also considered in the previous assessment, the status has decreased, and in the remaining 10 assessment units there was no change in status. The differences partly reflect the inclusion of additional areas and functional groups (mesopredators) in some assessment units and areas, and the use of a stricter integrating approach across monitoring locations (majority rule was used in HOLAS II and the One-Out-All-Out principle in the current assessment).

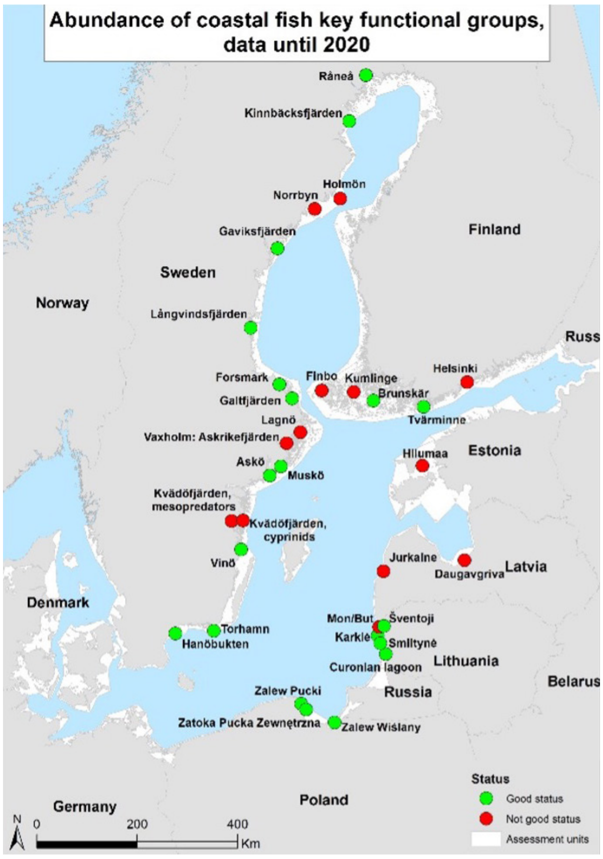


Figure 8. Status of coastal fish during 2016–2020 for the *Abundance of coastal fish key functional groups* (cyprinids and/or mesopredators) per monitoring area.

3.3.2 Confidence in the assessment

The confidence scoring followed the principles as outlined in the HELCOM integrated biodiversity assessment. Confidence was scored using four criteria with three different levels (1= high, 0.5 = intermediate, and 0 = low). The criteria used were:

Confidence in the accuracy of the estimate (ConfA).

- In the ASCETS approach, confidence of the status assessment for each location is determined by the C(S) value. C(S) varies between 0 and 1, with values <0.1 representing high confidence of changed status (in both directions) and values >0.9 high confidence of unchanged status (Level 1). Values of 0.1-0.3 represent medium confidence in changed status and 0.7-0.9 medium confidence in unchanged status (Level 0.5). Values of 0.3-0.5 represent low confidence of changed status and 0.5-0.7 low confidence in unchanged status (Level 0).
- In the trend-based approach, confidence in the evaluation is determined by the p-value of the linear regression, with p-values <0.05 representing high confidence in a trend (Level 1), 0.05<p<0.1 medium confidence in a trend (Level 0.5), p 0.10-0.20 low confidence in no trend (Level 0), p 0.21-0.49 medium confidence in no trend (Level 0.5), and p 0.5-1.0 high confidence in no trend (Level 1).
- For the size-based indicator, Confidence in the assessment is determined by the number of years during the assessment period that falls above or below the median. If all values fall either below or above the median, the confidence is high. If all values except one fall above/below the median, the confidence is medium, and if all values except two fall above/below, the confidence is low.

Confidence in the temporal coverage of assessment (ConfT). Level 1 = data for all years during 2016-2020, 0.5 = one or two years of data missing during 2016-2020, and 0 = three or more years of data missing during 2016-2020.

Confidence in spatial representability of the assessment (ConfS). Level = 1 full coverage/several monitoring locations per assessment unit given its size, 0.5 = two or more monitoring locations per assessment unit but insufficient numbers given its size, and 0 = one monitoring location per assessment unit.

Methodological confidence (ConfM). For coastal fish all assessment units reach level 1 since all monitoring programs included in the assessment are described in the coastal fish monitoring guidelines .

In general, the confidence varies across assessment units, countries and monitoring programmes since, for example, the number of years for which coastal fish monitoring has been carried out varies between locations, as does the spatial coverage of monitoring within assessment units, and thus the confidence in the actual evaluation. Generally, the confidence of the evaluation is higher in locations where monitoring started before 1999 and where data is available for all the years during the assessment period (2016-2020, high ConfT), where there is good spatial coverage of monitoring (high ConfS), and where the monitoring is fisheries independent and targeting the focal species of the evaluation. To note is that this confidence concept as developed for the purposes of the integrated biodiversity assessment is not fully applicable to coastal fish as further assessment of the precision in data and the congruence in status across monitoring locations within assessment units would provide additional needed information.

Considered across the three indicators, the methodological confidence (ConfM) is **high** in all monitoring locations. The confidence in the temporal coverage (ConfT) is **high** in all assessed units except for in six, where the individual monitoring locations have data missing for one or more years (in Finland, Denmark, Poland and Sweden). The confidence in spatial representability (ConfS) is **high** along the Lithuanian and Polish coasts, but **low** along the southern Swedish coast (Arkona basin) and in Latvian and Estonian coastal waters. In all other areas, ConfS is scored as being **intermediate**. The confidence in the accuracy of the evaluation (confA) varies between the three indicators and ranges from **low** to **high**. The integrated confidence considering all four categories varies between high and intermediate depending on assessment unit (See Figure 5 and Appendix 1 results Table 3, 7, 11).

4. Measures for coastal fish

A multitude of factors can potentially impact coastal fish community development and status, and in addition most coastal fish species have rather local population structures and are thus likely to show local responses to changes in the environment (Chapter 2). Therefore, it is generally not possible to identify a single generic measure to restore and support coastal fish communities in the Baltic Sea. Rather, the recommended plan of action will likely differ between areas, and should be developed while accounting for the specific environmental setting (including food-web structure and function), current anthropogenic pressures, and structure of the fish community in focus.

In general, there are two main non-mutually exclusive routes to improve the status of a population of a key species: to reduce mortality and to increase production. The reviewed measures as presented in this chapter are therefore subdivided into those primarily aiming to reduce *the mortality* of the population, and those primarily aiming to support *its recruitment or growth*. To achieve these two aims, measures can target individual species or species assemblages, or take a broader approach and target a whole food-web or ecosystem. For example, in an ecosystem-based approach to management, multiple goals should be targeted where the management action may aim to increase both the productivity of key species in the ecosystem, as well as more general aims that indirectly will support the productivity of individual species, such as increasing the resilience of the ecosystem to disturbances, as well as to balance the food-web in the ecosystem. Therefore, measures that target the whole food-web or ecosystem are also, briefly discussed in this chapter.

Table 3 lists potential measures to restore and protect coastal fish communities in the Baltic Sea, provide their links to pressures, and the scientific support for their effectiveness. Based on this summary, the measures that are potentially suitable for restoring or protecting coastal fish communities are presented in detail in the text. The focus of this detailed presentation is on measures that have been scientifically validated and have shown positive effects within current management structures in the Baltic Sea. However, also factors that are difficult to manage within a short time-frame (like climate change and eutrophication), or that constitute natural parts of the ecosystem (such as natural predation) are also important regulators of coastal fish community development and status (Chapter 2). Such factors should, even if there may be little scientific support for effective management actions, nevertheless be considered when restoring and supporting coastal fish communities.

Table 3. Table of potential measures for coastal fish in the Baltic Sea organized by the major aim of the measure (reducing mortality or supporting productivity). The table shows the name of the measure, the pressures that the measure is targeting and whether there is scientific support for the effectiveness of the measure in the Baltic Sea. The scientific support is described in detail in Ch. 4.1–4.2.

Aim of measure	Measure name	Link to major pressures	Scientific support for effectiveness for fish in the Baltic Sea
Reducing mortality			
	Permanent fisheries closures; no-take areas	Fishing	Yes
	Partial fisheries closures	Fishing	Limited
	Regulation of fishing gears and catch	Fishing	Partly
	Reduction of natural predators	Natural mortality	Lacking
Supporting productivity			
	Habitat protection	Coastal development	Yes
	Habitat restoration	Coastal development, eutrophication	Partly
	Nutrient reduction	Eutrophication	Mixed
	Reduction of harmful substances	Harmful substances	Partly
	Biomanipulation	Fishing, eutrophication	Lacking
	Stocking of young fish	Fishing	Lacking

4.1. Measures reducing mortality

Two major sources of mortality for fish in the Baltic Sea are mortality as a result of fishing, and natural mortality from diseases, starvation, and predation from other fish and apex or top predators such as birds and mammals. One measure to regulate mortality induced by fishing is to set allowable catches. However, key coastal fish species in the Baltic Sea, like perch, pikeperch, pike, whitefish and cyprinid species, are mainly targeted by fisheries that are for various reasons not often regulated by allowable catches. Thus, other options for measures need to be considered. The majority of fishing methods, both those targeting coastal as well as those targeting offshore fish communities and stocks, target large individuals and species at the top of the food-web, hence leading to changes in the fish size- and age distribution and fish community function (Pauly *et al.* 1998; Olsson *et al.* 2015; Bergström *et al.* 2016a; Griffiths *et al.* 2024).

In this report, measures that regulate fishing mortality are mainly evaluated with respect to the effects on the coastal fish community as described by the indicators *Coastal fish key species* and *Coastal fish size*. The species in the indicator *Coastal fish functional groups* (cyprinids and mesopredators) are much less affected by fishing, with only limited small-scale fishing targeting mainly cyprinids locally in Sweden and Finland (Lappalainen *et al.* 2019; Dahlin *et al.* 2021), and to some extent in the Baltic States and Polish coasts. An indirect effect on lower trophic level fish such as cyprinids and mesopredators from fisheries regulations focusing on piscivorous fish is, however, likely as a result of cascading effects in the food-web (Eriksson *et al.* 2011; Casini *et al.* 2012). In particular, a decreased predation pressure from declining stocks of piscivorous fish species might favour the increase in abundance of mesopredatory fish species (Östman *et al.* 2016) and can lead to further negative effects on the ecosystem due to trophic cascades (Donadi *et al.* 2017; Eklöf *et al.* 2020).

Measures that aim at regulating fishing mortality and that have scientifically documented effectiveness for coastal fish in the Baltic Sea include permanent fisheries closures, partial fisheries closures, as well as gear and catch regulations. These measures are described in detail in the paragraphs below, both with respect to the expected effects of the measure, as well as evidence from the Baltic and other geographical regions for the effectiveness of the measure. Importantly, fisheries closures are in some cases pertaining only to commercial fisheries, with the assumption that recreational fisheries will have a negligible impact on fish population recovery rates. This assumption was tested in a recent study in inland waters in Lithuania, which showed that recreational angling slowed the recovery rates of predatory species (e.g. pikeperch and perch) while species that are rarely caught by anglers (e.g. roach) showed rapid recovery after a complete commercial fishing ban in 2013 (Dainys *et al.* 2022).

4.1.1 Permanent fisheries closures (no-take areas)

No-take marine reserves, where no harvesting is allowed, have been recommended as a general tool for ecosystem-based fisheries management (Halpern 2003; Halpern *et al.* 2009). Indeed, it has been pointed out that biodiversity conservation should focus on no-take marine reserves because 94% of marine protected areas globally allow fishing (Costello & Ballantine 2015). Furthermore, in the Mediterranean, a recent study found that small-scale fisheries catch more threatened elasmobranchs inside partially protected areas than in unprotected areas (Di Lorenzo *et al.* 2022). In no-take areas, fishing mortality is regulated by permanent cessation of fishing activity in a particular area, allowing fish populations and communities within the boundaries of the closed areas to recover from fisheries exploitation with respect to both abundance and size structure. Indeed, there is evidence of positive effects of no-take areas in marine ecosystems, regardless of their size (Halpern 2003; Bergström *et al.* 2019). No-take areas can lead to increases in biomass, density, individual size, and diversity in all functional groups of the targeted fish community (Halpern *et al.* 2009; Bostedt *et al.* 2020; Bergström *et al.* 2022a). European marine reserves have been shown to promote key biological functions and variables such as species richness, biomass, density, and body size of targeted populations (Fenberg *et al.* 2012). However, careful design of no-take areas is imperative for their success. Studies show that a match in geographical scale between the home-ranges of the focal species and the size of the no-take area will increase the benefit (Palumbi 2003; Claudet *et al.* 2008; Baskett & Barnett 2015). For open sea populations, a large complete no-take zone surrounded by partially protected areas in the Kattegat, targeting the cod, and remaining closed over a 13- year period was not enough to restore the Kattegat cod, possibly at least partly due to a mismatch between the size of the protected area and the home-range of the cod. However, other species in the fish assemblage showed a positive response, namely dab, lemon sole, turbot, and Norway lobster (Sköld *et al.* 2022). Similarly, there was no detectable recovery in cod and flatfish abundances after 12 years of full protection in no-take zones and strict fishing regulations in the large surrounding buffer zones in Havstensfjorden on the Swedish West coast, indicating that recovery of populations that are highly diminished when no-take zones are established may take a long time (Bergström *et al.* 2022a). Thus, the placement and duration of the no-take area needs to be tailored to the life-history and migration patterns of the focal species (Halpern & Warner 2002; Claudet *et al.* 2008; Molloy *et al.* 2009; Vandeperre *et al.* 2011).

Fish monitoring using small boats in Estonia. © Luari Saks

No-take areas might also lead to spill-over effects of adult fish, pelagic eggs, and larvae to adjacent areas and systems (Abesamis & Russ 2005; Halpern *et al.* 2009). They may also lead to general and positive ecosystem effects on other parts of the food-web besides the targeted fish populations (Thrush & Dayton 2010; Baskett & Barnett 2015; Bergström *et al.* 2022a). For example, no-take areas often result in an increase in large predatory fish, which in turn may restore food-web functions and thereby counteract the effects of eutrophication and decrease the risk of regime shifts in the coastal ecosystem (Eriksson *et al.* 2011; Baden *et al.* 2012; Östman *et al.* 2016; Donadi *et al.* 2017; Eklöf *et al.* 2020). No-take areas can also result in populations and food-webs that are more resilient to marine heat waves and other strong environmental perturbations (Ziegler *et al.* 2023). Many of these effects might, however, be slow since fish populations in marine reserves can have slower growth rates as a result of increased density dependence (Gårdmark *et al.* 2006), although this is not always the case (Berggren *et al.* 2022).

In the Baltic Sea, several no-take areas have been established and some have been closed to fishing for 10 years or more (Bergström *et al.* 2022a; HELCOM 2023c), see also (Berkström *et al.* 2021). In a recent report, Bergström et al. (2022) evaluated the effect of eight no-take areas in Swedish coastal and off-shore waters, where each no-take zone focused on 1 to 4 target species. They found that the abundance of the focal species (perch, pike, pikeperch, and whitefish, as well as cod and sea trout, and also flatfishes: turbot, dab, lemon sole and plaice, and finally crustaceans: Norway lobster, lobster, and brown crab) in each no-take area was on average 3.8 times higher than in a comparable reference area after six years of protection. This means that abundances increased in most of the target species, however in five out of 22 cases, abundances of the target species did not recover in the short (5-6-year) or long (10 or more years) term (pertaining to cod, turbot, plaice, and perch in one area). Concurrently, the proportion of old and large individuals increased in most of the no-take areas. In most cases, these effects persisted and increased in the longer term over 10 years or more. Growth rates in no-take areas were lower in some populations, showing that density-dependent effects may decrease the effect of the no-take areas. However, one population showed a clearly higher growth rate in the no-take area compared to the reference area. Two of the eight evaluated no-take areas (one with the target species whitefish, and one with the target species perch and pike) were reopened to fishing after 5 years, at which point the positive effects on fish stocks quickly eroded to pre-protection levels, and this happened despite the areas remaining closed during the spawning period. In a rare example of a very long-term (>30 years) no-take area along the Swedish coast, the catch biomass of piscivores was 2-3 times higher than in reference areas (Bergström *et al.* 2019), and pike in the no-take area were significantly larger and older than pike in reference exploited populations, likely due to lower mortality and not due to differences in body growth (Berggren *et al.* 2022). Studying the same no-take area, Bergström et al. (2019) also looked at the effects of a eutrophication gradient and found that the abundance of cyprinids in the no-take area, which had intermediate eutrophication levels, corresponded to that of reference areas with low eutrophication. These results suggest that reduction of predatory fish, may enhance eutrophication-like symptoms. In another example of effects on the food-web, marine protected areas were more resistant to invasion by round goby in the Baltic Sea (Holmes *et al.* 2019). Thus, no-take areas could increase the resilience of the food-web to disturbances.

4.1.2 Partial fisheries closures

This measure concerns closing of an area from fishing during a specific time of year or season in order to reduce the mortality of targeted species and populations. The timing of a closure usually targets vulnerable life stages such as spawning females and/or sensitive juvenile stages of the targeted population. The key objective of this measure is to ensure reproduction by allowing fish to spawn, to protect juveniles from overexploitation, and to reduce the risk of potential genetic selective effects of fishing. To that end, this measure is similar to no-take areas with the only difference that the less restrictive partial closures might be easier to advocate for fisheries managers.

Seasonal closures have been considered beneficial mostly for restoring commercial shellfish (e.g. shrimp and lobster fisheries; reviewed by (Everson 1986)). Studies have also demonstrated positive effects of partial closures on fish populations (Gwinn & Allen 2010; Samy-Kamal *et al.* 2015). In the Baltic Sea, a recent study found that spawning closures along the Swedish coast positively impact the catch and weight per unit effort of pike, while the catch per unit effort of the more common predator perch, and of the mesopredators roach and three-spined stickleback, did not increase compared to the reference areas (Eklöf *et al.* 2023). An additional study along the Swedish coast showed similar results of a fisheries closure targeting whitefish (Berkström *et al.* 2021). However, more studies are needed to determine if the increased catches of pike are due to increased abundances or behavioral changes in the protected areas and to elucidate the potential for cascading effects on lower trophic levels (Eklöf *et al.* 2023).

4.1.3 Regulations on fishing gears and catch

These measures aim to reduce the mortality of targeted fish populations and communities by limiting the number and types of gears and vessels in the fishery, as well as by restricting fishing licenses and total allowable catch. The measures in this section can also aim to preserve the size and age structure of the targeted fish populations by imposing restrictions on the mesh size of the gears used and minimum and/or maximum size limits of the catchable size of the fish (only a sub-section of the exploited populations and communities are targeted).

A reduction in the effort (number of gears and vessels allowed, and licenses permitted) of a fishery can have a positive effect on targeted stocks and species by reducing mortality (Roberts & Polunin 1991; Dickey-Collas *et al.* 2010; Hannesson 2022). This might result in long-term sustainable out-take from the fishery and maintain the spawning stock biomass of targeted populations at a sustainable level. The type of gear used typically impacts both target and non-target species. As pointed out above, overharvest of large and piscivorous fish might result in undesirable alterations of the size structure and species composition in the food web (Pauly *et al.* 1998). Discarding of non-target species still occurs in the Baltic Sea (ICES 2022a; b), despite being illegal for the major commercial fisheries (EU 2013) and this can affect the trophic structure of the ecosystem (e.g., increased abundance of scavengers; (Gislason 2003) ultimately impacting non-targeted species and populations negatively if the incidental catch is substantial. By altering the size and species selectivity of the gears used in the fishery, the negative effects on targeted and non-targeted fish populations and communities might be reduced.

Several measures of the types discussed in this section are in place for coastal fish in the Baltic Sea (HELCOM 2015). Indirectly supporting the possible benefits of catch regulations, a recent study found that a reduced total fishing mortality of pikeperch in the coastal waters of southern Finland was associated with a declining trend in the total mortality, despite increased abundances of cormorants and seals (Olin *et al.* 2023). According to a bio-economic simulation model by (Heikinheimo *et al.* 2006) mesh size regulations have been suggested to have a positive effect on the biological sustainability of the pikeperch fishery in the Archipelago Sea, Finland. The model indicated that a larger mesh size would double the spawning stock biomass of pikeperch, which in turn would benefit the fishery in the long term (Heikinheimo *et al.* 2006). A recent simulation study focusing on the German western Baltic Sea recreational cod fishery found that a combi-

A perch caught in a multimesh gillnet during coastal fish monitoring in Ploand. © Adam Lejk nation of seasonal closure and size or slot limits, while allowing a high (10 cod) bag limit, would be the most suitable combination of management measures for limiting cod removals while at the same time minimizing impacts on angler welfare (Haase *et al.* 2022). Despite the enforcement of both size and bag limits for pike fishing along the Swedish cost since 2010 the status of the assessed population has not improved.

4.1.4 Reduction of natural predation

Changing patterns of natural predation could potentially be a target of management actions. Studies have shown local effects of natural predation by for example cormorants and seals on coastal fish species and communities, but effects vary drastically between different areas in Sweden, Finland, and Germany (Heikinheimo *et al.* 2016; Lehikoinen *et al.* 2017; Hansson *et al.* 2018; Arlinghaus *et al.* 2021; Ovegård *et al.* 2021; Bergström *et al.* 2022b; Olin *et al.* 2023, 2024), and studies of consumption rates of apex predators likewise indicate local effects on the fish community (Lehikoinen *et al.* 2011; Salmi *et al.* 2015; Veneranta *et al.* 2020). Furthermore, a global meta-analysis of cormorant predation effects on fish populations found that species within the *Cyprinidae* and *Percidae* families appear most vulnerable to cormorant predation, which means that changing levels of cormorant predation could result in the changed composition of fish species in the ecosystem (Ovegård *et al.* 2021). More generally, empirical knowledge of effects on non-target species and possible resulting trophic cascades in the food web as a result of anthropogenic reduction of natural predation (from seals and cormorants) is scarce (Eriksson *et al.* 2023).

4.2. Measures supporting fish recruitment and growth

The measures discussed above that are aimed at reducing mortality are mainly targeting the adult life stage of the fish populations and communities. The measures in this section are instead generally focused on safeguarding or boosting the production of early life stages. Studies in the Baltic Sea have suggested that the perhaps single most important factor in this regard for coastal fish is the availability and quality of essential habitats (Sundblad *et al.* 2014; Kraufvelin *et al.* 2018; Bergström *et al.* 2022a). Scientific support remains weak for other measures, but there is evidence that the reduction of hazardous substances can have strong effects on population level viability of eelpout in the Baltic Sea (Bergek *et al.* 2012).

4.2.1 Habitat protection

The first and most important measure in this category focuses on the protection of already functioning and essential habitats of coastal fish. Here, it can be noted that it is always more cost-effective to protect the habitats and minimize further loss and damage than to restore essential habitats in a deteriorated state (Kraufvelin *et al.* 2018, 2021b). The idea behind habitat protection is to prevent further habitat degradation that has negative impacts on the recruitment and production of juvenile fish, thus safeguarding sustained yields of adult fish populations (Sundblad *et al.* 2014; Kraufvelin *et al.* 2018). This is achieved through the protection of habitats from various impacts such as physical exploitation via coastal constructions and infrastructure, boating traffic, eutrophication, dredging and destructive fishing methods (Kraufvelin *et al.* 2021a). It could also include protection from dam constructions in river mouths and upstream brooks and rivers. To maximize the effect of this type of measure, it is best to combine it with fisheries regulations as presented in Section 4.1 (Bergström *et al.* 2022a).

Although there is no direct evidence from the Baltic Sea of positive effects on coastal fish from habitat protection, substantial indirect evidence for the support of the measure is available (Kraufvelin *et al.* 2018). (Sundblad *et al.* 2014) showed that habitat limitation in early life stages of perch and pikeperch may restrict the abundance of later adult stage fish. In addition, from Sweden there is evidence of long-term negative effects of coastal development on fish reproduction habitats (Sundblad & Bergström 2014), and of negative impacts on the habitat and hence production of juvenile fish from recreational boating traffic (Sandström *et al.* 2005; Hansen *et al.* 2019). Moreover, in Denmark the extraction of large boulders (i.e. “stone-fishing”) from coastal reefs for construction of harbours and coastal protection in Kattegat has destroyed many cavernous reefs and modified macroalgal coverage in the area, which in turn have led to degradation of the habitat for local fish populations (Støttrup *et al.* 2014; Kristensen *et al.* 2015).

4.2.2 Habitat restoration

An alternative and often complementary measure to that of habitat protection is to restore already impacted and partly destroyed habitats for fish. The main objective of this measure is to restore degraded habitats affected by physical interferences to a state where they can support biodiversity and productivity of fish populations. Learning how to do this in effective ways has been listed as one of the great challenges within marine ecosystem ecology (Borja 2014), and ways forward have been proposed to deal with the criticism of 'too small and too expensive' that often hamper the large-scale adoption of marine restoration efforts (McAfee *et al.* 2021).

Habitat restoration can be undertaken by either re-creating the physical structures of the habitats, or by compensatory efforts where new and artificial habitats are constructed (Loughlin & Clarke 2014; Paxton *et al.* 2020; Kraufvelin *et al.* 2021b). Examples of habitat restoration along the Baltic Sea coast include the construction of artificial stone reefs (Støttrup *et al.* 2014, 2017; Kristensen *et al.* 2015; Stenberg *et al.* 2015), the restoration of eelgrass meadows (Moksnes *et al.* 2016), the restoration of wetlands and tributaries as reproduction habitats for coastal anadromous fish species like pike, ide and turbot (Nilsson *et al.* 2014), and the lowering of eutrophication levels by various means(Reusch *et al.* 2018; Bergström *et al.* 2023).

Artificial reefs have been constructed in the Baltic Sea in German, Polish, Russian, Finnish, Swedish and Danish waters (Fabi *et al.* 2011). In Denmark, artificially built stone reefs and mussel beds have attracted fish species with a preference for rocky habitats, and also increased biodiversity and the abundance of larger specimens of certain species of fish (Støttrup *et al.* 2014; Kristensen *et al.* 2015; Stenberg *et al.* 2015). Biogenic reefs of mussels can also increase the structural complexity and biodiversity of the habitat and associated fauna. This could lead to an increase in fish growth and diversity. However, it is not established to date whether such an increase is the result of attraction effects of the fish or population abundance level effects.

Eelgrass meadows are of substantial importance for the production of juvenile fish in marine habitats (Lilley & Unsworth 2014; Cole & Moksnes 2016), but a substantial proportion of these important habitats has disappeared along the Baltic coasts over the last decades (Baden *et al.* 2003; Frederiksen *et al.* 2004). Despite the uncertain success of eelgrass meadow restoration attempts and the resulting effects on fish production to date (Moksnes *et al.* 2018), eelgrass meadow restoration might be an important measure to consider in the future when more evidence has accumulated. A recent review pointed out that a focus on not only reducing physical stressors but also on incorporating positive species interactions throughout the ecosystem into restoration methods can be a promising avenue forward (Valdez *et al.* 2020). Examples of this that pertain to eelgrass meadow restoration include re-establishing top-down control and considering positive density dependence, for example by using large numbers (<100000) of shoots or seeds in seagrass meadow restoration (van Katwijk *et al.* 2016).

Many coastal fish species of freshwater origin in the coastal zones of the Baltic Sea undertake spawning migrations to coastal tributaries and wetlands (Engstedt *et al.* 2010; Nilsson *et al.* 2014; Rohtla *et al.* 2014, 2015). In many regions of the Baltic Sea, these habitats have substantially deteriorated in quality due to anthropogenic pressures during the past decades (Engstedt *et al.* 2010; Nilsson *et al.* 2014), and spawning ground reconstruction has for example been suggested as the main management measure to rebuild the anadromous pike population along the Baltic coasts (Greszkiewicz *et al.* 2022). Indeed, efforts to restore these wetlands as reproduction areas for foremost pike have proven to result in a drastic increase in the production of juvenile pike as a result of optimal spawning conditions, predation refuge and food production (Nilsson *et al.* 2014; Larsson *et al.* 2015; Hansen *et al.* 2020). The resulting effects on the adult populations of pike are, however, not yet well established (but see (Fredriksson *et al.* 2013; Hansen *et al.* 2020). Furthermore, restoration efforts need to consider interactions between species in the food-web. For example, along the Swedish and Finnish coast, perch and pike larval densities decrease with three-spined stickleback abundance and increase with increasing summer cumulative temperature. Thus, more enclosed bays that are less accessible to stickleback and have a comparatively higher temperature are crucial for higher larval survival of perch and pike and should be prioritized in management (Donadi *et al.* 2017). Similarly, in the Northern Baltic Sea, the most sheltered habitat types showed the highest pike larvae abundances (Pursiainen *et al.* 2021). In general, restoration efforts need to consider the spatial scale of the intervention because species in the food-web can interact in different ways at different spatial scales (Donadi *et al.* 2020).

Restoration measures with limited implementation and evaluation to date in the Baltic Sea include restoration of soft bottom macrophytes other than eelgrass, restoration of brown macroalgae, restoration of soft bottoms naturally free of vegetation, rehabilitation of hypoxic areas by oxygen pumping, and rehabilitation of anoxic, nutrient rich or polluted sediments by removal or coverage (reviewed in Kraufvelin *et al.* 2021b).

4.2.3 Nutrient reduction

Habitats in the Baltic Sea have long been affected by excess anthropogenic input of nutrients. Nitrogen and phosphorous loads peaked around 1990, then decreased substantially, and have plateaued in recent years (Reusch *et al.* 2018). Thus, eutrophication levels remain high in many coastal areas. Few studies have shown direct effects on fish from of lowered eutrophication levels, but one recent study that followed the effects over one decade of a successful drastic initial reduction in nutrient levels in a Swedish coastal area, found an increase in mean trophic level and proportion of piscivores, but responses were weak and slow (Bergström *et al.* 2023). Importantly, responses to changes in eutrophication may be species-specific. A recent modelling study projected a 37% increase in perch and 59% decrease in pikeperch biomass if the reference level for water clarity (a core indicator of the status of eutrophication) in the Baltic Sea Action Plan would be reached (Sundblad *et al.* 2020).

Measures aimed at nutrient reduction with limited implementation and evaluation to date in the Baltic Sea include reduction of nutrient loading by farming and harvesting blue mussels, and reduction of internal phosphorous loads by metal binding (reviewed in Kraufvelin *et al.* 2021b).

4.2.4 Biomanipulation, stocking of fish

Biomanipulation by removing for example cyprinids and sticklebacks has been suggested to rehabilitate coastal ecosystems by restoring top-down control and balance the food-webs. However, this measure has limited implementation and evaluation to date (Kraufvelin *et al.* 2021b).

Stocking, i.e. the release of wild-captured or hatchery-reared animals, continues to be a standard practice in fisheries management to support and restore fish communities and fishing opportunities. However, stocking can have lasting negative ecological and evolutionary effects on populations, food webs, and ecosystems, and it may often fail to increase populations (Lorenzen *et al.* 2012). To this end, ecosystem-based management may outperform species-focused stocking as a means to enhance fish populations and communities including also improved fishing opportunities (Radinger *et al.* 2023).

Roach is the most abundant species within the cyprind fish family in the Baltic Sea. © Adam Lejk

5. Future recommendations

Despite the recent advances presented in this report, there are still several knowledge gaps and development needs in order for future coastal fish assessments to be regionally adequate with sufficient spatial coverage and confidence. There is also a need to maintain and possibly expand the current monitoring programs and cooperation within and between contracting parties.

Important future aims/activities include (responsible body for implementation in italics):

- The current level of monitoring locations should be seen as a minimum level, and new monitoring programs and relevant data collection procedures for coastal fish needs to be initiated to increase the spatial coverage. This is essential for increasing the confidence of future status assessments, as the current assessment only covers about half of the assessment units in the Baltic Sea. Contracting parties of HELCOM.
- To a larger extent make use of alternative data sources for coastal fish assessments to increase spatial coverage. Besides fisheries independent monitoring programs, alternative sources include commercial catch statistics and citizen science data. Contracting parties of HELCOM and EG Costal Fish.
- Make better use of existing coastal fish monitoring data by intercalibrating historical and current data sets using different monitoring strategies and methods. EG Costal Fish.
- Further refinement and development of the present set of indicators used. This includes deriving thresholds for the size structure indicator for additional species besides perch, including indicators to assess the status for abundance of additional key coastal fish species besides perch, pike, pikeperch, whitefish and flounder, improving data quality and if needed integration/aggregation principles for all indicators, and increasing the confidence level for the threshold values. EG Costal Fish.
- Further harmonization and development of assessment methods. This includes developing assessment methods that do not require long time series to enable the inclusion of assessment results from additional monitoring programs. EG Costal Fish.
- Expand the use of coastal fish data. This could for example include using the existing monitoring network for coastal fish to further follow the distribution, expansion, and effects of the round goby. The network of coastal fish monitoring stations offers a unique possibility to study these effects, as data from before and after the establishment of the species exist in many areas. Contracting parties of HELCOM and relevant HELCOM groups with the support of EG Costal Fish.
- Evaluation of measures to restore and support coastal fish communities. A wide range of measures has been implemented for fish in the Baltic Sea, but there is generally a lack of scientific evaluations and evidence on the effects of many of the measures. This significantly limits the work of restoring and supporting coastal fish communities and stocks. Contracting parties of HELCOM and relevant HELCOM groups with the support of EG Costal Fish.
- Improved understanding and knowledge of the spatial variation and gradients in pressures impacting coastal fish communities including also information on where specific measures are most likely to be most effective and where additional measures needs to be taken. Contracting parties of HELCOM with the support of EG Costal Fish.

6. References

Abesamis RA and GR Russ (2005). Density-Dependent Spillover from a Marine Reserve: Long-Term Evidence. *Ecological Applications*, 15 (5), 1798–1812. https://doi.org/10.1890/05-0174

Ådjers K, M Appelberg, R Eschbaum, A Lappalainen, A Minde and R Repe (2006). Trends in coastal fish stocks of the Baltic Sea. *Boreal Env. Res*, 11, 13–25

Airoldi L and MW Beck (2007). Loss, Status and Trends for Coastal Marine Habitats of Europe. In: Gibson, R.N., Atkinson, R.J.A., & Gordon, J.D.M. (eds) *Oceanography and Marine Biology*. CRC Press. 345–405.

Almqvist G, AK Strandmark and M Appelberg (2010). Has the invasive round goby caused new links in Baltic food webs? *Environmental Biology of Fishes*, 89 (1), 79–93. https://doi.org/10.1007/s10641-010-9692-z

Arlinghaus R, J Lucas, MS Weltersbach, D Kömle, HM Winkler, C Riepe, C Kühn and HV Strehlow (2021). Niche overlap among anglers, fishers and cormorants and their removals of fish biomass: A case from brackish lagoon ecosystems in the southern Baltic Sea. *Fisheries Research*, 238, 105894. https://doi.org/10.1016/j.fishres.2021.105894

Baden S, A Emanuelsson, L Pihl, C Svensson and P Åberg (2012). Shift in seagrass food web structure over decades is linked to overfishing. *Marine Ecology Progress Series*, 451, 61–73. https://doi.org/10.3354/meps09585

Baden S, M Gullström, B Lundén, L Pihl and R Rosenberg (2003). Vanishing Seagrass (*Zostera marina*, L.) in Swedish Coastal Waters. *AMBIO: A Journal of the Human Environment*, 32 (5), 374–377. https://doi.org/10.1579/0044-7447-32.5.374

Baer J, JT DeWeber, R Rösch and A Brinker (2021). Aquaculture of Coregonid Species — Quo vadis? *Annales Zoologici Fennici*, 58 (4–6), 307–318. https://doi.org/10.5735/086.058.0414

Barneche DR, DR Robertson, CR White and DJ Marshall (2018). Fish reproductive-energy output increases disproportionately with body size. *Science*, 360 (6389), 642–645. https://doi.org/10.1126/science.aao6868

Baskett ML and LAK Barnett (2015). The Ecological and Evolutionary Consequences of Marine Reserves. *Annual Review of Ecology, Evolution and Systematics*, 46 (Volume 46, 2015), 49–73. https://doi.org/10.1146/annurev-ecolsys-112414-054424

Ben Khadher S, P Fontaine, S Milla, J-F Agnèse and F Teletchea (2016). Genetic characterization and relatedness of wild and farmed Eurasian perch (*Perca fluviatilis*): Possible implications for aquaculture practices. *Aquaculture Reports*, 3, 136–146. https://doi.org/10.1016/j.aqrep.2015.12.003

Bendtsen J, KE Gustafsson, J Söderkvist and JLS Hansen (2009). Ventilation of bottom water in the North Sea–Baltic Sea transition zone. *Journal of Marine Systems*, 75 (1), 138–149. https://doi.org/10.1016/j.jmarsys.2008.08.006

Bergek S, Q Ma, M Vetemaa, F Franzén and M Appelberg (2012). From individuals to populations: Impacts of environmental pollution on natural eelpout populations. *Ecotoxicology and Environmental Safety*, 79, 1–12. https://doi.org/10.1016/j.ecoenv.2012.01.019

Berggren T, U Bergström, G Sundblad and Ö Östman (2022). Warmer water increases early body growth of northern pike (*Esox lucius*), but mortality has larger impact on decreasing body sizes. *Canadian Journal of Fisheries and Aquatic Sciences*, 79 (5), 771–781. https://doi.org/10.1139/cjfas-2020-0386

Bergström L, U Bergström, J Olsson and J Carstensen (2016a). Coastal fish indicators response to natural and anthropogenic drivers–variability at temporal and different spatial scales. *Estuarine, Coastal and Shelf Science*, 183, 62–72. https://doi.org/10.1016/j.ecss.2016.10.027

Bergström L, R Fredriksson, U Bergström, E Rydin and L Kumblad (2023). Fish community responses to restoration of a eutrophic coastal bay. *Ambio*,. https://doi.org/10.1007/s13280-023-01907-3

Bergström L, O Heikinheimo, R Svirgsden, E Kruze, L Ložys, A Lappalainen, L Saks, A Minde, J Dainys and E Jakubavičiūtė (2016b). Long term changes in the status of coastal fish in the Baltic Sea. *Estuarine, Coastal and Shelf Science*, 169, 74–84

Bergström L, M Karlsson, U Bergström, L Pihl and P Kraufvelin (2016c). Distribution of mesopredatory fish determined by habitat variables in a predator-depleted coastal system. *Marine Biology*, 163 (10), 201. https://doi.org/10.1007/s00227-016-2977-9

Bergström L, M Karlsson, U Bergström, L Pihl and P Kraufvelin (2019). Relative impacts of fishing and eutrophication on coastal fish assessed by comparing a no-take area with an environmental gradient. *Ambio*, 48 (6), 565–579. https://doi.org/10.1007/s13280-018-1133-9

Bergström U, C Berkström, M Sköld, P Börjesson, M Eggertsen, L Fetterplace, A-B Florin, R Fredriksson, S Fredriksson, P Kraufvelin, K Lundström, J Nilsson, M Ovegård, D Perry, A Sundelöf, A Wikström and H Wennhage (2022a). *Long-term effects of no-take zones in Swedish waters*. Aqua reports, 2022:20. Swedish University of Agricultural Sciences. https://doi.org/10.54612/a.10da2mgf51

Bergström U, S Larsson, M Erlandsson, M Ovegård, H Ragnarsson Stabo, Ö Östman and G Sundblad (2022b). Long-term decline in northern pike (*Esox lucius L.*) populations in the Baltic Sea revealed by recreational angling data. *Fisheries Research*, 251, 106307. https://doi.org/10.1016/j.fishres.2022.106307

Bergström U, G Sundblad, A-L Downie, M Snickars, C Boström and M Lindegarth (2013). Evaluating eutrophication management scenarios in the Baltic Sea using species distribution modelling. *Journal of Applied Ecology*, 50 (3), 680–690. https://doi.org/10.1111/1365-2664.12083

Berkström C, A-B Florin, R Fredriksson, K Lundström and U Bergström (2021). Rapid effects of a fishing closure on whitefish (*Coregonus maraena*) in the northern Baltic Sea. *Boreal Environmental Research*, 26, 89–104

Bianchi D, DA Carozza, ED Galbraith, J Guiet and T DeVries (2021). Estimating global biomass and biogeochemical cycling of marine fish with and without fishing. *Science Advances*, 7 (41), eabd7554. https://doi.org/10.1126/sciadv.abd7554

Birkeland C and PK Dayton (2005). The importance in fishery management of leaving the big ones. *Trends in Ecology & Evolution*, 20 (7), 356–358. https://doi.org/10.1016/j.tree.2005.03.015

Biro PA, C Beckmann and JA Stamps (2009). Small within-day increases in temperature affects boldness and alters personality in coral reef fish. *Proceedings of the Royal Society B: Biological Sciences*, 277 (1678), 71–77. https://doi.org/10.1098/rspb.2009.1346

Blenckner T, C Möllmann, J Stewart Lowndes, JR Griffiths, E Campbell, A De Cervo, A Belgrano, C Boström, V Fleming, M Frazier, S Neuenfeldt, S Niiranen, A Nilsson, H Ojaveer, J Olsson, CS Palmlöv, M Quaas, W Rickels, A Sobek, M Viitasalo, SA Wikström and BS Halpern (2021). The Baltic Health Index (BHI): Assessing the social–ecological status of the Baltic Sea. *People and Nature*, 3 (2), 359–375. https://doi.org/10.1002/pan3.10178

Böhling P, R Hudd, H Lehtonen, P Karås, E Neuman and G Thoresson (1991). Variations in Year-Class Strength of Different Perch (*Perca fluviatilis*) Populations in the Baltic Sea with Special Reference to Temperature and Pollution. *Canadian Journal of Fisheries and Aquatic Sciences*, 48 (7), 1181–1187. https://doi.org/10.1139/f91-142

Bolund E (in prep). An approach for deriving threshold values of the size distribution for data-limited coastal fish species in the Baltic Sea.

Bonsdorff E, E Blomqvist, J Mattila and A Norkko (1997). Long-term changes and coastal eutrophication. Examples from the Aland Islands and the Archipelago Sea, northern Baltic Sea. *Oceanolica Acta*, 20 (1), 319–329. https://archimer.ifremer.fr/doc/00093/20402/ [2023-09-14]

Borja A (2014). Grand challenges in marine ecosystems ecology. *Frontiers in Marine Science*, 1. https://doi.org/10.3389/fmars.2014.00001

Bostedt G, C Berkström, R Brännlund, O Carlén, A-B Florin, L Persson and U Bergström (2020). Benefits and costs of two temporary no-take zones. *Marine Policy*, 117, 103883. https://doi.org/10.1016/j.marpol.2020.103883

Brown EJ, RP Vasconcelos, H Wennhage, U Bergström, JG Støttrup, K Van De Wolfshaar, G Millisenda, F Colloca and O Le Pape (2018). Conflicts in the coastal zone: human impacts on commercially important fish species utilizing coastal habitat. Anderson, E. (ed.) (Anderson, E., ed.) *ICES Journal of Marine Science*, 75 (4), 1203–1213. https://doi.org/10.1093/icesjms/fsx237

Bryhn AC, PH Dimberg, L Bergström, RE Fredriksson, J Mattila and U Bergström (2017). External nutrient loading from land, sea and atmosphere to all 656 Swedish coastal water bodies. *Marine Pollution Bulletin*, 114 (2), 664–670. https://doi.org/10.1016/j.marpolbul.2016.10.054

Byström P, U Bergström, A Hjälten, S Ståhl, D Jonsson and J Olsson (2015). Declining coastal piscivore populations in the Baltic Sea: Where and when do sticklebacks matter? *AMBIO*, 44 (3), 462–471. https://doi.org/10.1007/s13280-015-0665-5

Cardinale M, J Hagberg, H Svedäng, V Bartolino, T Gedamke, J Hjelm, P Börjesson and F Norén (2009). Fishing through time: population dynamics of plaice (Pleuronectes platessa) in the Kattegat–Skagerrak over a century. *Population Ecology*, 52 (2), 251–262. https://doi.org/10.1007/s10144-009-0177-x

Carl JD, CR Sparrevohn, H Nicolajsen and JG Støttrup (2008). Substratum selection by juvenile flounder *Platichthys flesus* (L.): effect of ephemeral filamentous macroalgae. *Journal of Fish Biology*, 72 (10), 2570–2578. https://doi.org/10.1111/j.1095-8649.2008.01866.x

Casini M, T Blenckner, C Möllmann, A Gårdmark, M Lindegren, M Llope, G Kornilovs, M Plikshs and NC Stenseth (2012). Predator transitory spillover induces trophic cascades in ecological sinks. *Proceedings of the National Academy of Sciences*, 109 (21), 8185–8189. https://doi.org/10.1073/pnas.1113286109

Christoffersen M, JC Svendsen, JA Kuhn, A Nielsen, A Martjanova and JG Støttrup (2018). Benthic habitat selection in juvenile European eel *Anguilla anguilla*: implications for coastal habitat management and restoration. *Journal of Fish Biology*, 93 (5), 996–999. https://doi.org/10.1111/jfb.13807

Cingi S, M Keinänen and PJ Vuorinen (2010). Elevated water temperature impairs fertilization and embryonic development of whitefish *Coregonus lavaretus*. *Journal of Fish Biology*, 76 (3), 502–521. https://doi.org/10.1111/j.1095-8649.2009.02502.x

Claudet J, CW Osenberg, L Benedetti-Cecchi, P Domenici, J-A García-Charton, Á Pérez-Ruzafa, F Badalamenti, J Bayle-Sempere, A Brito, F Bulleri, J-M Culioli, M Dimech, JM Falcón, I Guala, M Milazzo, J Sánchez-Meca, PJ Somerfield, B Stobart, F Vandeperre, C Valle and S Planes (2008). Marine reserves: size and age do matter. *Ecology Letters*, 11 (5), 481–489. https://doi.org/10.1111/j.1461-0248.2008.01166.x

Cole SG and P-O Moksnes (2016). Valuing Multiple Eelgrass Ecosystem Services in Sweden: Fish Production and Uptake of Carbon and Nitrogen. *Frontiers in Marine Science*, 2. https://doi.org/10.3389/fmars.2015.00121

Collie JS, AD Wood and HP Jeffries (2008). Long-term shifts in the species composition of a coastal fish community. *Canadian Journal of Fisheries and Aquatic Sciences*, 65 (7), 1352–1365. https://doi.org/10.1139/F08-048

Costello MJ and B Ballantine (2015). Biodiversity conservation should focus on no-take Marine Reserves: 94% of Marine Protected Areas allow fishing. *Trends in Ecology & Evolution*, 30 (9), 507–509. https://doi.org/10.1016/j.tree.2015.06.011

Dabrowska H, O Kopko, KK Lehtonen, T Lang, I Waszak, M Balode and E Strode (2017). An integrated assessment of pollution and biological effects in flounder, mussels and sediment in the southern Baltic Sea coastal area. *Environmental Science and Pollution Research*, 24 (4), 3626–3639. https://doi.org/10.1007/s11356-016-8117-8

Dafforn KA, M Mayer-Pinto, RL Morris and NJ Waltham (2015). Application of management tools to integrate ecological principles with the design of marine infrastructure. *Journal of Environmental Management*, 158, 61–73. https://doi.org/10.1016/j.jenvman.2015.05.001

Dahlin I, S Levin, J Olsson and Ö Östman (2021). Fishing cyprinids for food - Evaluation of ecosystem effects and contaminants in cyprinid fish. *Aqua reports*, (20)

Daily GC and M Ruckelshaus (2022). 25 years of valuing ecosystems in decision-making. *Nature*, 606 (7914), 465–466. https://doi.org/10.1038/d41586-022-01480-x

Dainys J, E Jakubavičiūtė, H Gorfine, M Kirka, A Raklevičiūtė, A Morkvėnas, Ž Pūtys, L Ložys and A Audzijonyte (2022). Impacts of Recreational Angling on Fish Population Recovery after a Commercial Fishing Ban. *Fishes*, 7 (5), 232. https://doi.org/10.3390/fishes7050232

DeFaveri J and J Merilä (2014). Local adaptation to salinity in the three-spined stickleback? *Journal of Evolutionary Biology*, 27 (2), 290–302. https://doi.org/10.1111/jeb.12289

Di Lorenzo M, A Calò, A Di Franco, G Milisenda, G Aglieri, C Cattano, M Milazzo and P Guidetti (2022). Small-scale fisheries catch more threatened elasmobranchs inside partially protected areas than in unprotected areas. *Nature Communications*, 13 (1), 4381. https://doi.org/10.1038/s41467-022-32035-3

Dickey-Collas M, RDM Nash, T Brunel, CJG van Damme, CT Marshall, MR Payne, A Corten, AJ Geffen, MA Peck, EMC Hatfield, NT Hintzen, K Enberg, LT Kell and EJ Simmonds (2010). Lessons learned from stock collapse and recovery of North Sea herring: a review. *ICES Journal of Marine Science*, 67 (9), 1875–1886. https://doi.org/10.1093/icesjms/fsq033

Dierschke V, A Kreutle, N Häubner, C Magliozzi, S Bennecke, L Bergström, A Borja, ST Boschetti, A Cheilari, D Connor, F Haas, M Hauswirth, S Koschinski, C Liquete, J Olsson, D Schönberg-Alm, F Somma, H Wennhage and A Palialexis (2021*). Integration methods for Marine Strategy Framework Directive's biodiversity assessments Descriptor 1: species*. https://doi.org/10.2760/475

Donadi S, ÅN Austin, U Bergström, BK Eriksson, JP Hansen, P Jacobson, G Sundblad, M van Regteren and JS Eklöf (2017). A cross-scale trophic cascade from large predatory fish to algae in coastal ecosystems. *Proceedings of the Royal Society B: Biological Sciences*, 284 (1859), 20170045. https://doi.org/10.1098/rspb.2017.0045

Donadi S, L Bergström, JM Bertil Berglund, B Anette, R Mikkola, A Saarinen and U Bergström (2020). Perch and pike recruitment in coastal bays limited by stickleback predation and environmental forcing. *Estuarine, Coastal and Shelf Science*, 246, 107052. https://doi.org/10.1016/j.ecss.2020.107052

van Dorst RM, A Gårdmark, R Svanbäck, U Beier, GA Weyhenmeyer and M Huss (2019). Warmer and browner waters decrease fish biomass production. *Global Change Biology*, 25 (4), 1395–1408. https://doi.org/10.1111/gcb.14551

Eero M, H V. Strehlow, CM Adams and M Vinther (2015). Does recreational catch impact the TAC for commercial fisheries? *ICES Journal of Marine Science*, 72 (2), 450–457. https://doi.org/10.1093/icesjms/fsu121

Eklöf JS, JP Hansen, BK Eriksson, Ö Östman, ÅN Austin, C Yanos, R Fredriksson, U Bergström and HC Andersson (2023). Effects of seasonal spawning closures on pike (*Esox lucius L.*) and perch (*Perca fluviatilis L.*) catches and coastal food webs in the western Baltic Sea. *Fisheries Research*, 263, 106674. https://doi.org/10.1016/j.fishres.2023.106674

Eklöf JS, G Sundblad, M Erlandsson, S Donadi, JP Hansen, BK Eriksson and U Bergström (2020). A spatial regime shift from predator to prey dominance in a large coastal ecosystem. *Communications Biology*, 3 (1), 1–9. https://doi.org/10.1038/s42003-020-01180-0

Engstedt O, P Stenroth, P Larsson, L Ljunggren and M Elfman (2010). Assessment of natal origin of pike (*Esox lucius*) in the Baltic Sea using Sr:Ca in otoliths. *Environmental Biology of Fishes*, 89 (3), 547–555. https://doi.org/10.1007/s10641-010-9686-x

Eriksson BK, JS Eklöf, L Govers and U Bergström (2023). Trophic cascades in coastal ecosystems. In: *Reference Module in Earth Systems and Environmental Sciences*. Elsevier. 1–44. https://doi.org/10.1016/B978-0-323-90798-9.00006-8

Eriksson BK, L Ljunggren, A Sandström, G Johansson, J Mattila, A Rubach, S Råberg and M Snickars (2009). Declines in predatory fish promote bloom-forming macroalgae. *Ecological Applications*, 19 (8), 1975–1988. https://doi.org/10.1890/08-0964.1

Eriksson BK, K Sieben, J Eklöf, L Ljunggren, J Olsson, M Casini and U Bergström (2011). Effects of Altered Offshore Food Webs on Coastal Ecosystems Emphasize the Need for Cross-Ecosystem Management. *AMBIO*, 40 (7), 786–797. https://doi.org/10.1007/s13280-011-0158-0

EU (2013). *Regulation (EU) No 1380/2013 of the European Parliament and of the Council of 11 December 2013, on the Common Fisheries Policy, amending Council Regulations (EC) No 1954/2003 and (EC) No 1224/2009 and repealing Council Regulations (EC) No 2371/2002 and (EC).* http://data.europa.eu/eli/reg/2013/1380/oj

European Commission (2008). *Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008 establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive)*. http://data.europa.eu/eli/dir/2008/56/2017-06-07

European Commission (2017). *COMMISSION DIRECTIVE (EU) 2017/845 amending Directive 2008/56/EC of the European Parliament and of the Council as regards the indicative lists of elements to be taken into account for the preparation of marine strategies*. http://data.europa.eu/eli/dir/2017/845/oj

European Commission (2022). *Council Regulation (EU) 2022/2090 of 27 October 2022 fixing the fishing opportunities for certain fish stocks and groups of fish stocks applicable in the Baltic Sea for 2023 and amending Regulation (EU) 2022/109 as regards certain fishing opportunities in other waters*. http://data.europa.eu/eli/reg/2022/2090/oj

European Commission (2023). *Regulation (EU) 2023/2842 of the european parliament and of the council*. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=OJ:L_202302842

Everson A (1986). *Closed season as a management policy in lobster fisheries*. NOAA. Southwest Fisheries Center, Administrative Report H-86-7

Fabi G, A Spagnolo, D Bellan-Santini, E Charbonnel, BA Çiçek, JJG García, AC Jensen, A Kallianiotis and MN dos Santos (2011). Overview on artificial reefs in Europe. *Brazilian Journal of Oceanography*, 59, 155–166. https://www.scielo.br/j/bjoce/a/jTX7Wrqfrp5r6fgj9sd6Snn/?lang=en [2024-03-25]

Fenberg PB, JE Caselle, J Claudet, M Clemence, SD Gaines, J Antonio García-Charton, EJ Gonçalves, K Grorud-Colvert, P Guidetti, SR Jenkins, PJS Jones, SE Lester, R McAllen, E Moland, S Planes and TK Sørensen (2012). The science of European marine reserves: Status, efficacy, and future needs. *Marine Policy*, 36 (5), 1012–1021. https://doi.org/10.1016/j.marpol.2012.02.021

Ferter K, MS Weltersbach, H V. Strehlow, JH Volstad, J Alos, R Arlinghaus, M Armstrong, M Dorow, M de Graaf, T van der Hammen, K Hyder, H Levrel, A Paulrud, K Radtke, D Rocklin, CR Sparrevohn and P Veiga (2013). Unexpectedly high catch-and-release rates in European marine recreational fisheries: implications for science and management. *ICES Journal of Marine Science*, 70 (7), 1319–1329. https://doi.org/10.1093/icesjms/fst104

Fey DP and M Greszkiewicz (2021). Effects of temperature on somatic growth, otolith growth, and uncoupling in the otolith to fish size relationship of larval northern pike, *Esox lucius* L. *Fisheries Research*, 236, 105843. https://doi.org/10.1016/j.fishres.2020.105843

Flávio H, R Seitz, D Eggleston, JC Svendsen and J Støttrup (2023). Hard-bottom habitats support commercially important fish species: a systematic review for the North Atlantic Ocean and Baltic Sea. *PeerJ*, 11, e14681. https://doi.org/10.7717/peerj.14681

Fleming-Lehtinen V, JH Andersen, J Carstensen, E Łysiak-Pastuszak, C Murray, M Pyhälä and M Laamanen (2015). Recent developments in assessment methodology reveal that the Baltic Sea eutrophication problem is expanding. *Ecological Indicators*, 48, 380–388. https://doi.org/10.1016/j.ecolind.2014.08.022

Florin A-B, U Bergström, D Ustups, K Lundström and PR Jonsson (2013). Effects of a large northern European no-take zone on flatfish populations. *Journal of fish biology*, 83 (4), 939–62. https://doi.org/10.1111/jfb.12097

Florin A-B and J Höglund (2007). Absence of population structure of turbot (Psetta maxima) in the Baltic Sea. *Molecular Ecology*, 16 (1), 115–126. https://doi.org/10.1111/j.1365-294X.2006.03120.x

Frederiksen M, D Krause-Jensen, M Holmer and JS Laursen (2004). Long-term changes in area distribution of eelgrass (*Zostera marina*) in Danish coastal waters. *Aquatic Botany*, 78 (2), 167–181. https://doi.org/10.1016/j.aquabot.2003.10.002

Fredriksson R, U Bergström and J Olsson (2013). *Riktlinjer för uppföljning av fiskevårdsåtgärder i kustmynnande våtmarker med fokus på gädda*. Aqua reports, 2013: 7

Gårdmark A, N Jonzén and M Mangel (2006). Density-dependent body growth reduces the potential of marine reserves to enhance yields. *Journal of Applied Ecology*, 43 (1), 61–69. https://doi.org/10.1111/j.1365-2664.2005.01104.x

Gislason H (2003). The effects of fishing on non-target species and ecosystem structure and function. *Responsible fisheries in the marine ecosystem*, 255–274. https://doi.org/10.1079/9780851996332.0255

Greszkiewicz M, DP Fey, AM Lejk and M Zimak (2022). The effect of salinity on the development of freshwater pike (*Esox lucius*) eggs in the context of drastic pike population decline in Puck Lagoon, Baltic Sea. *Hydrobiologia*, 849 (12), 2781–2795. https://doi.org/10.1007/s10750-022-04893-x

Griffiths CA, H Winker, V Bartolino, H Wennhage, A Orio and M Cardinale (2024). Including older fish in fisheries management: A new age-based indicator and reference point for exploited fish stocks. *Fish and Fisheries*, 25 (1), 18–37. https://doi.org/10.1111/faf.12789

Guzzo MM, PJ Blanchfield and MD Rennie (2017). Behavioral responses to annual temperature variation alter the dominant energy pathway, growth, and condition of a cold-water predator. *Proceedings of the National Academy of Sciences*, 114 (37), 9912–9917. https://doi.org/10.1073/pnas.1702584114

Gwinn DC and MS Allen (2010). Exploring Population-Level Effects of Fishery Closures during Spawning: An Example Using Largemouth Bass. *Transactions of the American Fisheries Society*, 139 (2), 626–634. https://doi.org/10.1577/T08-089.1

Haase K, MS Weltersbach, W-C Lewin, C Zimmermann and HV Strehlow (2022). Potential effects of management options on marine recreational fisheries – the example of the western Baltic cod fishery. *ICES Journal of Marine Science*, 79 (3), 661–676. https://doi.org/10.1093/icesjms/fsac012

Haines-Young R and M Potschin-Young (2018). Revision of the Common International Classification for Ecosystem Services (CICES V5.1): A Policy Brief. *One Ecosystem*, 3, e27108. https://doi.org/10.3897/oneeco.3.e27108

Halpern BS (2003). The Impact of Marine Reserves: Do Reserves Work and Does Reserve Size Matter? *Ecological Applications*, 13 (sp1), 117–137. https://doi.org/10.1890/1051-0761(2003)013[0117:TIOMRD]2.0.CO;2

Halpern BS, SE Lester and JB Kellner (2009). Spillover from marine reserves and the replenishment of fished stocks. *Environmental Conservation*, 36 (4), 268–276. https://doi.org/10.1017/S0376892910000032

Halpern BS and RR Warner (2002). Marine reserves have rapid and lasting effects. *Ecology Letters*, 5 (3), 361–366. https://doi.org/10.1046/j.1461-0248.2002.00326.x

Hannesson R (2022). Stock crash and recovery: The Norwegian spring spawning herring. *Economic Analysis and Policy*, 74, 45–58. https://doi.org/10.1016/j.eap.2022.01.007

Hansen J, HC Andersson, U Bergström, T Borger, D Brelin, P Byström, P Eklöf, P Kraufvelin, L Kumblad and L Ljunggren (2020). *Våtmarker som fiskevårdsåtgärd vid kusten: Utvärdering av restaurerade våtmarkers effekt på fiskreproduktion och ekosystemet längs Östersjökusten (Wetlands as a management tool for coastal fish in the Baltic Sea. An evaluation of the effects of restored wetlands on fish recruitment and the ecosystem along the Swedish coast)*. Stockholms universitets Östersjöcentrum, Stockholms universitet.

Hansen JP, G Sundblad, U Bergström, ÅN Austin, S Donadi, BK Eriksson and JS Eklöf (2019). Recreational boating degrades vegetation important for fish recruitment. *Ambio*, 48 (6), 539–551. https://doi.org/10.1007/s13280-018-1088-x

Hanson N, S Persson and Å Larsson (2009). Analyses of perch (*Perca fluviatilis*) bile suggest increasing exposure to PAHs and other pollutants in a reference area on the Swedish Baltic coast. *Journal of Environmental Monitoring*, 11 (2), 389–393. https://doi.org/10.1039/B817703A

Hansson S, U Bergström, E Bonsdorff, T Härkönen, N Jepsen, L Kautsky, K Lundström, S-G Lunneryd, M Ovegård, J Salmi, D Sendek and M Vetemaa (2018). Competition for the fish – fish extraction from the Baltic Sea by humans, aquatic mammals, and birds. *ICES Journal of Marine Science*, 75 (3), 999–1008. https://doi.org/10.1093/icesjms/fsx207

Härmä M, A Lappalainen and L Urho (2008). Reproduction areas of roach (*Rutilus rutilus*) in the northern Baltic Sea: potential effects of climate change. *Canadian Journal of Fisheries and Aquatic Sciences*, 65 (12), 2678–2688. https://doi.org/10.1139/F08-167

Harvey CJ, SP Cox, TE Essington, S Hansson and JF Kitchell (2003). An ecosystem model of food web and fisheries interactions in the Baltic Sea. *ICES Journal of Marine Science*, 60 (5), 939–950. https://doi.org/10.1016/S1054-3139(03)00098-5

Heikinheimo O, P Rusanen and K Korhonen (2016). Estimating the mortality caused by great cormorant predation on fish stocks: pikeperch in the Archipelago Sea, northern Baltic Sea, as an example. *Canadian Journal of Fisheries and Aquatic Sciences*, 73 (1), 84–93. https://doi.org/10.1139/cjfas-2015-0033

Heikinheimo O, J Setälä, K Saarni and J Raitaniemi (2006). Impacts of mesh-size regulation of gillnets on the pikeperch fisheries in the Archipelago Sea, Finland. *Fisheries Research*, 77 (2), 192–199. https://doi.org/10.1016/j.fishres.2005.11.005

HELCOM (2006). *Assessment of Coastal Fish in the Baltic Sea*. Baltic Sea Environment Proceedings, No 103 A

HELCOM (2007). Baltic Sea Action Plan. *Proceedings of HELCOM Ministerial Meeting, Krakow, Poland*, November 15 2007. 101 pp

HELCOM (2010). *Ecosystem Health of the Baltic Sea 2003–2007: HELCOM Initial Holistic Assessment*. Baltic Sea Environment Proceedings, No 122. https://helcom.fi/wp-content/uploads/2019/08/BSEP122.pdf [2023-09-14]

HELCOM (2012). *Indicator-based assessment of coastal fish community status in the Baltic Sea 2005–2009*. Baltic Sea Environment Proceedings, No 131. https://helcom.fi/wp-content/uploads/2019/08/BSEP131.pdf [2022-10-06]

HELCOM (2013). *HELCOM core indicators: Final report of the HELCOM CORESET project*. Baltic Sea Environment Proceedings, No 136

HELCOM (2015). *Recreational fisheries in the Baltic Sea and availability of data*. HELCOM FISH-PRO II 2-2015, 4-1- Rev. 3. https://helcom.sharepoint.com/sites/archive/Meetings/Forms/AllItems.aspx?id=%2Fsites%2Farchive%2FMeetings%2Fdocuments%2FFISH%2DPRO%20II%202%2D2015%2F4%2D1%2DRev%2E3%20Recreational%20fisheries%20in%20the%20Baltic%20Sea%20and%20availability%20of%20data%2Epdf&parent=%2Fsites%2Farchive%2FMeetings%2Fdocuments%2FFISH%2DPRO%20II%202%2D2015&p=true&ga=1

HELCOM (2018a). *State of the Baltic Sea – Second HELCOM holistic assessment 2011-2016*. Baltic Sea Environment Proceedings, 155

HELCOM (2018b). *Status of coastal fish communities in the Baltic Sea during 2011-2016 – the third thematic assessment.* Baltic Sea Environment Proceedings, No 161. https://helcom.fi/wp-content/uploads/2018/11/BSEP161.pdf [2022-10-06]

HELCOM (2019). *Guidelines for coastal fish monitoring sampling methods of HELCOM*. https://helcom.fi/wp-content/uploads/2020/01/HELCOM-Guidelines-for-coastal-fish-monitoring-2019.pdf

HELCOM (2023a). *Abundance of coastal fish key functional groups*. HELCOM core indicator report. https://indicators.helcom.fi/wp-content/uploads/2023/04/coastal-fish-key-groups_Final_Febuary_2024.pdf

HELCOM (2023b). *Abundance of coastal fish key species*. HELCOM core indicator report. https://indicators.helcom.fi/wp-content/uploads/2023/04/Coastal-fish-key-species_Final_Febuary_2024.pdf

HELCOM (2023c). *HELCOM Thematic assessment of biodiversity 2016-2021*. Baltic Sea Environment Proceedings, No 191. https://helcom.fi/wp-content/uploads/2023/03/HELCOM-Thematic-assessment-of-biodiversity-2016-2021-Main-report.pdf

HELCOM (2023d). *Size structure of coastal fish*. https://indicators.helcom.fi/wp-content/uploads/2023/04/coastal-fish-size-indicator_Final_Febuary_2024.pdf

Hempel M, R Neukamm and R Thiel (2016). Effects of introduced round goby (*Neogobius melanostomus*) on diet composition and growth of zander (*Sander lucioperca*), a main predator in European brackish waters. *Aquatic Invasions*, 11 (2), 167–178. https://doi.org/10.3391/ai.2016.11.2.06

Herlevi H, K Aarnio, R Puntila-Dodd and E Bonsdorff (2018). The food web positioning and trophic niche of the non-indigenous round goby: a comparison between two Baltic Sea populations. *Hydrobiologia*, 822 (1), 111–128. https://doi.org/10.1007/s10750-018-3667-z

Herlevi H, I Wallin Kihlberg, K Aarnio, E Bonsdorff, A-B Florin, A Ljung, K Lundström, J Mattila and Ö Östman (2023). Environmental abundances of the non-native round goby *Neogobius melanostomus* influence feeding of native fish predators. *Journal of Fish Biology*, 102 (6), 1340–1357. https://doi.org/10.1111/jfb.15380

Hinrichsen H-H, B von Dewitz, J Dierking, H Haslob, A Makarchouk, C Petereit and R Voss (2016). Oxygen depletion in coastal seas and the effective spawning stock biomass of an exploited fish species. *Royal Society Open Science*, 3 (1), 150338. https://doi.org/10.1098/rsos.150338

Hinrichsen H-H, K Hüssy and B Huwer (2012). Spatio-temporal variability in western Baltic cod early life stage survival mediated by egg buoyancy, hydrography and hydrodynamics. *ICES Journal of Marine Science*, 69 (10), 1744–1752. https://doi.org/10.1093/icesjms/fss137

Hjerne O and S Hansson (2002). The role of fish and fisheries in Baltic Sea nutrient dynamics. *Limnology and Oceanography*, 47 (4), 1023–1032. https://doi.org/10.4319/lo.2002.47.4.1023

Holmes M, J Kotta, A Persson and U Sahlin (2019). Marine protected areas modulate habitat suitability of the invasive round goby (*Neogobius melanostomus*) in the Baltic Sea. *Estuarine, Coastal and Shelf Science*, 229, 106380. https://doi.org/10.1016/j.ecss.2019.106380

Huss M, M Lindmark, P Jacobson, RM van Dorst and A Gårdmark (2019). Experimental evidence of gradual size-dependent shifts in body size and growth of fish in response to warming. *Global Change Biology*, 25 (7), 2285–2295. https://doi.org/10.1111/gcb.14637

Hyder K, MS Weltersbach, M Armstrong, K Ferter, B Townhill, A Ahvonen, R Arlinghaus, A Baikov, M Bellanger, J Birzaks, T Borch, G Cambie, M de Graaf, HMC Diogo, Ł Dziemian, A Gordoa, R Grzebielec, B Hartill, A Kagervall, K Kapiris, M Karlsson, AR Kleiven, AM Lejk, H Levrel, S Lovell, J Lyle, P Moilanen, G Monkman, B Morales-Nin, E Mugerza, R Martinez, P O'Reilly, HJ Olesen, A Papadopoulos, P Pita, Z Radford, K Radtke, W Roche, D Rocklin, J Ruiz, C Scougal, R Silvestri, C Skov, S Steinback, A Sundelöf, A Svagzdys, D Turnbull, T van der Hammen, D van Voorhees, F van Winsen, T Verleye, P Veiga, J-H Vølstad, L Zarauz, T Zolubas and HV Strehlow (2018). Recreational sea fishing in Europe in a global context—Participation rates, fishing effort, expenditure, and implications for monitoring and assessment. *Fish and Fisheries*, 19 (2), 225–243. https://doi.org/10.1111/faf.12251

ICES (2020). Baltic Salmon and Trout Assessment Working Group. https://doi.org/10.17895/ICES.PUB.5974

ICES (2022a). *Baltic Fisheries Assessment Working Group (WGBFAS)*. ICES Scientific Reports, 4:44. http://doi.org/10.17895/ices.pub.19793014

ICES (2022b). *Baltic Sea ecoregion – fisheries overview*. In Report of the ICES Advisory Committee, 2022. ICES Advice 2022, section 4.2. https://doi.org/10.17895/ices.advice.21646934

ICES (2023). *ICES Advice 2023*. ICES Advice 2023

Illing B, M Moyano, M Hufnagl and MA Peck (2016). Projected habitat loss for Atlantic herring in the Baltic Sea. *Marine Environmental Research*, 113, 164–173. https://doi.org/10.1016/j.marenvres.2015.12.007

IPBES (2019). *Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*. The Global Assessment Report on Biodiversity and Ecosystem Services: Summary for Policymakers Policymakers (eds Díaz, S. et al.)

Jacobson P, U Bergström and J Eklöf (2019). Size-dependent diet composition and feeding of Eurasian perch (*Perca fluviatilis*) and northern pike (*Esox lucius*) in the Baltic Sea. 24, 137–153

Jakubavičiūtė E, U Bergström, JS Eklöf, Q Haenel and SJ Bourlat (2017). DNA metabarcoding reveals diverse diet of the three-spined stickleback in a coastal ecosystem. *PLOS ONE*, 12 (10), e0186929. https://doi.org/10.1371/journal.pone.0186929

Jernberg S, H Kuosa, C Boström, D Burdon, F Haavisto, A-S Heiskanen, S Kiviluoto, S Kuningas, M Kunnasranta, L Uusitalo, A Villnäs, M Westerbom and K Kostamo (2024). Linking natural capital stocks with ecosystem services in the Northern Baltic Sea. *Ecosystem Services*, 65, 101585. https://doi.org/10.1016/j.ecoser.2023.101585

Johannesson K and C André (2006). INVITED REVIEW: Life on the margin: genetic isolation and diversity loss in a peripheral marine ecosystem, the Baltic Sea. *Molecular Ecology*, 15 (8), 2013–2029. https://doi.org/10.1111/j.1365-294X.2006.02919.x

Jokinen H, H Wennhage, A Lappalainen, K Ådjers, M Rask and A Norkko (2015). Decline of flounder (*Platichthys flesus* (L.)) at the margin of the species' distribution range. *Journal of Sea Research*, 105, 1–9. https://doi.org/10.1016/j.seares.2015.08.001

Jokinen H, H Wennhage, V Ollus, E Aro and A Norkko (2016). Juvenile flatfish in the northern Baltic Sea — long-term decline and potential links to habitat characteristics. *Journal of Sea Research*, 107, 67–75. https://doi.org/10.1016/j.seares.2015.06.002

De Jong MF, MJ Baptist, R van Hal, IJ de Boois, HJ Lindeboom and P Hoekstra (2014). Impact on demersal fish of a large-scale and deep sand extraction site with ecosystem-based landscaped sandbars. *Estuarine, Coastal and Shelf Science*, 146, 83–94. https://doi.org/10.1016/j.ecss.2014.05.029

Jørgensen HBH, MM Hansen, D Bekkevold, DE Ruzzante and V Loeschcke (2005). Marine landscapes and population genetic structure of herring (Clupea harengus L.) in the Baltic Sea. *Molecular Ecology*, 14 (10), 3219–3234. https://doi.org/10.1111/j.1365-294X.2005.02658.x

Karås P and G Thoresson (1992). An application of a bioenergetics model to Eurasian perch (*Perca fluviatilis L.*). *Journal of Fish Biology*, 41 (2), 217–230. https://doi.org/10.1111/j.1095-8649.1992.tb02652.x

Karlson AML, G Almqvist, KE Skóra and M Appelberg (2007). Indications of competition between non-indigenous round goby and native flounder in the Baltic Sea. *ICES Journal of Marine Science*, 64 (3), 479–486. https://doi.org/10.1093/icesjms/fsl049

Karlsson M, HR Stabo and E Petersson (2014). *Nationell plan för kunskapsförsörjning om fritidsfiske inom fisk-, havs- och vattenförvaltningen.* Aqua reports 2014:12. Drottningholm, Sweden: Department of Aquatic Resources, Swedish University of Agricultural Sciences.

van Katwijk MM, A Thorhaug, N Marbà, RJ Orth, CM Duarte, GA Kendrick, IHJ Althuizen, E Balestri, G Bernard, ML Cambridge, A Cunha, C Durance, W Giesen, Q Han, S Hosokawa, W Kiswara, T Komatsu, C Lardicci, K-S Lee, A Meinesz, M Nakaoka, KR O'Brien, EI Paling, C Pickerell, AMA Ransijn and JJ Verduin (2016). Global analysis of seagrass restoration: the importance of large-scale planting. *Journal of Applied Ecology*, 53 (2), 567–578. https://doi.org/10.1111/1365-2664.12562

Kijewska A, H Kalamarz-Kubiak, B Arciszewski, T Guellard, C Petereit and R Wenne (2016). Adaptation to salinity in Atlantic cod from different regions of the Baltic Sea. *Journal of Experimental Marine Biology and Ecology*, 478, 62–67. https://doi.org/10.1016/j.jembe.2016.02.003

Koehler B, M Erlandsson, M Karlsson and L Bergström (2022). Species richness and functional attributes of fish assemblages across a large-scale salinity gradient in shallow coastal areas. *Biogeosciences*, 19 (8), 2295–2312. https://doi.org/10.5194/bg-19-2295-2022

Kraufvelin P, AC Bryhn, J Kling and J Olsson (2021a). *Fysisk påverkan i kusten och effekter på ekosystemen [in Swedish]*. Havs- och vattenmyndighetens rapport, 2020:27: 213

Kraufvelin P, J Olsson, U Bergström, AC Bryhn and L Bergström (2021b). *Restoration measures for coastal habitats in the Baltic Sea: cost-efficiency and areas of highest significance and need*. HELCOM ACTION

Kraufvelin P, Z Pekcan-Hekim, U Bergström, A-B Florin, A Lehikoinen, J Mattila, T Arula, L Briekmane, EJ Brown, Z Celmer, J Dainys, H Jokinen, P Kääriä, M Kallasvuo, A Lappalainen, L Lozys, P Möller, A Orio, M Rohtla, L Saks, M Snickars, J Støttrup, G Sundblad, I Taal, D Ustups, A Verliin, M Vetemaa, H Winkler, A Wozniczka and J Olsson (2018). Essential coastal habitats for fish in the Baltic Sea. *Estuarine, Coastal and Shelf Science*, 204, 14–30. https://doi.org/10.1016/j.ecss.2018.02.014

Kristensen LD, C Stenberg, JG Støttrup, LK Poulsen, HT Christensen, A Landes, M Røjbek, SW Thorsen, M Holmer, MV Deurs and P Grønkjær (2015). Establishment of blue mussel beds to enhance fish habitats. *Applied Ecology and Environmental Research*, (3). https://doi.org/10.15666/aeer/1303_783798

Kruze E, A Avotins, L Rozenfelde, I Putnis, I Sics, L Briekmane and J Olsson (2023). The Population Development of the Invasive Round Goby Neogobius melanostomus in Latvian Waters of the Baltic Sea. *Fishes*, 8 (6), 305. https://doi.org/10.3390/fishes8060305

Laikre L, LM Miller, A Palmé, S Palm, AR Kapuscinski, G Thoresson and N Ryman (2005). Spatial genetic structure of northern pike (Esox lucius) in the Baltic Sea. *Molecular Ecology*, 14 (7), 1955–1964. https://doi.org/10.1111/j.1365-294X.2005.02570.x

Lappalainen A (2002). The Effects of Recent Eutrophication on Freshwater Fish Communities and Fishery on the Northern Coast of the Gulf of Finland, Baltic Sea.

Lappalainen A, O Heikinheimo, J Raitaniemi and L Puura (2019). *Tehostetun pyynnin vaikutuksista Saaristomeren lahna- ja särkikantoihin*. Luonnonvara- ja biotalouden tutkimus, 74/2019. Helsinki: Luonnonvarakeskus.

Lappalainen A, L Saks, M Šuštar, O Heikinheimo, K Jürgens, E Kokkonen, M Kurkilahti, A Verliin and M Vetemaa (2016). Length at maturity as a potential indicator of fishing pressure effects on coastal pikeperch (*Sander lucioperca*) stocks in the northern Baltic Sea. *Fisheries Research*, 174, 47–57. https://doi.org/10.1016/j.fishres.2015.08.013

Larsson P, P Tibblin, P Koch-Schmidt, O Engstedt, J Nilsson, O Nordahl and A Forsman (2015). Ecology, evolution, and management strategies of northern pike populations in the Baltic Sea. *Ambio*, 44 (Suppl 3), 451–461. https://doi.org/10.1007/s13280-015-0664-6

Lefcheck JS, BB Hughes, AJ Johnson, BW Pfirrmann, DB Rasher, AR Smyth, BL Williams, MW Beck and RJ Orth (2019). Are coastal habitats important nurseries? A meta-analysis. *Conservation Letters*, 12 (4), e12645. https://doi.org/10.1111/conl.12645

Lehikoinen A, O Heikinheimo and A Lappalainen (2011). Temporal changes in the diet of great cormorant (*Phalacrocorax carbo sinensis*) on the southern coast of Finland — comparison with available fish data. 16

Lehikoinen A, O Heikinheimo, H Lehtonen and P Rusanen (2017). The role of cormorants, fishing effort and temperature on the catches per unit effort of fisheries in Finnish coastal areas. *Fisheries Research*, 190, 175–182. https://doi.org/10.1016/j.fishres.2017.02.008

Lehtonen H and J Lappalainen (1995). The effects of climate on the year-class variations of certain freshwater fish species. In: *Climate Change and Northern Fish Populations*. Canadian Special Publication of Fisheries and Aquatic Sciences. 37–44.

Lehtonen TK and C Kvarnemo (2015). Infections may select for filial cannibalism by impacting egg survival in interactions with water salinity and egg density. *Oecologia*, 178 (3), 673–683. https://doi.org/10.1007/s00442-015-3246-1

Lewin W-C, F Barz, MS Weltersbach and HV Strehlow (2023). Trends in a European coastal fishery with a special focus on small-scale fishers – Implications for fisheries policies and management. *Marine Policy*, 155, 105680. https://doi.org/10.1016/j.marpol.2023.105680

Lilley RJ and RKF Unsworth (2014). Atlantic Cod (*Gadus morhua*) benefits from the availability of seagrass (*Zostera marina*) nursery habitat. *Global Ecology and Conservation*, 2, 367–377. https://doi.org/10.1016/j.gecco.2014.10.002

Lindeboom H (2002). The Coastal Zone: An Ecosystem Under Pressure. In: *Oceans 2020: Science, Trends, and the Challenge of Sustainability*. Island Press.

Lindmark M, A Audzijonyte, JL Blanchard and A Gårdmark (2022). Temperature impacts on fish physiology and resource abundance lead to faster growth but smaller fish sizes and yields under warming. *Global Change Biology*, 28 (21), 6239–6253. https://doi.org/10.1111/gcb.16341

Lindmark M, M Karlsson and A Gårdmark (2023). Larger but younger fish when growth outpaces mortality in heated ecosystem. *eLife*, 12, e82996. https://doi.org/10.7554/eLife.82996

Ljunggren L and A Sandström (2007). Influence of visual conditions on foraging and growth of juvenile fishes with dissimilar sensory physiology. *Journal of Fish Biology*, 70 (5), 1319–1334. https://doi.org/10.1111/j.1095-8649.2007.01412.x

Ljunggren L, A Sandström, U Bergström, J Mattila, A Lappalainen, G Johansson, G Sundblad, M Casini, O Kaljuste and BK Eriksson (2010). Recruitment failure of coastal predatory fish in the Baltic Sea coincident with an offshore ecosystem regime shift. *ICES Journal of Marine Science*, 67 (8), 1587–1595. https://doi.org/10.1093/icesjms/fsq109

Lorenzen K, MCM Beveridge and M Mangel (2012). Cultured fish: integrative biology and management of domestication and interactions with wild fish. *Biological Reviews*, 87 (3), 639–660. https://doi.org/10.1111/j.1469-185X.2011.00215.x

Loughlin K and K Clarke (2014). *A Review of Methods Used to Offset Residual Impacts of Development Projects on Fisheries Productivity.*

Mariani G, WWL Cheung, A Lyet, E Sala, J Mayorga, L Velez, SD Gaines, T Dejean, M Troussellier and D Mouillot (2020). Let more big fish sink: Fisheries prevent blue carbon sequestration—half in unprofitable areas. *Science Advances*, 6 (44), eabb4848. https://doi.org/10.1126/sciadv.abb4848

McAfee D, R Costanza and SD Connell (2021). Valuing marine restoration beyond the 'too small and too expensive.' *Trends in Ecology & Evolution*, 36 (11), 968–971. https://doi.org/10.1016/j.tree.2021.08.002

Miethe T, T Gröhsler, U Böttcher and C von Dorrien (2014). The effects of periodic marine inflow into the Baltic Sea on the migration patterns of Western Baltic spring-spawning herring. *ICES Journal of Marine Science*, 71 (3), 519–527. https://doi.org/10.1093/icesjms/fst166

Moksnes P-O, L Eriander, E Infantes and M Holmer (2018). Local Regime Shifts Prevent Natural Recovery and Restoration of Lost Eelgrass Beds Along the Swedish West Coast. *Estuaries and Coasts*, 41 (6), 1712–1731. https://doi.org/10.1007/s12237-018-0382-y

Moksnes PO, L Gipperth, L Eriander, K Laas, S Cole and E Infantes (2016). *Handbok för restaurering av ålgräs i Sverige: Vägledning*. Havs-och vattenmyndigheten

Möllmann C, R Diekmann, B Müller-Karulis, G Kornilovs, M Plikshs and P Axe (2009). Reorganization of a large marine ecosystem due to atmospheric and anthropogenic pressure: a discontinuous regime shift in the Central Baltic Sea. *Global Change Biology*, 15 (6), 1377–1393. https://doi.org/10.1111/j.1365-2486.2008.01814.x

Molloy PP, IB McLean and IM Côté (2009). Effects of marine reserve age on fish populations: a global meta-analysis. *Journal of Applied Ecology*, 46 (4), 743–751. https://doi.org/10.1111/j.1365-2664.2009.01662.x

Momigliano P, GPJ Denys, H Jokinen and J Merilä (2018). *Platichthys solemdali* sp. nov. (Actinopterygii, Pleuronectiformes): A New Flounder Species From the Baltic Sea. *Frontiers in Marine Science*, 5. https://www.frontiersin.org/articles/10.3389/fmars.2018.00225 [2023-08-07]

Mustamäki N, U Bergström, K Ådjers, A Sevastik and J Mattila (2014). Pikeperch (*Sander lucioperca* (L.)) in Decline: High Mortality of Three Populations in the Northern Baltic Sea. *Ambio*, 43. https://doi.org/10.1007/s13280-013-0429-z

Naddafi R, Ö Östman, L Bergström, N Mustamäki, M Appelberg and J Olsson (2022). Improving assessments of coastal ecosystems – Adjusting coastal fish indicators to variation in ambient environmental factors. *Ecological Indicators*, 145, 109604. https://doi.org/10.1016/j.ecolind.2022.109604

Nielsen EE, MM Hansen, DE Ruzzante, D Meldrup and P Grønkjær (2003). Evidence of a hybrid-zone in Atlantic cod (Gadus morhua) in the Baltic and the Danish Belt Sea revealed by individual admixture analysis. *Molecular Ecology*, 12 (6), 1497–1508. https://doi.org/10.1046/j.1365-294X.2003.01819.x

Nieminen E, H Ahtiainen, C-J Lagerkvist and S Oinonen (2019). The economic benefits of achieving Good Environmental Status in the Finnish marine waters of the Baltic Sea. *Marine Policy*, 99, 181–189. https://doi.org/10.1016/j.marpol.2018.10.014

Nilsson J (2006). Predation of Northern Pike (Esox lucius L.) Eggs: A Possible Cause of Regionally Poor Recruitment in the Baltic Sea. *Hydrobiologia*, 553 (1), 161–169. https://doi.org/10.1007/s10750-005-1949-8

Nilsson J, O Engstedt and P Larsson (2014). Wetlands for northern pike (Esox lucius L.) recruitment in the Baltic Sea. *Hydrobiologia*, 721 (1), 145–154. https://doi.org/10.1007/s10750-013-1656-9

Nilsson J, H Flink and P Tibblin (2019). Predator–prey role reversal may impair the recovery of declining pike populations. *Journal of Animal Ecology*, 88 (6), 927–939. https://doi.org/10.1111/1365-2656.12981

Nissling A and G Dahlman (2010). Fecundity of flounder, Pleuronectes flesus, in the Baltic Sea — Reproductive strategies in two sympatric populations. *Journal of Sea Research*, 64 (3), 190–198. https://doi.org/10.1016/j.seares.2010.02.001

Oesterwind D, C Bock, A Förster, M Gabel, C Henseler, P Kotterba, M Menge, D Myts and HM Winkler (2017). Predator and prey: the role of the round goby *Neogobius melanostomus* in the western Baltic. *Marine Biology Research*, 13 (2), 188–197. https://doi.org/10.1080/17451000.2016.1241412

Ojaveer H, A Jaanus, BR MacKenzie, G Martin, S Olenin, T Radziejewska, I Telesh, ML Zettler and A Zaiko (2010). Status of Biodiversity in the Baltic Sea. *PLOS ONE*, 5 (9), e12467. https://doi.org/10.1371/journal.pone.0012467

Olin AB, U Bergström, Ö Bodin, G Sundblad, BK Eriksson, M Erlandsson, R Fredriksson and JS Eklöf (2024). Predation and spatial connectivity interact to shape ecosystem resilience to an ongoing regime shift. *Nature Communications*, 15 (1), 1304. https://doi.org/10.1038/s41467-024-45713-1

Olin AB, J Olsson, JS Eklöf, BK Eriksson, O Kaljuste, L Briekmane and U Bergström (2022). Increases of opportunistic species in response to ecosystem change: the case of the Baltic Sea three-spined stickleback. *ICES Journal of Marine Science*, 79 (5), 1419–1434. https://doi.org/10.1093/icesjms/fsac073

Olin M, O Heikinheimo, TK Lehtonen and J Raitaniemi (2023). Long-term monitoring of pikeperch (Sander lucioperca) populations under increasing temperatures and predator abundances in the Finnish coastal waters of the Baltic Sea. *Ecology of Freshwater Fish*, 32 (4), 750–764. https://doi.org/10.1111/eff.12721

Olin M, J Jutila, H Lehtonen, M Vinni, J Ruuhijärvi, S Estlander, M Rask, A Kuparinen and J Lappalainen (2012). Importance of maternal size on the reproductive success of perch, *Perca fluviatilis*, in small forest lakes: implications for fisheries management. *Fisheries Management and Ecology*, 19 (5), 363–374. https://doi.org/10.1111/j.1365-2400.2012.00845.x

Olsson J (2019). Past and Current Trends of Coastal Predatory Fish in the Baltic Sea with a Focus on Perch, Pike, and Pikeperch. *Fishes*, 4 (1), 7. https://doi.org/10.3390/fishes4010007

Olsson J, L Bergström and A Gårdmark (2012a). Abiotic drivers of coastal fish community change during four decades in the Baltic Sea. *ICES Journal of Marine Science*, 69 (6), 961–970. https://doi.org/10.1093/icesjms/fss072

Olsson J, A-B Florin, K Mo, T Aho and N Ryman (2012b). Genetic structure of whitefish *(Coregonus maraena)* in the Baltic Sea. *Estuarine, Coastal and Shelf Science*, 97, 104–113. https://doi.org/10.1016/j.ecss.2011.11.032

Olsson J, K Mo, A-B Florin, T Aho and N Ryman (2011). Genetic population structure of perch *Perca fluviatilis* along the Swedish coast of the Baltic Sea. *Journal of Fish Biology*, 79 (1), 122–137. https://doi.org/10.1111/j.1095-8649.2011.02998.x

Olsson J, MT Tomczak, H Ojaveer, A Gårdmark, A Põllumäe, B Müller-Karulis, D Ustups, GE Dinesen, H Peltonen, I Putnis, L Szymanek, M Simm, O Heikinheimo, P Gasyukov, P Axe and L Bergström (2015). Temporal development of coastal ecosystems in the Baltic Sea over the past two decades. *ICES Journal of Marine Science*, 72 (9), 2539–2548. https://doi.org/10.1093/icesjms/fsv143

Orio A, U Bergström, M Casini, M Erlandsson, R Eschbaum, K Hüssy, A Lehmann, L Ložys, D Ustups and A-B Florin (2017). Characterizing and predicting the distribution of Baltic Sea flounder (*Platichthys flesus*) during the spawning season. *Journal of Sea Research*, 126, 46–55. https://doi.org/10.1016/j.seares.2017.07.002

Österblom H, S Hansson, U Larsson, O Hjerne, F Wulff, R Elmgren and C Folke (2007). Human-induced Trophic Cascades and Ecological Regime Shifts in the Baltic Sea. *Ecosystems*, 10 (6), 877–889. https://doi.org/10.1007/s10021-007-9069-0

Östman Ö, M Bergenius, MK Boström and S-G Lunneryd (2012). Do cormorant colonies affect local fish communities in the Baltic Sea? *Canadian Journal of Fisheries and Aquatic Sciences*, 69 (6), 1047–1055. https://doi.org/10.1139/f2012-042

Östman Ö, L Bergström, K Leonardsson, A Gårdmark, M Casini, Y Sjöblom, F Haas and J Olsson (2020). Analyses of structural changes in ecological time series (ASCETS). *Ecological Indicators*, 116, 106469. https://doi.org/10.1016/j.ecolind.2020.106469

Östman Ö, J Eklöf, BK Eriksson, J Olsson, P-O Moksnes and U Bergström (2016). Top-down control as important as nutrient enrichment for eutrophication effects in North Atlantic coastal ecosystems. *Journal of Applied Ecology*, 53 (4), 1138–1147. https://doi.org/10.1111/1365-2664.12654

Östman Ö, K Hommik, E Bolund, O Heikinheimo, M Olin, AM Lejk, R Svirgsden, S Smoliński and J Olsson (2023). Size-based indicators for assessments of ecological status of coastal fish communities. *ICES Journal of Marine Science*, 80 (10), 2478–2489. https://doi.org/10.1093/icesjms/fsad158

Östman Ö, A Lingman, L Bergström and J Olsson (2017a). Temporal development and spatial scale of coastal fish indicators in reference ecosystems: hydroclimate and anthropogenic drivers. *Journal of Applied Ecology*, 54 (2), 557–566. https://doi.org/10.1111/1365-2664.12719

Östman Ö, J Olsson, J Dannewitz, S Palm and A-B Florin (2017b). Inferring spatial structure from population genetics and spatial synchrony in demography of Baltic Sea fishes: implications for management. *Fish and Fisheries*, 18 (2), 324–339. https://doi.org/10.1111/faf.12182

Ovegård MK, N Jepsen, M Bergenius Nord and E Petersson (2021). Cormorant predation effects on fish populations: A global meta-analysis. *Fish and Fisheries*, 22 (3), 605–622. https://doi.org/10.1111/faf.12540

Palumbi SR (2003). Population Genetics, Demographic Connectivity, and the Design of Marine Reserves. *Ecological Applications*, 13 (sp1), 146–158. https://doi.org/10.1890/1051-0761(2003)013[0146:PGDCAT]2.0.CO;2

Pauly D, V Christensen, J Dalsgaard, R Froese and F Torres (1998). Fishing Down Marine Food Webs. *Science*, 279 (5352), 860–863. https://doi.org/10.1126/science.279.5352.860

Paxton AB, KW Shertzer, NM Bacheler, GT Kellison, KL Riley and JC Taylor (2020). Meta-Analysis Reveals Artificial Reefs Can Be Effective Tools for Fish Community Enhancement but Are Not One-Size-Fits-All. *Frontiers in Marine Science*, 7. https://doi.org/10.3389/fmars.2020.00282

Persson L, P Byström and E Wahlström (2000). Cannibalism and Competition in Eurasian Perch: Population Dynamics of an Ontogenetic Omnivore. *Ecology*, 81 (4), 1058–1071. https://doi.org/10.1890/0012-9658(2000)081[1058:CACIEP]2.0.CO;2

Petereit C, H-H Hinrichsen, A Franke and FW Köster (2014). Floating along buoyancy levels: Dispersal and survival of western Baltic fish eggs. *Progress in Oceanography*, 122, 131–152. https://doi.org/10.1016/j.pocean.2014.01.001

Puntila R, A-B Florin, R Naddafi, JW Behrens, J Kotta, S Smolinski and A Wozniczka (2018). Abundance and distribution of round goby (*Neogobius melanostomus*). 10

Pursiainen A, L Veneranta, S Kuningas, A Saarinen and M Kallasvuo (2021). The more sheltered, the better – Coastal bays and lagoons are important reproduction habitats for pike in the northern Baltic Sea. *Estuarine, Coastal and Shelf Science*, 259, 107477. https://doi.org/10.1016/j.ecss.2021.107477

R Core Team (2021). R: A language and environment for statistical computing. *R Foundation for Statistical Computing, Vienna, Austria*,. URL https://www.R-project.org/

Radinger J, S Matern, T Klefoth, C Wolter, F Feldhege, CT Monk and R Arlinghaus (2023). Ecosystem-based management outperforms species-focused stocking for enhancing fish populations. *Science*, 379 (6635), 946–951. https://doi.org/10.1126/science.adf0895

Rakauskas V, Ž Pūtys, J Dainys, J Lesutienė, L Ložpys and K Arbačiauskas (2013). Increasing Population of the Invader Round Goby, *Neogobius Melanostomus* (Actinopterygii: Perciformes: Gobiidae), and its Trophic Role in the Curonian Lagoon, Se Baltic Sea. *Acta Ichthyologica Et Piscatoria*, 43 (2), 95–108. https://doi.org/10.3750/AIP2013.43.2.02

Reusch TBH, J Dierking, HC Andersson, E Bonsdorff, J Carstensen, M Casini, M Czajkowski, B Hasler, K Hinsby, K Hyytiäinen, K Johannesson, S Jomaa, V Jormalainen, H Kuosa, S Kurland, L Laikre, BR MacKenzie, P Margonski, F Melzner, D Oesterwind, H Ojaveer, JC Refsgaard, A Sandström, G Schwarz, K Tonderski, M Winder and M Zandersen (2018). The Baltic Sea as a time machine for the future coastal ocean. *Science Advances*, 4 (5), eaar8195. https://doi.org/10.1126/sciadv.aar8195

Roberts CM and NVC Polunin (1991). Are marine reserves effective in management of reef fisheries? *Reviews in Fish Biology and Fisheries*, 1 (1), 65–91. https://doi.org/10.1007/BF00042662

Rohtla M, R Svirgsden, I Taal, L Saks, R Eschbaum and M Vetemaa (2015). Life-history characteristics of ide Leuciscus idus in the Eastern Baltic Sea. *Fisheries Management and Ecology*, 22 (3), 239–248. https://doi.org/10.1111/fme.12120

Rohtla M, M Vetemaa, I Taal, R Svirgsden, K Urtson, L Saks, A Verliin, M Kesler and T Saat (2014). Life history of anadromous burbot (Lota lota, Linneaus) in the brackish Baltic Sea inferred from otolith microchemistry. *Ecology of Freshwater Fish*, 23 (2), 141–148. https://doi.org/10.1111/eff.12057

Salmi JA, H Auvinen, J Raitaniemi, M Kurkilahti, J Lilja and R Maikola (2015). Perch (*Perca fluviatilis*) and pikeperch (*Sander lucioperca*) in the diet of the great cormorant (*Phalacrocorax carbo*) and effects on catches in the Archipelago Sea, Southwest coast of Finland. *Fisheries Research*, 164, 26–34. https://doi.org/10.1016/j.fishres.2014.10.011

Samy-Kamal M, A Forcada and JLS Lizaso (2015). Effects of seasonal closures in a multi-specific fishery. *Fisheries Research*, 172, 303–317. https://doi.org/10.1016/j.fishres.2015.07.027

Sandström A, BK Eriksson, P Karås, M Isæus and H Schreiber (2005). Boating and Navigation Activities Influence the Recruitment of Fish in a Baltic Sea Archipelago Area. *AMBIO: A Journal of the Human Environment*, 34 (2), 125–130. https://doi.org/10.1579/0044-7447-34.2.125

Saraiva S, HE Markus Meier, H Andersson, A Höglund, C Dieterich, M Gröger, R Hordoir and K Eilola (2019). Baltic Sea ecosystem response to various nutrient load scenarios in present and future climates. *Climate Dynamics*, 52 (5), 3369–3387. https://doi.org/10.1007/s00382-018-4330-0

Scotti M, S Opitz, L MacNeil, A Kreutle, C Pusch and R Froese (2022). Ecosystem-based fisheries management increases catch and carbon sequestration through recovery of exploited stocks: The western Baltic Sea case study. *Frontiers in Marine Science*, 9. https://doi.org/10.3389/fmars.2022.879998

Sieben K, L Ljunggren, U Bergström and BK Eriksson (2011). A meso-predator release of stickleback promotes recruitment of macroalgae in the Baltic Sea. *Journal of Experimental Marine Biology and Ecology*, 397 (2), 79–84. https://doi.org/10.1016/j.jembe.2010.11.020

Sköld M, P Börjesson, H Wennhage, J Hjelm, J Lövgren and K Ringdahl (2022). A no-take zone and partially protected areas are not enough to save the Kattegat cod, but enhance biomass and abundance of the local fish assemblage. *ICES Journal of Marine Science*, 79 (8), 2231–2246. https://doi.org/10.1093/icesjms/fsac152

Snickars M, B Weigel and E Bonsdorff (2015). Impact of eutrophication and climate change on fish and zoobenthos in coastal waters of the Baltic Sea. *Marine Biology*, 162 (1), 141–151. https://doi.org/10.1007/s00227-014-2579-3

Sparrevohn CR and M Storr-Paulsen (2012). *Eel, cod and seatrout harvest in Danish recreational fishing during 2011*. DTU Aqua report no. 253-2012. DTU Aqua. http://www.aqua.dtu.dk/Publikationer/Forskningsrapporter/Forskningsrapporter_siden_2008 [2024-04-02]

Stenberg C, JG Støttrup, M van Deurs, CW Berg, GE Dinesen, H Mosegaard, TM Grome and SB Leonhard (2015). Long-term effects of an offshore wind farm in the North Sea on fish communities. *Marine Ecology Progress Series*, 528, 257–265. https://doi.org/10.3354/meps11261

Støttrup JG, K Dahl, S Niemann, C Stenberg, J Reker, EM Stamphøj, C Göke and JC Svendsen (2017). Restoration of a boulder reef in temperate waters: Strategy, methodology and lessons learnt. *Ecological Engineering*, 102, 468–482. https://doi.org/10.1016/j.ecoleng.2017.02.058

Støttrup JG, A Kokkalis, EJ Brown, J Olsen, S Kærulf Andersen and EM Pedersen (2018). Harvesting geo-spatial data on coastal fish assemblages through coordinated citizen science. *Fisheries Research*, 208, 86–96. https://doi.org/10.1016/j.fishres.2018.07.015

Støttrup JG, C Stenberg, K Dahl, LD Kristensen and K Richardson (2014). Restoration of a Temperate Reef: Effects on the Fish Community. *Open Journal of Ecology*, 04 (16), 1045–1059. https://doi.org/10.4236/oje.2014.416086

Sundblad G, L Bergström, T Söderqvist and U Bergström (2020). Predicting the effects of eutrophication mitigation on predatory fish biomass and the value of recreational fisheries. *Ambio*, 49 (5), 1090–1099. https://doi.org/10.1007/s13280-019-01263-1

Sundblad G and U Bergström (2014). Shoreline development and degradation of coastal fish reproduction habitats. *AMBIO*, 43 (8), 1020–1028. https://doi.org/10.1007/s13280-014-0522-y

Sundblad G, U Bergström, A Sandström and P Eklöv (2014). Nursery habitat availability limits adult stock sizes of predatory coastal fish. *ICES Journal of Marine Science*, 71 (3), 672–680. https://doi.org/10.1093/icesjms/fst056

Sunde J, C Tamario, P Tibblin, P Larsson and A Forsman (2018). Variation in salinity tolerance between and within anadromous subpopulations of pike (*Esox lucius*). *Scientific Reports*, 8 (1), 22. https://doi.org/10.1038/s41598-017-18413-8

Tarkan AS and L Vilizzi (2015). Patterns, latitudinal clines and countergradient variation in the growth of roach *Rutilus rutilus* (Cyprinidae) in its Eurasian area of distribution. *Reviews in Fish Biology and Fisheries*, 25 (4), 587–602. https://doi.org/10.1007/s11160-015-9398-6

Thrush SF and PK Dayton (2010). What Can Ecology Contribute to Ecosystem-Based Management? *Annual Review of Marine Science*, 2 (Volume 2, 2010), 419–441. https://doi.org/10.1146/annurev-marine-120308-081129

Tomczak MT, B Müller-Karulis, T Blenckner, E Ehrnsten, M Eero, B Gustafsson, A Norkko, SA Otto, K Timmermann and C Humborg (2022). Reference state, structure, regime shifts, and regulatory drivers in a coastal sea over the last century: The Central Baltic Sea case. *Limnology and Oceanography*, 67 (S1), S266–S284. https://doi.org/10.1002/lno.11975

Tunney TD, KS McCann, NP Lester and BJ Shuter (2014). Effects of differential habitat warming on complex communities. *Proceedings of the National Academy of Sciences*, 111 (22), 8077–8082. https://doi.org/10.1073/pnas.1319618111

Uspenskiy A, Z Zhidkov and B Levin (2022). The Key Environmental Factors Shaping Coastal Fish Community in the Eastern Gulf of Finland, Baltic Sea. *Diversity*, 14 (11), 930. https://doi.org/10.3390/d14110930

Ustups D, U Bergström, AB Florin, E Kruze, D Zilniece, D Elferts, E Knospina and D Uzars (2016). Diet overlap between juvenile flatfish and the invasive round goby in the central Baltic Sea. *Journal of Sea Research*, 107, 121–129. https://doi.org/10.1016/j.seares.2015.06.021

Vaher A, J Kotta, R Szava-Kovats, A Kaasik, M Fetissov, R Aps and A Kõivupuu (2022). Assessing cumulative impacts of human-induced pressures on reef and sandbank habitats and associated biotopes in the northeastern Baltic Sea. *Marine Pollution Bulletin*, 183, 114042. https://doi.org/10.1016/j.marpolbul.2022.114042

Valdez SR, YS Zhang, T van der Heide, MA Vanderklift, F Tarquinio, RJ Orth and BR Silliman (2020). Positive Ecological Interactions and the Success of Seagrass Restoration. *Frontiers in Marine Science*, 7. https://doi.org/10.3389/fmars.2020.00091

Vandeperre F, RM Higgins, J Sánchez-Meca, F Maynou, R Goñi, P Martín-Sosa, A Pérez-Ruzafa, P Afonso, I Bertocci, R Crec'hriou, G D'Anna, M Dimech, C Dorta, O Esparza, JM Falcón, A Forcada, I Guala, L Le Direach, C Marcos, C Ojeda-Martínez, C Pipitone, PJ Schembri, V Stelzenmüller, B Stobart and RS Santos (2011). Effects of no-take area size and age of marine protected areas on fisheries yields: a meta-analytical approach. *Fish and Fisheries*, 12 (4), 412–426. https://doi.org/10.1111/j.1467-2979.2010.00401.x

Vanni MJ, G Boros and PB McIntyre (2013). When are fish sources vs. sinks of nutrients in lake ecosystems? *Ecology*, 94 (10), 2195–2206. https://doi.org/10.1890/12-1559.1

Veneranta L, O Heikinheimo and TJ Marjomäki (2020). Cormorant (*Phalacrocorax carbo*) predation on a coastal perch (*Perca fluviatilis*) population: estimated effects based on PIT tag mark-recapture experiment. Durif, C. (ed.) (Durif, C., ed.) *ICES Journal of Marine Science*, 77 (7–8), 2611–2622. https://doi.org/10.1093/icesjms/fsaa124

Veneranta L, R Hudd and J Vanhatalo (2013). Reproduction areas of sea-spawning coregonids reflect the environment in shallow coastal waters. *Marine Ecology Progress Series*, 477, 231–250. https://doi.org/10.3354/meps10169

Veneranta L, I Kallio-Nyberg, I Saloniemi and E Jokikokko (2021). Changes in age and maturity of anadromous whitefish (*Coregonus lavaretus*) in the northern Baltic Sea from 1998 to 2014. *Aquatic Living Resources*, 34, 9. https://doi.org/10.1051/alr/2021007

Vetemaa M, R Eschbaum, A Albert, L Saks, A Verliin, K Jürgens, M Kesler, K Hubel, R Hannesson and T Saat (2010). Changes in fish stocks in an Estonian estuary: overfishing by cormorants? *ICES Journal of Marine Science*, 67 (9), 1972–1979. https://doi.org/10.1093/icesjms/fsq113

Viitasalo M and E Bonsdorff (2022). Global climate change and the Baltic Sea ecosystem: direct and indirect effects on species, communities and ecosystem functioning. *Earth System Dynamics*, 13 (2), 711–747. https://doi.org/10.5194/esd-13-711-2022

Wallin Kihlberg I, A-B Florin, K Lundström and Ö Östman (2023). Detection of multiple fish species in the diet of the invasive round goby reveals new trophic interactions in the Baltic Sea. *Aquatic Invasions*, 18 (2), 141–162. https://doi.org/10.3391/ai.2023.18.2.104960

Wennerström L, E Jansson and L Laikre (2017). Baltic Sea genetic biodiversity: Current knowledge relating to conservation management. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 27 (6), 1069–1090. https://doi.org/10.1002/aqc.2771

Wennerström L, L Laikre, N Ryman, FM Utter, NI Ab Ghani, C André, J DeFaveri, D Johansson, L Kautsky, J Merilä, N Mikhailova, R Pereyra, A Sandström, AGF Teacher, R Wenne, A Vasemägi, M Zbawicka, K Johannesson and CR Primmer (2013). Genetic biodiversity in the Baltic Sea: species-specific patterns challenge management. *Biodiversity and Conservation*, 22 (13), 3045–3065. https://doi.org/10.1007/s10531-013-0570-9

Wennhage H and L Pihl (1994). Substratum selection by juvenile plaice (*Pleuronectes platessa* L.): Impact of benthic microalgae and filamentous macroalgae. *Netherlands Journal of Sea Research*, 32 (3), 343–351. https://doi.org/10.1016/0077-7579(94)90011-6

Ziegler SL, JM Johnson, RO Brooks, EM Johnston, JL Mohay, BI Ruttenberg, RM Starr, GT Waltz, DE Wendt and SL Hamilton (2023). Marine protected areas, marine heatwaves, and the resilience of nearshore fish communities. *Scientific Reports*, 13 (1), 1405. https://doi.org/10.1038/s41598-023-28507-1

Appendix 1.
Detailed indicator evaluation results

Abundance of coastal fish key species

Key species results Tables

Appendix result Table 1. Data and methods used for the key species status evaluation, per monitoring location and assessment unit. Column headings provide the following information: geographic location, the time period assessed, the key species used, the monitoring method, and the assessment approach applied.

Sub-basin	Country	Coastal area name (assessment unit)	Coastal area code	Monitoring area/data set	Time period assessed	Key species	Monitoring method	Assessment method
Bothnian Bay	Finland	Bothnian Bay Finnish Coastal waters	1	Finnish ICES SD 31	1998-2020	Perch	Commercial statistics	ASCETS
Bothnian Bay	Sweden	Bothnian Bay Swedish Coastal waters	2	Råneå	2002-2020	Perch	Fisheries independent data	ASCETS
Bothnian Bay	Sweden	Bothnian Bay Swedish Coastal waters	2	Råneå	2002-2020	Pike	Fisheries independent data	ASCETS
Bothnian Bay	Sweden	Bothnian Bay Swedish Coastal waters	2	Råneå	2002-2020	Whitefish	Fisheries independent data	ASCETS
Bothnian Bay	Sweden	Bothnian Bay Swedish Coastal waters	2	Kinnbäcksfjärden	2004-2020	Perch	Fisheries independent data	ASCETS
Bothnian Bay	Sweden	Bothnian Bay Swedish Coastal waters	2	Kinnbäcksfjärden	2004-2020	Whitefish	Fisheries independent data	ASCETS
The Quark	Finland	The Quark Finnish Coastal waters	3	Finnish ICES rect 23	1998-2020	Perch	Commercial statistics	ASCETS
The Quark	Finland	The Quark Finnish Coastal waters	3	Finnish ICES rect 28	1998-2020	Perch	Commercial statistics	ASCETS
The Quark	Sweden	The Quark Swedish Coastal waters	4	Holmön	2002-2020	Perch	Fisheries independent data	ASCETS
The Quark	Sweden	The Quark Swedish Coastal waters	4	Holmön	2002-2020	Whitefish	Fisheries independent data	ASCETS
The Quark	Sweden	The Quark Swedish Coastal waters	4	Norrbyn	2002-2020	Perch	Fisheries independent data	ASCETS
The Quark	Sweden	The Quark Swedish Coastal waters	4	Norrbyn	2002-2020	Whitefish	Fisheries independent data	ASCETS
Bothnian Sea	Finland	Bothnian Sea Finnish Coastal waters	5	Finnish ICES SD 30	1998-2020	Perch	Commercial statistics	ASCETS
Bothnian Sea	Finland	Bothnian Sea Finnish Coastal waters	5	Finnish ICES SD 30	1998-2020	Pikeperch	Commercial statistics	ASCETS
Bothnian Sea	Sweden	Bothnian Sea Swedish Coastal waters	6	Gaviksfjärden	2004-2020	Perch	Fisheries independent data	ASCETS
Bothnian Sea	Sweden	Bothnian Sea Swedish Coastal waters	6	Gaviksfjärden	2004-2020	Whitefish	Fisheries independent data	ASCETS
Bothnian Sea	Sweden	Bothnian Sea Swedish Coastal waters	6	Långvindsfjärden	2002-2020	Perch	Fisheries independent data	ASCETS
Bothnian Sea	Sweden	Bothnian Sea Swedish Coastal waters	6	Forsmark	2002-2020	Perch	Fisheries independent data	ASCETS
Bothnian Sea	Sweden	Bothnian Sea Swedish Coastal waters	6	Forsmark	2002-2020	Pikeperch	Fisheries independent data	ASCETS
Bothnian Sea	Sweden	Bothnian Sea Swedish Coastal waters	6	Forsmark	2002-2020	Whitefish	Fisheries independent data	ASCETS
Åland Sea	Finland	Åland Sea Finnish Coastal waters	7	NA	NA	NA	NA	NA
Åland Sea	Sweden	Åland Sea Swedish Coastal waters	8	Galtfjärden	2002-2020	Perch	Fisheries independent data	ASCETS
Åland Sea	Sweden	Åland Sea Swedish Coastal waters	8	Galtfjärden	2002-2020	Pikeperch	Fisheries independent data	ASCETS
Åland Sea	Sweden	Åland Sea Swedish Coastal waters	8	Galtfjärden	2002-2020	Whitefish	Fisheries independent data	ASCETS
Åland Sea	Sweden	Åland Sea Swedish Coastal waters	8	Lagnö	2002-2020	Perch	Fisheries independent data	ASCETS
Åland Sea	Sweden	Åland Sea Swedish Coastal waters	8	Lagnö	2002-2020	Pike	Fisheries independent data	ASCETS
Åland Sea	Sweden	Åland Sea Swedish Coastal waters	8	Lagnö	2002-2020	Whitefish	Fisheries independent data	ASCETS
Archipelago Sea	Finland	Archipelago Sea Coastal waters	9	Finbo	2002-2020	Perch	Fisheries independent data	ASCETS
Archipelago Sea	Finland	Archipelago Sea Coastal waters	9	Finbo	2002-2020	Pike	Fisheries independent data	ASCETS
Archipelago Sea	Finland	Archipelago Sea Coastal waters	9	Finbo	2002-2020	Pikeperch	Fisheries independent data	ASCETS
Archipelago Sea	Finland	Archipelago Sea Coastal waters	9	Kumlinge	2002-2020	Perch	Fisheries independent data	ASCETS
Archipelago Sea	Finland	Archipelago Sea Coastal waters	9	Kumlinge	2002-2020	Whitefish	Fisheries independent data	ASCETS
Archipelago Sea	Finland	Archipelago Sea Coastal waters	9	Finnish ICES SD 29	1998-2020	Perch	Commercial statistics	ASCETS
Archipelago Sea	Finland	Archipelago Sea Coastal waters	9	Finnish ICES SD 29	1998-2020	Pikeperch	Commercial statistics	ASCETS
Northern Baltic Sea	Finland	Northern Baltic Proper Finnish Coastal waters	10	NA	NA	NA	NA	NA
Northern Baltic Sea	Sweden	Northern Baltic Proper Swedish Coastal waters	11	Vaxholm: Askrikefjärden	2016-2020	Perch	Fisheries independent data	Trend
Northern Baltic Sea	Sweden	Northern Baltic Proper Swedish Coastal waters	11	Vaxholm: Askrikefjärden	2016-2020	Pikeperch	Fisheries independent data	Trend
Northern Baltic Sea	Sweden	Northern Baltic Proper Swedish Coastal waters	11	Askö	2005-2020	Perch	Fisheries independent data	ASCETS
Northern Baltic Sea	Sweden	Northern Baltic Proper Swedish Coastal waters	11	Askö	2005-2020	Pike	Fisheries independent data	ASCETS
Northern Baltic Sea	Sweden	Northern Baltic Proper Swedish Coastal waters	11	Askö	2005-2020	Whitefish	Fisheries independent data	ASCETS
Northern Baltic Sea	Sweden	Northern Baltic Proper Swedish Coastal waters	11	Muskö	1992-2020	Flounder	Fisheries independent data	ASCETS
Northern Baltic Sea	Estonia	Northern Baltic Proper Estonian Coastal waters	12	NA	NA	NA	NA	NA

Appendix result Table 1. (Continued). Data and methods used for the key species status evaluation, per monitoring location and assessment unit. Column headings provide the following information: geographic location, the time period assessed, the key species used, the monitoring method, and the assessment approach applied.

Sub-basin	Country	Coastal area name (assessment unit)	Coastal area code	Monitoring area/data set	Time period assessed	Key species	Monitoring method	Assessment method
Gulf of Finland	Finland	Gulf of Finland Finnish Coastal waters	13	Brunskär	2002-2020	Perch	Fisheries independent data	ASCETS
Gulf of Finland	Finland	Gulf of Finland Finnish Coastal waters	13	Tvärminne	2005-2020	Perch	Fisheries independent data	ASCETS
Gulf of Finland	Finland	Gulf of Finland Finnish Coastal waters	13	Helsinki	2005-2020	Perch	Fisheries independent data	ASCETS
Gulf of Finland	Finland	Gulf of Finland Finnish Coastal waters	13	Finnish ICES SD 32	1998-2020	Perch	Commercial statistics	ASCETS
Gulf of Finland	Finland	Gulf of Finland Finnish Coastal waters	13	Finnish ICES SD 32	1998-2020	Pikeperch	Commercial statistics	ASCETS
Gulf of Finland	Estonia	Gulf of Finland Estonian Coastal waters	14	NA	NA	NA	NA	NA
Gulf of Finland	Russia	Gulf of Finland Russian Coastal waters	15	NA	NA	NA	NA	NA
Gulf of Riga	Estonia	Gulf of Riga Estonian Coastal waters	16	Hiiumaa	1991-2020	Perch	Fisheries independent data	ASCETS
Gulf of Riga	Latvia	Gulf of Riga Latvian Coastal waters	17	Daugavgriva	2016-2020	Perch	Fisheries independent data	Trend
Gulf of Riga	Latvia	Gulf of Riga Latvian Coastal waters	17	Daugavgriva	2016-2020	Pikeperch	Fisheries independent data	Trend
Western Gotland Basin	Sweden	Western Gotland Basin Swedish Coastal waters	18	Kvädöfjärden, summer	2002-2020	Perch	Fisheries independent data	ASCETS
Western Gotland Basin	Sweden	Western Gotland Basin Swedish Coastal waters	18	Kvädöfjärden, summer	2002-2020	Pike	Fisheries independent data	ASCETS
Western Gotland Basin	Sweden	Western Gotland Basin Swedish Coastal waters	18	Kvädöfjärden, summer	2002-2022	Pikeperch	Fisheries independent data	ASCETS
Western Gotland Basin	Sweden	Western Gotland Basin Swedish Coastal waters	18	Kvädöfjärden, autumn	1998-2020	Flounder	Fisheries independent data	ASCETS
Western Gotland Basin	Sweden	Western Gotland Basin Swedish Coastal waters	18	Kvädöfjärden, autumn	1998-2020	Whitefish	Fisheries independent data	ASCETS
Western Gotland Basin	Sweden	Western Gotland Basin Swedish Coastal waters	18	Vinö	2007-2020	Perch	Fisheries independent data	ASCETS
Western Gotland Basin	Sweden	Western Gotland Basin Swedish Coastal waters	18	Vinö	2007-2020	Pike	Fisheries independent data	ASCETS
Eastern Gotland Basin	Estonia	Eastern Gotland Basin Estonian Coastal waters	19	NA	NA	NA	NA	NA
Eastern Gotland Basin	Latvia	Eastern Gotland Basin Latvian Coastal waters	20	Jurkalne	2016-2020	Flounder	Fisheries independent data	Trend
Eastern Gotland Basin	Lithuania	Eastern Gotland Basin Lithuanian Coastal waters	21	Mon/But	1998-2020	Flounder	Fisheries independent data	ASCETS
Eastern Gotland Basin	Lithuania	Eastern Gotland Basin Lithuanian Coastal waters	21	Šventoji	2000-2020	Flounder	Fisheries independent data	ASCETS
Eastern Gotland Basin	Lithuania	Eastern Gotland Basin Lithuanian Coastal waters	21	Karklė	2000-2020	Flounder	Fisheries independent data	Trend
Eastern Gotland Basin	Lithuania	Eastern Gotland Basin Lithuanian Coastal waters	21	Smiltynė	2000-2020	Flounder	Fisheries independent data	ASCETS
Eastern Gotland Basin	Lithuania	Eastern Gotland Basin Lithuanian Coastal waters	21	Curonian lagoon	1998-2020	Perch	Fisheries independent data	ASCETS
Eastern Gotland Basin	Lithuania	Eastern Gotland Basin Lithuanian Coastal waters	22	Curonian lagoon	1998-2020	Pikeperch	Fisheries independent data	ASCETS
Eastern Gotland Basin	Sweden	Eastern Gotland Basin Swedish Coastal waters	22	Herrvik	2018-2020	Flounder	Fisheries independent data	Trend
Eastern Gotland Basin	Russian	Eastern Gotland Basin Russian Coastal waters	23	NA	NA	NA	NA	NA
Eastern Gotland Basin	Poland	Eastern Gotland Basin Polish Coastal waters	24	NA	NA	NA	NA	NA
Gdansk Basin	Russia	Gdansk Basin Russian Coastal waters	25	NA	NA	NA	NA	NA
Gdansk Basin	Poland	Gdansk Basin Polish Coastal waters	26	Zatoka Pucka Zewnętrzna	2011-2020	Perch	Fisheries independent data	Trend
Gdansk Basin	Poland	Gdansk Basin Polish Coastal waters	26	Zatoka Pucka Zewnętrzna	2011-2020	Flounder	Fisheries independent data	Trend
Gdansk Basin	Poland	Gdansk Basin Polish Coastal waters	26	Zalew Pucki	2011-2020	Perch	Fisheries independent data	Trend
Gdansk Basin	Poland	Gdansk Basin Polish Coastal waters	26	Zalew Pucki	2011-2020	Flounder	Fisheries independent data	Trend
Gdansk Basin	Poland	Gdansk Basin Polish Coastal waters	26	Zalew Wiślany	2011-2020	Perch	Fisheries independent data	Trend
Bornholm Basin	Sweden	Bornholm Basin Swedish Coastal waters	27	Torhamn	2002-2020	Perch	Fisheries independent data	ASCETS
Bornholm Basin	Sweden	Bornholm Basin Swedish Coastal waters	27	Torhamn	2002-2020	Pike	Fisheries independent data	ASCETS
Bornholm Basin	Sweden	Bornholm Basin Swedish Coastal waters	27	Hanöbukten	2015-2020	Flounder	Fisheries independent data	Trend
Bornholm Basin	Poland	Bornholm Basin Polish Coastal waters	28	NA	NA	NA	NA	NA
Bornholm Basin	Denmark	Bornholm Basin Danish Coastal waters	29	NA	NA	NA	NA	NA
Bornholm Basin	Germany	Bornholm Basin German Coastal waters	30	NA	NA	NA	NA	NA
Arkona Basin	Sweden	Arkona Basin Swedish Coastal waters	31	Stavstendsudde	2018-2020	Flounder	Fisheries independent data	Trend
Arkona Basin	Denmark	Arkona Basin Danish Coastal waters	32	Præstø Fiord	2005-2020	Flounder	Citizen Science	ASCETS
Arkona Basin	Denmark	Arkona Basin Danish Coastal waters	32	Præstø Fiord	2005-2020	Eelpout	Citizen Science	ASCETS
Arkona Basin	Germany	Arkona Basin German Coastal waters	33	NA	NA	NA	NA	NA
Mecklenburg Bight	Germany	Mecklenburg Bight German Coastal waters	34	NA	NA	NA	NA	NA
Mecklenburg Bight	Denmark	Mecklenburg Bight Danish Coastal waters	35	Area south of Zealand	2003-2020	Flounder	Citizen Science	Trend
Mecklenburg Bight	Denmark	Mecklenburg Bight Danish Coastal waters	35	Fehmarn Belt	2002-2020	Flounder	Citizen Science	Trend
Mecklenburg Bight	Denmark	Mecklenburg Bight Danish Coastal waters	35	Fehmarn Belt	2002-2020	Eelpout	Citizen Science	Trend
Kiel Bight	Denmark	Kiel Bight Danish Coastal waters	36	NA	NA	NA	NA	NA
Kiel Bight	Germany	Kiel Bight German Coastal waters	37	NA	NA	NA	NA	NA
Belt Sea	Denmark	Belts Danish Coastal waters	38	The Great Belt	2003-2020	Flounder	Citizen Science	ASCETS
Belt Sea	Denmark	Belts Danish Coastal waters	38	The Great Belt	2003-2020	Eelpout	Citizen Science	ASCETS
Belt Sea	Denmark	Belts Danish Coastal waters	38	Southern Little Belt and the archipelago	2002-2020	Flounder	Citizen Science	ASCETS
Belt Sea	Denmark	Belts Danish Coastal waters	38	Odense Fiord	2002-2020	Flounder	Citizen Science	ASCETS
Belt Sea	Denmark	Belts Danish Coastal waters	38	Odense Fiord	2002-2020	Eelpout	Citizen Science	ASCETS
Belt Sea	Denmark	Belts Danish Coastal waters	38	Sejerø Bay	2002-2020	Flounder	Citizen Science	ASCETS
Belt Sea	Denmark	Belts Danish Coastal waters	38	Sejerø Bay	2002-2020	Eelpout	Citizen Science	Trend
Belt Sea	Denmark	Belts Danish Coastal waters	38	Århus Bay	2002-2020	Flounder	Citizen Science	ASCETS
Belt Sea	Denmark	Belts Danish Coastal waters	38	Århus Bay	2002-2020	Eelpout	Citizen Science	ASCETS
Belt Sea	Denmark	Belts Danish Coastal waters	38	Vejle Fjord	2002-2020	Flounder	Citizen Science	ASCETS
Belt Sea	Denmark	Belts Danish Coastal waters	38	Vejle Fjord	2002-2020	Eelpout	Citizen Science	ASCETS
Belt Sea	Denmark	Belts Danish Coastal waters	38	Fyn archipelago	2002-2020	Flounder	Citizen Science	ASCETS
Belt Sea	Denmark	Belts Danish Coastal waters	38	Fyn archipelago	2002-2020	Eelpout	Citizen Science	ASCETS
The Sound	Sweden	The Sound Swedish Coastal waters	39	NA	NA	NA	NA	NA
The Sound	Denmark	The Sound Danish Coastal waters	40	The sound	2002-2020	Flounder	Citizen Science	ASCETS
The Sound	Denmark	The Sound Danish Coastal waters	40	The sound	2002-2020	Eelpout	Citizen Science	ASCETS
Kattegat	Sweden	Kattegat Swedish Coastal waters, including Limfjorden	41	NA	NA	NA	NA	NA
Kattegat	Denmark	Kattegat Danish Coastal waters, including Limfjorden	42	Islefjord and Roskilde fjord	2003-2020	Flounder	Citizen Science	ASCETS
Kattegat	Denmark	Kattegat Danish Coastal waters, including Limfjorden	42	Islefjord and Roskilde fjord	2003-2020	Eelpout	Citizen Science	ASCETS
Kattegat	Denmark	Kattegat Danish Coastal waters, including Limfjorden	42	Northern Limfjord	2002-2020	Flounder	Citizen Science	ASCETS
Kattegat	Denmark	Kattegat Danish Coastal waters, including Limfjorden	42	Northern Limfjord	2002-2020	Eelpout	Citizen Science	ASCETS
Kattegat	Denmark	Kattegat Danish Coastal waters, including Limfjorden	42	Skive Fiord and Lovns Broad	2002-2020	Flounder	Citizen Science	ASCETS
Kattegat	Denmark	Kattegat Danish Coastal waters, including Limfjorden	42	Skive Fiord and Lovns Broad	2002-2020	Eelpout	Citizen Science	ASCETS
Kattegat	Denmark	Kattegat Danish Coastal waters, including Limfjorden	42	Aalborg Bay and Laesö	2004-2020	Flounder	Citizen Science	ASCETS
Kattegat	Denmark	Kattegat Danish Coastal waters, including Limfjorden	42	Aalborg Bay and Laesö	2004-2020	Eelpout	Citizen Science	ASCETS
Kattegat	Denmark	Kattegat Danish Coastal waters, including Limfjorden	42	Mariager and Horserns Fjords	2002-2020	Flounder	Citizen Science	ASCETS
Kattegat	Denmark	Kattegat Danish Coastal waters, including Limfjorden	42	Mariager and Horserns Fjords	2002-2020	Eelpout	Citizen Science	ASCETS

Appendix result Table 2. Key species status evaluation outcome per monitoring location and assessment unit for the assessment period 2016-2020. GS = good status, nGS = not good status. Column headings provide the geographical location, the status during the reference period, the threshold value for good status (for the trend-based approach the + or – sign indicate the desired direction of the trend), the current indicator value, the status of the monitoring area, and the aggregated status of the assessment unit. The status for each assessment unit is derived using the One-Out-All-Out principle across species and monitoring locations.

Sub-basin	Country	Coastal area name (assessment unit)	Monitoring area/data set	Key species	Status reference period	Threshold value	Current value	Status monitoring location	Status assessment unit
Bothnian Bay	Finland	Bothnian Bay Finnish Coastal waters	Finnish ICES SD 31	Perch	GS	0.082	0.2	GS	GS
Bothnian Bay	Sweden	Bothnian Bay Swedish Coastal waters	Råneå	Perch	GS	17.59	25.78	GS	
Bothnian Bay	Sweden	Bothnian Bay Swedish Coastal waters	Råneå	Pike	GS	0.045	0.089	GS	
Bothnian Bay	Sweden	Bothnian Bay Swedish Coastal waters	Råneå	Whitefish	GS	0.014	0.089	GS	
Bothnian Bay	Sweden	Bothnian Bay Swedish Coastal waters	Kinnbäcksfjärden	Perch	GS	6.81	7.02	GS	
Bothnian Bay	Sweden	Bothnian Bay Swedish Coastal waters	Kinnbäcksfjärden	Whitefish	GS	3.61	4.38	GS	GS
The Quark	Finland	The Quark Finnish Coastal waters	Finnish ICES rect 23	Perch	GS	0.13	0.4	GS	
The Quark	Finland	The Quark Finnish Coastal waters	Finnish ICES rect 28	Perch	GS	0.192	0.19	nGS	nGS
The Quark	Sweden	The Quark Swedish Coastal waters	Holmön	Perch	GS	18.64	11.4	nGS	
The Quark	Sweden	The Quark Swedish Coastal waters	Holmön	Whitefish	nGS	1.27	1.97	GS	
The Quark	Sweden	The Quark Swedish Coastal waters	Norrbyn	Perch	nGS	19.78	5.4	nGS	
The Quark	Sweden	The Quark Swedish Coastal waters	Norrbyn	Whitefish	GS	1.66	2.7	GS	nGS
Bothnian Sea	Finland	Bothnian Sea Finnish Coastal waters	Finnish ICES SD 30	Perch	GS	0.19	0.28	GS	
Bothnian Sea	Finland	Bothnian Sea Finnish Coastal waters	Finnish ICES SD 30	Pikeperch	GS	0.11	0.12	GS	GS
Bothnian Sea	Sweden	Bothnian Sea Swedish Coastal waters	Gaviksfjärden	Perch	GS	5.87	7.4	GS	
Bothnian Sea	Sweden	Bothnian Sea Swedish Coastal waters	Gaviksfjärden	Whitefish	nGS	1.5	1.3	nGS	
Bothnian Sea	Sweden	Bothnian Sea Swedish Coastal waters	Långvindsfjärden	Perch	GS	13.9	14.18	GS	
Bothnian Sea	Sweden	Bothnian Sea Swedish Coastal waters	Forsmark	Perch	GS	14.7	20.7	GS	
Bothnian Sea	Sweden	Bothnian Sea Swedish Coastal waters	Forsmark	Pikeperch	nGS	1.5	0.044	nGS	
Bothnian Sea	Sweden	Bothnian Sea Swedish Coastal waters	Forsmark	Whitefish	nGS	0.11	0	nGS	nGS
Åland Sea	Finland	Åland Sea Finnish Coastal waters	NA	NA	NA	NA	NA	NA	NA
Åland Sea	Sweden	Åland Sea Swedish Coastal waters	Galtfjärden	Perch	GS	6.95	8.87	GS	
Åland Sea	Sweden	Åland Sea Swedish Coastal waters	Galtfjärden	Pikeperch	nGS	5.87	2.87	nGS	
Åland Sea	Sweden	Åland Sea Swedish Coastal waters	Galtfjärden	Whitefish	nGS	0.48	0.23	nGS	
Åland Sea	Sweden	Åland Sea Swedish Coastal waters	Lagnö	Perch	GS	15.78	25.72	GS	
Åland Sea	Sweden	Åland Sea Swedish Coastal waters	Lagnö	Pike	nGS	0.14	0	nGS	
Åland Sea	Sweden	Åland Sea Swedish Coastal waters	Lagnö	Whitefish	nGS	1.11	0.54	nGS	nGS
Archipelago Sea	Finland	Archipelago Sea Coastal waters	Finbo	Perch	GS	23.1	27.3	GS	
Archipelago Sea	Finland	Archipelago Sea Coastal waters	Finbo	Pike	GS	0.02	0.11	GS	
Archipelago Sea	Finland	Archipelago Sea Coastal waters	Finbo	Pikeperch	GS	0.29	0.47	GS	
Archipelago Sea	Finland	Archipelago Sea Coastal waters	Kumlinge	Perch	GS	20.9	37.9	GS	
Archipelago Sea	Finland	Archipelago Sea Coastal waters	Kumlinge	Whitefish	nGS	0.46	0.13	nGS	
Archipelago Sea	Finland	Archipelago Sea Coastal waters	Finnish ICES SD 29	Perch	GS	0.22	0.45	GS	
Archipelago Sea	Finland	Archipelago Sea Coastal waters	Finnish ICES SD 29	Pikeperch	GS	0.25	0.31	GS	nGS
Northern Baltic Sea	Finland	Northern Baltic Proper Finnish Coastal waters	NA	NA	NA	NA	NA	NA	NA
Northern Baltic Sea	Sweden	Northern Baltic Proper Swedish Coastal waters	Vaxholm: Askrikefjärden	Perch	GS	Slope p >0.1 (+)	P slope = 0.37	GS	
Northern Baltic Sea	Sweden	Northern Baltic Proper Swedish Coastal waters	Vaxholm: Askrikefjärden	Pikeperch	GS	Slope p >0.1 (+)	P slope = 0.67	GS	
Northern Baltic Sea	Sweden	Northern Baltic Proper Swedish Coastal waters	Askö	Perch	GS	16.6	5.85	nGS	
Northern Baltic Sea	Sweden	Northern Baltic Proper Swedish Coastal waters	Askö	Pike	nGS	0.17	0	nGS	
Northern Baltic Sea	Sweden	Northern Baltic Proper Swedish Coastal waters	Askö	Whitefish	nGS	0.62	0.625	GS	
Northern Baltic Sea	Sweden	Northern Baltic Proper Swedish Coastal waters	Muskö	Flounder	GS	6.65	2.75	nGS	nGS
Northern Baltic Sea	Estonia	Northern Baltic Proper Estonian Coastal waters	NA	NA	NA	NA	NA	NA	NA
Gulf of Finland	Finland	Gulf of Finland Finnish Coastal waters	Brunskär	Perch	GS	2.8	3.4	GS	
Gulf of Finland	Finland	Gulf of Finland Finnish Coastal waters	Tvärminne	Perch	GS	1.26	1.16	nGS	
Gulf of Finland	Finland	Gulf of Finland Finnish Coastal waters	Helsinki	Perch	nGS	1.38	1.62	GS	
Gulf of Finland	Finland	Gulf of Finland Finnish Coastal waters	Finnish ICES SD 32	Perch	GS	0.09	0.11	GS	
Gulf of Finland	Finland	Gulf of Finland Finnish Coastal waters	Finnish ICES SD 32	Pikeperch	GS	0.23	0.25	GS	nGS
Gulf of Finland	Estonia	Gulf of Finland Estonian Coastal waters	NA	NA	NA	NA	NA	NA	NA
Gulf of Finland	Russia	Gulf of Finland Russian Coastal waters	NA	NA	NA	NA	NA	NA	NA
Gulf of Riga	Estonia	Gulf of Riga Estonian Coastal waters	Hiiumaa	Perch	nGS	30.46	33.5	GS	GS
Gulf of Riga	Latvia	Gulf of Riga Latvian Coastal waters	Daugavgriva	Perch	GS	Slope p >0.1 (+)	P slope = 0.18	GS	
Gulf of Riga	Latvia	Gulf of Riga Latvian Coastal waters	Daugavgriva	Pikeperch		Slope p >0.1 (+)	P slope = 0.58		GS
Western Gotland Basin	Sweden	Western Gotland Basin Swedish Coastal waters	Kvädöfjärden, summer	Perch	nGS	18.47	11.75	nGS	
Western Gotland Basin	Sweden	Western Gotland Basin Swedish Coastal waters	Kvädöfjärden, summer	Pike	nGS	0.23	0	nGS	
Western Gotland Basin	Sweden	Western Gotland Basin Swedish Coastal waters	Kvädöfjärden, summer	Pikeperch	nGS	0.48	1.82	GS	
Western Gotland Basin	Sweden	Western Gotland Basin Swedish Coastal waters	Kvädöfjärden, autumn	Flounder	nGS	16.68	2.25	nGS	
Western Gotland Basin	Sweden	Western Gotland Basin Swedish Coastal waters	Kvädöfjärden, autumn	Whitefish	nGS	2.53	0.25	nGS	
Western Gotland Basin	Sweden	Western Gotland Basin Swedish Coastal waters	Vinö	Perch	nGS	57.67	36.81	nGS	
Western Gotland Basin	Sweden	Western Gotland Basin Swedish Coastal waters	Vinö	Pike	nGS	0.0063	0	nGS	nGS
Eastern Gotland Basin	Estonia	Eastern Gotland Basin Estonian Coastal waters	NA	NA	NA	NA	NA	NA	NA
Eastern Gotland Basin	Latvia	Eastern Gotland Basin Latvian Coastal waters	Jurkalne	Flounder	GS	Slope p >0.1 (+)	P slope = 0.48	GS	GS
Eastern Gotland Basin	Lithuania	Eastern Gotland Basin Lithuanian Coastal waters	Mon/But	Flounder	GS	4.11	57	GS	
Eastern Gotland Basin	Lithuania	Eastern Gotland Basin Lithuanian Coastal waters	Šventoji	Flounder	GS	1.64	2.67	GS	
Eastern Gotland Basin	Lithuania	Eastern Gotland Basin Lithuanian Coastal waters	Karklė	Flounder	GS	Slope p >0.1 (+)	P slope = 0.52	GS	
Eastern Gotland Basin	Lithuania	Eastern Gotland Basin Lithuanian Coastal waters	Smiltynė	Flounder	GS	2.45	6.87	GS	
Eastern Gotland Basin	Lithuania	Eastern Gotland Basin Lithuanian Coastal waters	Curonian lagoon	Perch	GS	20.13	53	GS	
Eastern Gotland Basin	Lithuania	Eastern Gotland Basin Lithuanian Coastal waters	Curonian lagoon	Pikeperch	GS	1.33	0.9	nGS	nGS
Eastern Gotland Basin	Sweden	Eastern Gotland Basin Swedish Coastal waters	Herrvik	Flounder		Slope p >0.1 (+)	P slope = 0.88		NA
Eastern Gotland Basin	Russian	Eastern Gotland Basin Russian Coastal waters	NA	NA	NA	NA	NA	NA	NA
Eastern Gotland Basin	Poland	Eastern Gotland Basin Polish Coastal waters	NA	NA	NA	NA	NA	NA	NA
Gdansk Basin	Russia	Gdansk Basin Russian Coastal waters	NA	NA	NA	NA	NA	NA	NA
Gdansk Basin	Poland	Gdansk Basin Polish Coastal waters	Zatoka Pucka Zewnętrzna	Perch	GS	Slope p >0.1 (+)	P slope = 0.96	GS	
Gdansk Basin	Poland	Gdansk Basin Polish Coastal waters	Zatoka Pucka Zewnętrzna	Flounder	GS	Slope p >0.1 (+)	P slope = 0.54	GS	
Gdansk Basin	Poland	Gdansk Basin Polish Coastal waters	Zalew Pucki	Perch	GS	Slope p >0.1 (+)	P slope = 0.94	GS	
Gdansk Basin	Poland	Gdansk Basin Polish Coastal waters	Zalew Pucki	Flounder	nGS	Slope p >0.1 (+)	P slope = 0.13	nGS	
Gdansk Basin	Poland	Gdansk Basin Polish Coastal waters	Zalew Wiślany	Perch	GS	Slope p >0.1 (+)	P slope = 0.8	GS	GS
Bornholm Basin	Sweden	Bornholm Basin Swedish Coastal waters	Torhamn	Perch	GS	11.97	21.75	GS	
Bornholm Basin	Sweden	Bornholm Basin Swedish Coastal waters	Torhamn	Pike	nGS	0.62	0.05	nGS	
Bornholm Basin	Sweden	Bornholm Basin Swedish Coastal waters	Hanöbukten	Flounder	nGS	Slope p >0.1 (+)	P slope = 0.14	nGS	nGS
Bornholm Basin	Poland	Bornholm Basin Polish Coastal waters	NA	NA	NA	NA	NA	NA	NA
Bornholm Basin	Denmark	Bornholm Basin Danish Coastal waters	NA	NA	NA	NA	NA	NA	NA
Bornholm Basin	Germany	Bornholm Basin German Coastal waters	NA	NA	NA	NA	NA	NA	NA

Appendix result Table 2. (Continued). Key species status evaluation outcome per monitoring location and assessment unit for the assessment period 2016–2020. GS = good status, nGS = not good status. Column headings provide the geographical location, the status during the reference period, the threshold value for good status (for the trend-based approach the + or – sign indicate the desired direction of the trend), the current indicator value, the status of the monitoring area, and the aggregated status of the assessment unit. The status for each assessment unit is derived using the One-Out-All-Out principle across species and monitoring locations.

Sub-basin	Country	Coastal area name (assessment unit)	Monitoring area/data set	Key species	Status reference period	Threshold value	Current value	Status monitoring location	Status assessment unit
Arkona Basin	Sweden	Arkona Basin Swedish Coastal waters	Stavstendsudde	Flounder		Slope p >0.1 (+)	P slope = 0.42		NA
Arkona Basin	Denmark	Arkona Basin Danish Coastal waters	Præstø Fiord	Flounder	nGS	2.72	0.86	nGS	
Arkona Basin	Denmark	Arkona Basin Danish Coastal waters	Præstø Fiord	Eelpout	GS	0.22	0.48	GS	nGS
Arkona Basin	Germany	Arkona Basin German Coastal waters	NA	NA	NA	NA	NA	NA	NA
Mecklenburg Bight	Germany	Mecklenburg Bight German Coastal waters	NA	NA	NA	NA	NA	NA	NA
Mecklenburg Bight	Denmark	Mecklenburg Bight Danish Coastal waters	Area south of Zealand	Flounder	GS	Slope p >0.1 (+)	P slope = 0.58	GS	
Mecklenburg Bight	Denmark	Mecklenburg Bight Danish Coastal waters	Fehmarn Belt	Flounder	nGS	Slope p >0.1 (+)	P slope = 0.46	nGS	
Mecklenburg Bight	Denmark	Mecklenburg Bight Danish Coastal waters	Fehmarn Belt	Eelpout	GS	3.2	4.7	GS	nGS
Kiel Bight	Denmark	Kiel Bight Danish Coastal waters	NA	NA	NA	NA	NA	NA	NA
Kiel Bight	Germany	Kiel Bight German Coastal waters	NA	NA	NA	NA	NA	NA	NA
Belt Sea	Denmark	Belts Danish Coastal waters	The Great Belt	Flounder	nGS	3.34	1.97	nGS	
Belt Sea	Denmark	Belts Danish Coastal waters	The Great Belt	Eelpout	GS	0.6	0.76	GS	
Belt Sea	Denmark	Belts Danish Coastal waters	Southern Little Belt and the archipelago	Flounder	nGS	2.28	1.38	nGS	
Belt Sea	Denmark	Belts Danish Coastal waters	Odense Fiord	Flounder	nGS	4.75	2.68	nGS	
Belt Sea	Denmark	Belts Danish Coastal waters	Odense Fiord	Eelpout	GS	0.3	0.35	GS	
Belt Sea	Denmark	Belts Danish Coastal waters	Sejerø Bay	Flounder	nGS	5.02	3.64	nGS	
Belt Sea	Denmark	Belts Danish Coastal waters	Sejerø Bay	Eelpout	GS	Slope p >0.1 (+)	P slope = 0.08	nGS	
Belt Sea	Denmark	Belts Danish Coastal waters	Århus Bay	Flounder	nGS	2.39	1.08	nGS	
Belt Sea	Denmark	Belts Danish Coastal waters	Århus Bay	Eelpout	GS	2.08	1.71	nGS	
Belt Sea	Denmark	Belts Danish Coastal waters	Vejle Fjord	Flounder	nGS	1.37	0.33	nGS	
Belt Sea	Denmark	Belts Danish Coastal waters	Vejle Fjord	Eelpout	GS	0.74	1.72	GS	
Belt Sea	Denmark	Belts Danish Coastal waters	Fyn archipelago	Flounder	nGS	7.84	2.01	nGS	
Belt Sea	Denmark	Belts Danish Coastal waters	Fyn archipelago	Eelpout	GS	2.9	2.74	nGS	nGS
The Sound	Sweden	The Sound Swedish Coastal waters	NA	NA	NA	NA	NA	NA	NA
The Sound	Denmark	The Sound Danish Coastal waters	The sound	Flounder	nGS	3.84	1.23	nGS	
The Sound	Denmark	The Sound Danish Coastal waters	The sound	Eelpout	GS	0.042	2.15	GS	nGS
Kattegat	Sweden	Kattegat Swedish Coastal waters, including Limfjorden	NA	NA	NA	NA	NA	NA	NA
Kattegat	Denmark	Kattegat Danish Coastal waters, including Limfjorden	Islefjord and Roskilde fjord	Flounder	GS	1.6	4.51	GS	
Kattegat	Denmark	Kattegat Danish Coastal waters, including Limfjorden	Islefjord and Roskilde fjord	Eelpout	GS	1.11	3.28	GS	
Kattegat	Denmark	Kattegat Danish Coastal waters, including Limfjorden	Northern Limfjord	Flounder	nGS	0.3	0.49	nGS	
Kattegat	Denmark	Kattegat Danish Coastal waters, including Limfjorden	Northern Limfjord	Eelpout	GS	0.92	0.94	GS	
Kattegat	Denmark	Kattegat Danish Coastal waters, including Limfjorden	Skive Fiord and Lovns Broad	Flounder	nGS	1.34	0.29	nGS	
Kattegat	Denmark	Kattegat Danish Coastal waters, including Limfjorden	Skive Fiord and Lovns Broad	Eelpout	nGS	4.06	0	GS	
Kattegat	Denmark	Kattegat Danish Coastal waters, including Limfjorden	Aalborg Bay and Laesö	Flounder	nGS	2.44	1.96	nGS	
Kattegat	Denmark	Kattegat Danish Coastal waters, including Limfjorden	Aalborg Bay and Laesö	Eelpout	GS	1.69	1.32	nGS	
Kattegat	Denmark	Kattegat Danish Coastal waters, including Limfjorden	Mariager and Horserns Fjords	Flounder	nGS	1.07	0.51	nGS	
Kattegat	Denmark	Kattegat Danish Coastal waters, including Limfjorden	Mariager and Horserns Fjords	Eelpout	GS	2.73	0.12	GS	nGS

Appendix results Table 3. Confidence in the status evaluation of key species according to the criteria developed within HELCOM for the integrated biodiversity assessment.

Sub-basin	Country	Coastal area name (assessment unit)	Monitoring area/data set	key species	ConfA	ConfT	ConfS	ConfM
Bothnian Bay	Finland	Bothnian Bay Finnish Coastal waters	Finnish ICES SD 31	Perch	0.5	1	1	1
Bothnian Bay	Sweden	Bothnian Bay Swedish Coastal waters	Råneå	Perch	1	1	0.5	1
Bothnian Bay	Sweden	Bothnian Bay Swedish Coastal waters	Råneå	Pike	1	1	0.5	1
Bothnian Bay	Sweden	Bothnian Bay Swedish Coastal waters	Råneå	Whitefish	1	1	0.5	1
Bothnian Bay	Sweden	Bothnian Bay Swedish Coastal waters	Kinnbäcksfjärden	Perch	0.5	1	0.5	1
Bothnian Bay	Sweden	Bothnian Bay Swedish Coastal waters	Kinnbäcksfjärden	Whitefish	1	1	0.5	1
The Quark	Finland	The Quark Finnish Coastal waters	Finnish ICES rect 23	Perch	1	1	1	1
The Quark	Finland	The Quark Finnish Coastal waters	Finnish ICES rect 28	Perch	0.5	1	1	1
The Quark	Sweden	The Quark Swedish Coastal waters	Holmön	Perch	0.5	1	0.5	1
The Quark	Sweden	The Quark Swedish Coastal waters	Holmön	Whitefish	1	1	0.5	1
The Quark	Sweden	The Quark Swedish Coastal waters	Norrbyn	Perch	1	1	0.5	1
The Quark	Sweden	The Quark Swedish Coastal waters	Norrbyn	Whitefish	1	1	0.5	1
Bothnian Sea	Finland	Bothnian Sea Finnish Coastal waters	Finnish ICES SD 30	Perch	0	1	1	1
Bothnian Sea	Finland	Bothnian Sea Finnish Coastal waters	Finnish ICES SD 30	Pikeperch	0.5	1	1	1
Bothnian Sea	Sweden	Bothnian Sea Swedish Coastal waters	Gaviksfjärden	Perch	1	1	0.5	1
Bothnian Sea	Sweden	Bothnian Sea Swedish Coastal waters	Gaviksfjärden	Whitefish	0.5	1	0.5	1
Bothnian Sea	Sweden	Bothnian Sea Swedish Coastal waters	Långvindsfjärden	Perch	0.5	1	0.5	1
Bothnian Sea	Sweden	Bothnian Sea Swedish Coastal waters	Forsmark	Perch	1	1	0.5	1
Bothnian Sea	Sweden	Bothnian Sea Swedish Coastal waters	Forsmark	Pikeperch	0	1	0.5	1
Bothnian Sea	Sweden	Bothnian Sea Swedish Coastal waters	Forsmark	Whitefish	0.5	1	0.5	1
Åland Sea	Finland	Åland Sea Finnish Coastal waters	NA	NA	NA	NA	NA	NA
Åland Sea	Sweden	Åland Sea Swedish Coastal waters	Galtfjärden	Perch	1	1	0.5	1
Åland Sea	Sweden	Åland Sea Swedish Coastal waters	Galtfjärden	Pikeperch	1	1	0.5	1
Åland Sea	Sweden	Åland Sea Swedish Coastal waters	Galtfjärden	Whitefish	1	1	0.5	1
Åland Sea	Sweden	Åland Sea Swedish Coastal waters	Lagnö	Perch	0	1	0	1
Åland Sea	Sweden	Åland Sea Swedish Coastal waters	Lagnö	Pike	1	1	0	1
Åland Sea	Sweden	Åland Sea Swedish Coastal waters	Lagnö	Whitefish	0.5	1	0	1

Appendix results Table 3. (Continued). Confidence in the status evaluation of key species according to the criteria developed within HELCOM for the integrated biodiversity assessment.

Sub-basin	Country	Coastal area name (assessment unit)	Monitoring area/data set	key species	ConfA	ConfT	ConfS	ConfM
Archipelago Sea	Finland	Archipelago Sea Coastal waters	Finbo	Perch	1	1	1	1
Archipelago Sea	Finland	Archipelago Sea Coastal waters	Finbo	Pike	0.5	1	1	1
Archipelago Sea	Finland	Archipelago Sea Coastal waters	Finbo	Pikeperch	0.5	1	1	1
Archipelago Sea	Finland	Archipelago Sea Coastal waters	Kumlinge	Perch	0.5	1	1	1
Archipelago Sea	Finland	Archipelago Sea Coastal waters	Kumlinge	Whitefish	0.5	1	1	1
Archipelago Sea	Finland	Archipelago Sea Coastal waters	Finnish ICES SD 29	Perch	1	1	1	1
Archipelago Sea	Finland	Archipelago Sea Coastal waters	Finnish ICES SD 29	Pikeperch	1	1	1	1
Northern Baltic Sea	Finland	Northern Baltic Proper Finnish Coastal waters	NA	NA	NA	NA	NA	NA
Northern Baltic Sea	Sweden	Northern Baltic Proper Swedish Coastal waters	Vaxholm: Askrikefjärden	Perch	0.5	1	0.5	1
Northern Baltic Sea	Sweden	Northern Baltic Proper Swedish Coastal waters	Vaxholm: Askrikefjärden	Pikeperch	1	1	0.5	1
Northern Baltic Sea	Sweden	Northern Baltic Proper Swedish Coastal waters	Askö	Perch	1	1	0.5	1
Northern Baltic Sea	Sweden	Northern Baltic Proper Swedish Coastal waters	Askö	Pike	1	1	0.5	1
Northern Baltic Sea	Sweden	Northern Baltic Proper Swedish Coastal waters	Askö	Whitefish	0	1	0.5	1
Northern Baltic Sea	Sweden	Northern Baltic Proper Swedish Coastal waters	Muskö	Flounder	1	1	0.5	1
Northern Baltic Sea	Estonia	Northern Baltic Proper Estonian Coastal waters	NA	NA	NA	NA	NA	NA
Gulf of Finland	Finland	Gulf of Finland Finnish Coastal waters	Brunskär	Perch	1	1	1	1
Gulf of Finland	Finland	Gulf of Finland Finnish Coastal waters	Tvärminne	Perch	0	1	1	1
Gulf of Finland	Finland	Gulf of Finland Finnish Coastal waters	Helsinki	Perch	0.5	0.5	1	1
Gulf of Finland	Finland	Gulf of Finland Finnish Coastal waters	Finnish ICES SD 32	Perch	0.5	1	1	1
Gulf of Finland	Finland	Gulf of Finland Finnish Coastal waters	Finnish ICES SD 32	Pikeperch	0.5	1	1	1
Gulf of Finland	Estonia	Gulf of Finland Estonian Coastal waters	NA	NA	NA	NA	NA	NA
Gulf of Finland	Russia	Gulf of Finland Russian Coastal waters	NA	NA	NA	NA	NA	NA
Gulf of Riga	Estonia	Gulf of Riga Estonian Coastal waters	Hiiumaa	Perch	0	1	0	1
Gulf of Riga	Latvia	Gulf of Riga Latvian Coastal waters	Daugavgriva	Perch	0	1	0	1
Gulf of Riga	Latvia	Gulf of Riga Latvian Coastal waters	Daugavgriva	Pikeperch	0.5	1	0	1
Western Gotland Basin	Sweden	Western Gotland Basin Swedish Coastal waters	Kvädöfjärden, summer	Perch	0.5	1	0.5	1
Western Gotland Basin	Sweden	Western Gotland Basin Swedish Coastal waters	Kvädöfjärden, summer	Pike	1	1	0.5	1
Western Gotland Basin	Sweden	Western Gotland Basin Swedish Coastal waters	Kvädöfjärden, summer	Pikeperch	1	1	0.5	1
Western Gotland Basin	Sweden	Western Gotland Basin Swedish Coastal waters	Kvädöfjärden, autumn	Flounder	0.5	1	0.5	1
Western Gotland Basin	Sweden	Western Gotland Basin Swedish Coastal waters	Kvädöfjärden, autumn	Whitefish	0.5	1	0.5	1
Western Gotland Basin	Sweden	Western Gotland Basin Swedish Coastal waters	Vinö	Perch	0	1	0.5	1
Western Gotland Basin	Sweden	Western Gotland Basin Swedish Coastal waters	Vinö	Pike	0	1	0.5	1
Eastern Gotland Basin	Estonia	Eastern Gotland Basin Estonian Coastal waters	NA	NA	NA	NA	NA	NA
Eastern Gotland Basin	Latvia	Eastern Gotland Basin Latvian Coastal waters	Jurkalne	Flounder	0.5	1	0	1
Eastern Gotland Basin	Lithuania	Eastern Gotland Basin Lithuanian Coastal waters	Mon/But	Flounder	0	1	1	1
Eastern Gotland Basin	Lithuania	Eastern Gotland Basin Lithuanian Coastal waters	Šventoji	Flounder	0.5	1	1	1
Eastern Gotland Basin	Lithuania	Eastern Gotland Basin Lithuanian Coastal waters	Karklė	Flounder	1	1	1	1
Eastern Gotland Basin	Lithuania	Eastern Gotland Basin Lithuanian Coastal waters	Smiltynė	Flounder	1	1	1	1
Eastern Gotland Basin	Lithuania	Eastern Gotland Basin Lithuanian Coastal waters	Curonian lagoon	Perch	1	1	1	1
Eastern Gotland Basin	Lithuania	Eastern Gotland Basin Lithuanian Coastal waters	Curonian lagoon	Pikeperch	0.5	1	1	1
Eastern Gotland Basin	Sweden	Eastern Gotland Basin Swedish Coastal waters	Herrvik	Flounder	1	0.5	0	1
Eastern Gotland Basin	Russian	Eastern Gotland Basin Russian Coastal waters	NA	NA	NA	NA	NA	NA
Eastern Gotland Basin	Poland	Eastern Gotland Basin Polish Coastal waters	NA	NA	NA	NA	NA	NA
Gdansk Basin	Russia	Gdansk Basin Russian Coastal waters	NA	NA	NA	NA	NA	NA
Gdansk Basin	Poland	Gdansk Basin Polish Coastal waters	Zatoka Pucka Zewnętrzna	Perch	1	0.5	1	1
Gdansk Basin	Poland	Gdansk Basin Polish Coastal waters	Zatoka Pucka Zewnętrzna	Flounder	1	0.5	1	1
Gdansk Basin	Poland	Gdansk Basin Polish Coastal waters	Zalew Pucki	Perch	1	1	1	1
Gdansk Basin	Poland	Gdansk Basin Polish Coastal waters	Zalew Pucki	Flounder	0	1	1	1
Gdansk Basin	Poland	Gdansk Basin Polish Coastal waters	Zalew Wiślany	Perch	1	1	1	1
Bornholm Basin	Sweden	Bornholm Basin Swedish Coastal waters	Torhamn	Perch	1	1	0.5	1
Bornholm Basin	Sweden	Bornholm Basin Swedish Coastal waters	Torhamn	Pike	0.5	1	0.5	1
Bornholm Basin	Sweden	Bornholm Basin Swedish Coastal waters	Hanöbukten	Flounder	0	1	0.5	1
Bornholm Basin	Poland	Bornholm Basin Polish Coastal waters	NA	NA	NA	NA	NA	NA
Bornholm Basin	Denmark	Bornholm Basin Danish Coastal waters	NA	NA	NA	NA	NA	NA
Bornholm Basin	Germany	Bornholm Basin German Coastal waters	NA	NA	NA	NA	NA	NA
Arkona Basin	Sweden	Arkona Basin Swedish Coastal waters	Stavstendsudde	Flounder	0.5	0.5	0	1
Arkona Basin	Denmark	Arkona Basin Danish Coastal waters	Præstø Fiord	Flounder	1	0	0	1
Arkona Basin	Denmark	Arkona Basin Danish Coastal waters	Præstø Fiord	Eelpout	1	1	0	1
Arkona Basin	Germany	Arkona Basin German Coastal waters	NA	NA	NA	NA	NA	NA
Mecklenburg Bight	Germany	Mecklenburg Bight German Coastal waters	NA	NA	NA	NA	NA	NA
Mecklenburg Bight	Denmark	Mecklenburg Bight Danish Coastal waters	Area south of Zealand	Flounder	1	1	0.5	1
Mecklenburg Bight	Denmark	Mecklenburg Bight Danish Coastal waters	Fehmarn Belt	Flounder	0.5	1	0.5	1
Mecklenburg Bight	Denmark	Mecklenburg Bight Danish Coastal waters	Fehmarn Belt	Eelpout	1	1	0.5	1
Kiel Bight	Denmark	Kiel Bight Danish Coastal waters	NA	NA	NA	NA	NA	NA
Kiel Bight	Germany	Kiel Bight German Coastal waters	NA	NA	NA	NA	NA	NA
Belt Sea	Denmark	Belts Danish Coastal waters	The Great Belt	Flounder	1	1	1	1
Belt Sea	Denmark	Belts Danish Coastal waters	The Great Belt	Eelpout	0.5	1	1	1
Belt Sea	Denmark	Belts Danish Coastal waters	Southern Little Belt and the archipelago	Flounder	1	1	1	1
Belt Sea	Denmark	Belts Danish Coastal waters	Odense Fiord	Flounder	1	1	1	1
Belt Sea	Denmark	Belts Danish Coastal waters	Odense Fiord	Eelpout	0.5	1	1	1
Belt Sea	Denmark	Belts Danish Coastal waters	Sejerø Bay	Flounder	1	1	1	1
Belt Sea	Denmark	Belts Danish Coastal waters	Sejerø Bay	Eelpout	0.5	0.5	1	1
Belt Sea	Denmark	Belts Danish Coastal waters	Århus Bay	Flounder	0	1	1	1
Belt Sea	Denmark	Belts Danish Coastal waters	Århus Bay	Eelpout	0.5	1	1	1
Belt Sea	Denmark	Belts Danish Coastal waters	Vejle Fjord	Flounder	0.5	0.5	1	1
Belt Sea	Denmark	Belts Danish Coastal waters	Vejle Fjord	Eelpout	1	1	1	1
Belt Sea	Denmark	Belts Danish Coastal waters	Fyn archipelago	Flounder	1	1	1	1
Belt Sea	Denmark	Belts Danish Coastal waters	Fyn archipelago	Eelpout	0	1	1	1

Appendix results Table 3. (Continued). Confidence in the status evaluation of key species according to the criteria developed within HELCOM for the integrated biodiversity assessment.

Sub-basin	Country	Coastal area name (assessment unit)	Monitoring area/data set	key species	ConfA	ConfT	ConfS	ConfM
Belt Sea	Denmark	Belts Danish Coastal waters	The Great Belt	Flounder	1	1	1	1
Belt Sea	Denmark	Belts Danish Coastal waters	The Great Belt	Eelpout	0.5	1	1	1
Belt Sea	Denmark	Belts Danish Coastal waters	Southern Little Belt and the archipelago	Flounder	1	1	1	1
Belt Sea	Denmark	Belts Danish Coastal waters	Odense Fiord	Flounder	1	1	1	1
Belt Sea	Denmark	Belts Danish Coastal waters	Odense Fiord	Eelpout	0.5	1	1	1
Belt Sea	Denmark	Belts Danish Coastal waters	Sejerø Bay	Flounder	1	1	1	1
Belt Sea	Denmark	Belts Danish Coastal waters	Sejerø Bay	Eelpout	0.5	0.5	1	1
Belt Sea	Denmark	Belts Danish Coastal waters	Århus Bay	Flounder	0	1	1	1
Belt Sea	Denmark	Belts Danish Coastal waters	Århus Bay	Eelpout	0.5	1	1	1
Belt Sea	Denmark	Belts Danish Coastal waters	Vejle Fjord	Flounder	0.5	0.5	1	1
Belt Sea	Denmark	Belts Danish Coastal waters	Vejle Fjord	Eelpout	1	1	1	1
Belt Sea	Denmark	Belts Danish Coastal waters	Fyn archipelago	Flounder	1	1	1	1
Belt Sea	Denmark	Belts Danish Coastal waters	Fyn archipelago	Eelpout	0	1	1	1
The Sound	Sweden	The Sound Swedish Coastal waters	NA	NA	NA	NA	NA	NA
The Sound	Denmark	The Sound Danish Coastal waters	The sound	Flounder	1	1	0	1
The Sound	Denmark	The Sound Danish Coastal waters	The sound	Eelpout	1	1	0	1
Kattegat	Sweden	Kattegat Swedish Coastal waters, including Limfjorden	NA	NA	NA	NA	NA	NA
Kattegat	Denmark	Kattegat Danish Coastal waters, including Limfjorden	Islefjord and Roskilde fjord	Flounder	1	1	1	1
Kattegat	Denmark	Kattegat Danish Coastal waters, including Limfjorden	Islefjord and Roskilde fjord	Eelpout	1	1	1	1
Kattegat	Denmark	Kattegat Danish Coastal waters, including Limfjorden	Northern Limfjord	Flounder	0.5	1	1	1
Kattegat	Denmark	Kattegat Danish Coastal waters, including Limfjorden	Northern Limfjord	Eelpout	0.5	1	1	1
Kattegat	Denmark	Kattegat Danish Coastal waters, including Limfjorden	Skive Fiord and Lovns Broad	Flounder	1	1	1	1
Kattegat	Denmark	Kattegat Danish Coastal waters, including Limfjorden	Skive Fiord and Lovns Broad	Eelpout	1	1	1	1
Kattegat	Denmark	Kattegat Danish Coastal waters, including Limfjorden	Aalborg Bay and Laesö	Flounder	1	1	1	1
Kattegat	Denmark	Kattegat Danish Coastal waters, including Limfjorden	Aalborg Bay and Laesö	Eelpout	0.5	1	1	1
Kattegat	Denmark	Kattegat Danish Coastal waters, including Limfjorden	Mariager and Horserns Fjords	Flounder	1	1	1	1
Kattegat	Denmark	Kattegat Danish Coastal waters, including Limfjorden	Mariager and Horserns Fjords	Eelpout	1	1	1	1

Appendix results Table 4. Overview of trends for key species between current and previous assessment in year 2018 (HOLAS II, including data until 2016). For each HELCOM assessment unit, it is noted whether the integrated status using the BEAT tool achieves of fails to achieve the threshold value. The current integrated status is compared to the pervious status with regards to any distinct increasing or decreasing trend. In case of changed integrated status, the outcome is briefly described focusing on the relevant changes compared to the previous assessment.

HELCOM Assessment unit name (and ID)	Threshold value: achieved/failed	Distinct trend between current and previous assessment	Description of outcomes
Archipelago Sea Coastal waters	failed	decrease	All location-species combinations besides whitefish and Kumlinge have GS. Due to inclusion of whitefish in Kumlinge the combined status decreased
Arkona Basin Danish Coastal waters	failed	no change	
Belts Danish Coastal waters	failed	no change	
Bornholm Basin Swedish Coastal waters	failed	NA	Not included in previous assessment
Bothnian Bay Finnish Coastal waters	achieved	no change	
Bothnian Bay Swedish Coastal waters	achieved	no change	
Bothnian Sea Finnish Coastal waters	achieved	no change	
Bothnian Sea Swedish Coastal waters	failed	decrease	All comparable location-species combinations have GS. Due to inclusion of whitefish in Gaviksfjärden and pikeperch and whitefish in Forsmark the combined status decreased
Eastern Gotland Basin Latvian Coastal waters	achieved	no change	
Eastern Gotland Basin Lithuanian Coastal waters	failed	decrease	All comparable location-species combinations have GS. Due to inclusion of pikeperch in Curonian Lagoon the combined status has decreased
Gdansk Basin Polish Coastal waters	failed	NA	Not included in previous assessment
Gulf of Finland Finnish Coastal waters	failed	decrease	Inclusion of 3 new monitoring locations, the status is decreased due to nGS of perch in Tvärminne
Gulf of Riga Estonian Coastal waters	achieved	increase	Only one assessment. Status of perch in Hiiumaa has increased
Gulf of Riga Latvian Coastal waters	achieved	no change	
Kattegat Danish Coastal waters, including Limfjorden	failed	no change	
Mecklenburg Bight Danish Coastal waters	failed	no change	
Northern Baltic Proper Swedish Coastal waters	failed	decrease	Both comparable location-species combinations have decreased. In addition, pike in Askö has nGS
The Quark Finnish Coastal waters	failed	decrease	The status of perch in ICES SD rect 28 has decreased
The Quark Swedish Coastal waters	failed	no change	
The Sound Danish Coastal waters	failed	no change	
Western Gotland Basin Swedish Coastal waters	failed	no change	
Åland Sea Swedish Coastal waters	failed	decrease	Due to inclusion of pike and whitefish in Lagnö the combined status has decreased

Abundance of coastal fish key functional groups

Functional groups results Tables

Appendix results Table 5. Data and methods used for the functional groups (cyprinids/mesopredators) status evaluation for the assessment. Column headings provide the following information: geographic location, the time period assessed, the key species used, the monitoring method, and the assessment approach applied.

Sub-basin	Country	Coastal area name (assessment unit)	Coastal area code	Monitoring area/data set	Time period assessed	Identity of indicator	Monitoring method	Assessment method
Bothnian Bay	Finland	Bothnian Bay Finnish Coastal waters	1	NA	NA	NA	NA	NA
Bothnian Bay	Sweden	Bothnian Bay Swedish Coastal waters	2	Kinnbäcksfjärden	2004-2020	Cyprinids	Fisheries independent data	ASCETS
Bothnian Bay	Sweden	Bothnian Bay Swedish Coastal waters	2	Råneå	2002-2020	Cyprinids	Fisheries independent data	ASCETS
The Quark	Finland	The Quark Finnish Coastal waters	3	NA	NA	NA	NA	NA
The Quark	Sweden	The Quark Swedish Coastal waters	4	Holmön	2002-2020	Cyprinids	Fisheries independent data	ASCETS
The Quark	Sweden	The Quark Swedish Coastal waters	4	Norrbyn	2002-2020	Cyprinids	Fisheries independent data	ASCETS
Bothnian Sea	Finland	Bothnian Sea Finnish Coastal waters	5	NA	NA	NA	NA	NA
Bothnian Sea	Sweden	Bothnian Sea Swedish Coastal waters	6	Forsmark	2002-2020	Cyprinids	Fisheries independent data	ASCETS
Bothnian Sea	Sweden	Bothnian Sea Swedish Coastal waters	6	Gaviksfjärden	2004-2020	Cyprinids	Fisheries independent data	ASCETS
Bothnian Sea	Sweden	Bothnian Sea Swedish Coastal waters	6	Långvindsfjärden	2002-2020	Cyprinids	Fisheries independent data	ASCETS
Åland Sea	Finland	Åland Sea Finnish Coastal waters	7	NA	NA	NA	NA	NA
Åland Sea	Sweden	Åland Sea Swedish Coastal waters	8	Galtfjärden	2002-2020	Cyprinids	Fisheries independent data	ASCETS
Åland Sea	Sweden	Åland Sea Swedish Coastal waters	8	Lagnö	2002-2020	Cyprinids	Fisheries independent data	ASCETS
Archipelago Sea	Finland	Archipelago Sea Coastal waters	9	Finbo	2002-2021	Cyprinids	Fisheries independent data	ASCETS
Archipelago Sea	Finland	Archipelago Sea Coastal waters	9	Kumlinge	2002-2021	Cyprinids	Fisheries independent data	ASCETS
Northern Baltic Sea	Finland	Northern Baltic Proper Finnish Coastal waters	10	NA	NA	NA	NA	NA
Northern Baltic Sea	Sweden	Northern Baltic Proper Swedish Coastal waters	11	Askö	2005-2020	Cyprinids	Fisheries independent data	ASCETS
Northern Baltic Sea	Sweden	Northern Baltic Proper Swedish Coastal waters	11	Muskö	1992-2020	Mesopredators	Fisheries independent data	ASCETS
Northern Baltic Sea	Sweden	Northern Baltic Proper Swedish Coastal waters	11	Vaxholm: Askrikefjärden	2016-2020	Cyprinids	Fisheries independent data	Trend
Northern Baltic Sea	Estonia	Northern Baltic Proper Estonian Coastal waters	12	NA	NA	NA	NA	NA
Gulf of Finland	Finland	Gulf of Finland Finnish Coastal waters	13	Brunskär	2002-2020	Cyprinids	Fisheries independent data	ASCETS
Gulf of Finland	Finland	Gulf of Finland Finnish Coastal waters	13	Helsinki	2005-2020	Cyprinids	Fisheries independent data	ASCETS
Gulf of Finland	Finland	Gulf of Finland Finnish Coastal waters	13	Tvärminne	2005-2020	Cyprinids	Fisheries independent data	ASCETS
Gulf of Finland	Estonia	Gulf of Finland Estonian Coastal waters	14	NA	NA	NA	NA	NA
Gulf of Finland	Russia	Gulf of Finland Russian Coastal waters	15	NA	NA	NA	NA	NA
Gulf of Riga	Estonia	Gulf of Riga Estonian Coastal waters	16	Hiiumaa	1991-2020	Cyprinids	Fisheries independent data	ASCETS
Gulf of Riga	Latvia	Gulf of Riga Latvian Coastal waters	17	Daugavgriva	2016-2020	Cyprinids	Fisheries independent data	Trend
Western Gotland Basin	Sweden	Western Gotland Basin Swedish Coastal waters	18	Kvädöfjärden	1998-2020	Mesopredators	Fisheries independent data	ASCETS
Western Gotland Basin	Sweden	Western Gotland Basin Swedish Coastal waters	18	Kvädöfjärden	2002-2020	Cyprinids	Fisheries independent data	ASCETS
Western Gotland Basin	Sweden	Western Gotland Basin Swedish Coastal waters	18	Vinö	2007-2020	Cyprinids	Fisheries independent data	ASCETS
Eastern Gotland Basin	Estonia	Eastern Gotland Basin Estonian Coastal waters	19	NA	NA	NA	NA	NA
Eastern Gotland Basin	Latvia	Eastern Gotland Basin Latvian Coastal waters	20	Jurkalne	2016-2020	Cyprinids	Fisheries independent data	Trend
Eastern Gotland Basin	Lithuania	Eastern Gotland Basin Lithuanian Coastal waters	21	Curonian lagoon	1998-2020	Cyprinids	Fisheries independent data	ASCETS
Eastern Gotland Basin	Lithuania	Eastern Gotland Basin Lithuanian Coastal waters	21	Karklė	2000-2020	Mesopredators	Fisheries independent data	Trend
Eastern Gotland Basin	Lithuania	Eastern Gotland Basin Lithuanian Coastal waters	21	Mon/But	1998-2020	Mesopredators	Fisheries independent data	ASCETS
Eastern Gotland Basin	Lithuania	Eastern Gotland Basin Lithuanian Coastal waters	21	Smiltynė	2000-2020	Mesopredators	Fisheries independent data	ASCETS
Eastern Gotland Basin	Lithuania	Eastern Gotland Basin Lithuanian Coastal waters	21	Šventoji	2000-2020	Mesopredators	Fisheries independent data	ASCETS
Eastern Gotland Basin	Sweden	Eastern Gotland Basin Swedish Coastal waters	22	Herrvik	2018-2020	Mesopredators	Fisheries independent data	Trend
Eastern Gotland Basin	Russian	Eastern Gotland Basin Russian Coastal waters	23	NA	NA	NA	NA	NA
Eastern Gotland Basin	Poland	Eastern Gotland Basin Polish Coastal waters	24	NA	NA	NA	NA	NA
Gdansk Basin	Russia	Gdansk Basin Russian Coastal waters	25	NA	NA	NA	NA	NA
Gdansk Basin	Poland	Gdansk Basin Polish Coastal waters	26	Zalew Pucki	2011-2020	Mesopredators	Fisheries independent data	Trend
Gdansk Basin	Poland	Gdansk Basin Polish Coastal waters	26	Zalew Wiślany	2011-2020	Cyprinids	Fisheries independent data	Trend
Gdansk Basin	Poland	Gdansk Basin Polish Coastal waters	26	Zatoka Pucka Zewnętrzna	2011-2020	Mesopredators	Fisheries independent data	Trend
Bornholm Basin	Sweden	Bornholm Basin Swedish Coastal waters	27	Hanöbukten	2015-2020	Mesopredators	Fisheries independent data	Trend
Bornholm Basin	Sweden	Bornholm Basin Swedish Coastal waters	27	Torhamn	2002-2020	Cyprinids	Fisheries independent data	ASCETS
Bornholm Basin	Poland	Bornholm Basin Polish Coastal waters	28	NA	NA	NA	NA	NA
Bornholm Basin	Denmark	Bornholm Basin Danish Coastal waters	29	NA	NA	NA	NA	NA
Bornholm Basin	Germany	Bornholm Basin German Coastal waters	30	NA	NA	NA	NA	NA
Arkona Basin	Sweden	Arkona Basin Swedish Coastal waters	31	Stavstendsudde	2018-2020	Mesopredators	Fisheries independent data	Trend
Arkona Basin	Denmark	Arkona Basin Danish Coastal waters	32	NA	NA	NA	NA	NA
Arkona Basin	Germany	Arkona Basin German Coastal waters	33	NA	NA	NA	NA	NA
Mecklenburg Bight	Germany	Mecklenburg Bight German Coastal waters	34	NA	NA	NA	NA	NA
Mecklenburg Bight	Denmark	Mecklenburg Bight Danish Coastal waters	35	NA	NA	NA	NA	NA
Kiel Bight	Denmark	Kiel Bight Danish Coastal waters	36	NA	NA	NA	NA	NA
Kiel Bight	Germany	Kiel Bight German Coastal waters	37	NA	NA	NA	NA	NA
Belt Sea	Denmark	Belts Danish Coastal waters	38	NA	NA	NA	NA	NA
The Sound	Sweden	The Sound Swedish Coastal waters	39	NA	NA	NA	NA	NA
The Sound	Denmark	The Sound Danish Coastal waters	40	NA	NA	NA	NA	NA
Kattegat	Sweden	Kattegat Swedish Coastal waters, including Limfjorden	41	NA	NA	NA	NA	NA
Kattegat	Denmark	Kattegat Danish Coastal waters, including Limfjorden	42	NA	NA	NA	NA	NA

Appendix results Table 6. Functional groups (cyprinids/mesopredators) evaluation results for the assessment period 2016–2021. GS = good status, nGS = not good status. Column headings provide the following information: geographic location, the status during the reference period, the threshold value for good status (for the trend-based approach the + or − sign indicate the desired direction of the trend), the current indicator value, the status of the monitoring area, and the aggregated status of the assessment unit. The status for each assessment unit is derived using the One-Out-All-Out principle across monitoring locations.

Sub-basin	Country	Coastal area name (assessment unit)	Monitoring area/data set	Identity of indicator	Ref. period status	Threshold value(s)	Current value	Status monitoring location	Status assessment unit
Bothnian Bay	Finland	Bothnian Bay Finnish Coastal waters	NA	NA	NA	NA	NA	NA	NA
Bothnian Bay	Sweden	Bothnian Bay Swedish Coastal waters	Kinnbäcksfjärden	Cyprinids	GS	0.013;0.19	0.14	GS	
Bothnian Bay	Sweden	Bothnian Bay Swedish Coastal waters	Råneå	Cyprinids	GS	18.15;35.7	26.25	GS	GS
The Quark	Finland	The Quark Finnish Coastal waters	NA	NA	NA	NA	NA	NA	NA
The Quark	Sweden	The Quark Swedish Coastal waters	Holmön	Cyprinids	nGS	4.66;13.9	12.74	nGS	
The Quark	Sweden	The Quark Swedish Coastal waters	Norrbyn	Cyprinids	nGS	4.54;10	12.69	nGS	nGS
Bothnian Sea	Finland	Bothnian Sea Finnish Coastal waters	NA	NA	NA	NA	NA	NA	NA
Bothnian Sea	Sweden	Bothnian Sea Swedish Coastal waters	Forsmark	Cyprinids	GS	4.36;9.27	8.3	GS	
Bothnian Sea	Sweden	Bothnian Sea Swedish Coastal waters	Gaviksfjärden	Cyprinids	GS	9.27;17.85	15.2	GS	
Bothnian Sea	Sweden	Bothnian Sea Swedish Coastal waters	Långvindsfjärden	Cyprinids	GS	4.59;14.87	13.36	GS	GS
Åland Sea	Finland	Åland Sea Finnish Coastal waters	NA	NA	NA	NA	NA	NA	NA
Åland Sea	Sweden	Åland Sea Swedish Coastal waters	Galtfjärden	Cyprinids	GS	14.36;21.31	20.97	GS	
Åland Sea	Sweden	Åland Sea Swedish Coastal waters	Lagnö	Cyprinids	nGS	34.5;10.67	14.7	nGS	nGS
Archipelago Sea	Finland	Archipelago Sea Coastal waters	Finbo	Cyprinids	nGS	12.1;22.7	22.1	nGS	
Archipelago Sea	Finland	Archipelago Sea Coastal waters	Kumlinge	Cyprinids	nGS	3.07;7.28	5.23	nGS	nGS
Northern Baltic Sea	Finland	Northern Baltic Proper Finnish Coastal waters	NA	NA	NA	NA	NA	NA	NA
Northern Baltic Sea	Sweden	Northern Baltic Proper Swedish Coastal waters	Askö	Cyprinids	GS	1.86;22.3	10.5	GS	
Northern Baltic Sea	Sweden	Northern Baltic Proper Swedish Coastal waters	Muskö	Mesopredators	GS	12;51.41	16.75	GS	
Northern Baltic Sea	Sweden	Northern Baltic Proper Swedish Coastal waters	Vaxholm: Askrikefjärden	Cyprinids	nGS	Slope p >0.1 (-)	P slope = 0.46	nGS	nGS
Northern Baltic Sea	Estonia	Northern Baltic Proper Estonian Coastal waters	NA	NA	NA	NA	NA	NA	NA
Gulf of Finland	Finland	Gulf of Finland Finnish Coastal waters	Brunskär	Cyprinids	GS	0.07;0.8	0.32	GS	
Gulf of Finland	Finland	Gulf of Finland Finnish Coastal waters	Helsinki	Cyprinids	nGS	1.79;3.34	2.71	nGS	
Gulf of Finland	Finland	Gulf of Finland Finnish Coastal waters	Tvärminne	Cyprinids	GS	1.48;3.7	2.46	GS	nGS
Gulf of Finland	Estonia	Gulf of Finland Estonian Coastal waters	NA	NA	NA	NA	NA	NA	NA
Gulf of Finland	Russia	Gulf of Finland Russian Coastal waters	NA	NA	NA	NA	NA	NA	NA
Gulf of Riga	Estonia	Gulf of Riga Estonian Coastal waters	Hiiumaa	Cyprinids	nGS	2.66;10.48	1.06	nGS	nGS
Gulf of Riga	Latvia	Gulf of Riga Latvian Coastal waters	Daugavgriva	Cyprinids	nGS	Slope p >0.1 (-)	P slope = 0.17	nGS	nGS
Western Gotland Basin	Sweden	Western Gotland Basin Swedish Coastal waters	Kvädöfjärden	Mesopredators	nGS	12.01;65.4	19.44	nGS	
Western Gotland Basin	Sweden	Western Gotland Basin Swedish Coastal waters	Kvädöfjärden	Cyprinids	GS	10.88;18.2	20.18	nGS	
Western Gotland Basin	Sweden	Western Gotland Basin Swedish Coastal waters	Vinö	Cyprinids	GS	24.9;86.28	65.42	GS	nGS
Eastern Gotland Basin	Estonia	Eastern Gotland Basin Estonian Coastal waters	NA	NA	NA	NA	NA	NA	NA
Eastern Gotland Basin	Latvia	Eastern Gotland Basin Latvian Coastal waters	Jurkalne	Cyprinids	nGS	Slope p >0.1 (+)	P slope = 0.03	nGS	nGS
Eastern Gotland Basin	Lithuania	Eastern Gotland Basin Lithuanian Coastal waters	Curonian lagoon	Cyprinids	GS	141.3;308.7	175	GS	
Eastern Gotland Basin	Lithuania	Eastern Gotland Basin Lithuanian Coastal waters	Karklė	Mesopredators	GS	Slope p >0.1	P slope = 0.91	GS	
Eastern Gotland Basin	Lithuania	Eastern Gotland Basin Lithuanian Coastal waters	Mon/But	Mesopredators	GS	43;104.3	133	nGS	
Eastern Gotland Basin	Lithuania	Eastern Gotland Basin Lithuanian Coastal waters	Smiltynė	Mesopredators	GS	8.99;43	39.8	GS	
Eastern Gotland Basin	Lithuania	Eastern Gotland Basin Lithuanian Coastal waters	Šventoji	Mesopredators	GS	4.1;34.3	20.1	GS	nGS
Eastern Gotland Basin	Sweden	Eastern Gotland Basin Swedish Coastal waters	Herrvik	Mesopredators			P slope = 0.2		NA
Eastern Gotland Basin	Russian	Eastern Gotland Basin Russian Coastal waters	NA	NA	NA	NA	NA	NA	NA
Eastern Gotland Basin	Poland	Eastern Gotland Basin Polish Coastal waters	NA	NA	NA	NA	NA	NA	NA
Gdansk Basin	Russia	Gdansk Basin Russian Coastal waters	NA	NA	NA	NA	NA	NA	NA
Gdansk Basin	Poland	Gdansk Basin Polish Coastal waters	Zalew Pucki	Mesopredators	GES	Slope p >0.1	P slope = 0.62	GS	
Gdansk Basin	Poland	Gdansk Basin Polish Coastal waters	Zalew Wiślany	Cyprinids	GES	Slope p >0.1	P slope = 0.69	GS	
Gdansk Basin	Poland	Gdansk Basin Polish Coastal waters	Zatoka Pucka Zewnętrzna	Mesopredators	GES	Slope p >0.1	P slope = 0.94	GS	GS
Bornholm Basin	Sweden	Bornholm Basin Swedish Coastal waters	Hanöbukten	Mesopredators	GS	Slope p >0.1	P slope = 0.2	GS	
Bornholm Basin	Sweden	Bornholm Basin Swedish Coastal waters	Torhamn	Cyprinids	GS	10.5;17.95	16.4	GS	GS
Bornholm Basin	Poland	Bornholm Basin Polish Coastal waters	NA	NA	NA	NA	NA	NA	NA
Bornholm Basin	Denmark	Bornholm Basin Danish Coastal waters	NA	NA	NA	NA	NA	NA	NA
Bornholm Basin	Germany	Bornholm Basin German Coastal waters	NA	NA	NA	NA	NA	NA	NA
Arkona Basin	Sweden	Arkona Basin Swedish Coastal waters	Stavstensudde	Mesopredators			P slope = 0.62		NA
Arkona Basin	Denmark	Arkona Basin Danish Coastal waters	NA	NA	NA	NA	NA	NA	NA
Arkona Basin	Germany	Arkona Basin German Coastal waters	NA	NA	NA	NA	NA	NA	NA
Mecklenburg Bight	Germany	Mecklenburg Bight German Coastal waters	NA	NA	NA	NA	NA	NA	NA
Mecklenburg Bight	Denmark	Mecklenburg Bight Danish Coastal waters	NA	NA	NA	NA	NA	NA	NA
Kiel Bight	Denmark	Kiel Bight Danish Coastal waters	NA	NA	NA	NA	NA	NA	NA
Kiel Bight	Germany	Kiel Bight German Coastal waters	NA	NA	NA	NA	NA	NA	NA
Belt Sea	Denmark	Belts Danish Coastal waters	NA	NA	NA	NA	NA	NA	NA
The Sound	Sweden	The Sound Swedish Coastal waters	NA	NA	NA	NA	NA	NA	NA
The Sound	Denmark	The Sound Danish Coastal waters	NA	NA	NA	NA	NA	NA	NA
Kattegat	Sweden	Kattegat Swedish Coastal waters, including Limfjorden	NA	NA	NA	NA	NA	NA	NA
Kattegat	Denmark	Kattegat Danish Coastal waters, including Limfjorden	NA	NA	NA	NA	NA	NA	NA

Appendix results Table 7. Confidence in the status evaluation of the functional group cyprinids/mesopredators indicator according to the criteria developed within HELCOM for the integrated biodiversity assessment.

Sub-basin	Country	Coastal area name (assessment unit)	Monitoring area/data set	Identity of indicator	ConfA	ConfT	ConfS	ConfM
Bothnian Bay	Finland	Bothnian Bay Finnish Coastal waters	NA	NA	NA	NA	NA	NA
Bothnian Bay	Sweden	Bothnian Bay Swedish Coastal waters	Kinnbäcksfjärden	Cyprinids	0.5	1	0.5	1
Bothnian Bay	Sweden	Bothnian Bay Swedish Coastal waters	Råneå	Cyprinids	0	1	0.5	1
The Quark	Finland	The Quark Finnish Coastal waters	NA	NA	NA	NA	NA	NA
The Quark	Sweden	The Quark Swedish Coastal waters	Holmön	Cyprinids	0	1	0.5	1
The Quark	Sweden	The Quark Swedish Coastal waters	Norrbyn	Cyprinids	1	1	0.5	1
Bothnian Sea	Finland	Bothnian Sea Finnish Coastal waters	NA	NA	NA	NA	NA	NA
Bothnian Sea	Sweden	Bothnian Sea Swedish Coastal waters	Forsmark	Cyprinids	0.5	1	0.5	1
Bothnian Sea	Sweden	Bothnian Sea Swedish Coastal waters	Gaviksfjärden	Cyprinids	0.5	1	0.5	1
Bothnian Sea	Sweden	Bothnian Sea Swedish Coastal waters	Långvindsfjärden	Cyprinids	0.5	1	0.5	1
Åland Sea	Finland	Åland Sea Finnish Coastal waters	NA	NA	NA	NA	NA	NA
Åland Sea	Sweden	Åland Sea Swedish Coastal waters	Galtfjärden	Cyprinids	0.5	1	0.5	1
Åland Sea	Sweden	Åland Sea Swedish Coastal waters	Lagnö	Cyprinids	1	1	0.5	1
Archipelago Sea	Finland	Archipelago Sea Coastal waters	Finbo	Cyprinids	0.5	1	0.5	1
Archipelago Sea	Finland	Archipelago Sea Coastal waters	Kumlinge	Cyprinids	1	1	0.5	1
Northern Baltic Sea	Finland	Northern Baltic Proper Finnish Coastal waters	NA	NA	NA	NA	NA	NA
Northern Baltic Sea	Sweden	Northern Baltic Proper Swedish Coastal waters	Askö	Cyprinids	1	1	0.5	1
Northern Baltic Sea	Sweden	Northern Baltic Proper Swedish Coastal waters	Muskö	Mesopredators	1	1	0.5	1
Northern Baltic Sea	Sweden	Northern Baltic Proper Swedish Coastal waters	Vaxholm: Askrikefjärden	Cyprinids	0.5	1	0.5	1
Northern Baltic Sea	Estonia	Northern Baltic Proper Estonian Coastal waters	NA	NA	NA	NA	NA	NA
Gulf of Finland	Finland	Gulf of Finland Finnish Coastal waters	Brunskär	Cyprinids	1	1	1	1
Gulf of Finland	Finland	Gulf of Finland Finnish Coastal waters	Helsinki	Cyprinids	0	0.5	1	1
Gulf of Finland	Finland	Gulf of Finland Finnish Coastal waters	Tvärminne	Cyprinids	0.5	1	1	1
Gulf of Finland	Estonia	Gulf of Finland Estonian Coastal waters	NA	NA	NA	NA	NA	NA
Gulf of Finland	Russia	Gulf of Finland Russian Coastal waters	NA	NA	NA	NA	NA	NA
Gulf of Riga	Estonia	Gulf of Riga Estonian Coastal waters	Hiiumaa	Cyprinids	1	1	0	1
Gulf of Riga	Latvia	Gulf of Riga Latvian Coastal waters	Daugavgriva	Cyprinids	0	1	0	1
Western Gotland Basin	Sweden	Western Gotland Basin Swedish Coastal waters	Kvädöfjärden	Mesopredators	0.5	1	0.5	1
Western Gotland Basin	Sweden	Western Gotland Basin Swedish Coastal waters	Kvädöfjärden	Cyprinids	0.5	1	0.5	1
Western Gotland Basin	Sweden	Western Gotland Basin Swedish Coastal waters	Vinö	Cyprinids	0.5	1	0.5	1
Eastern Gotland Basin	Estonia	Eastern Gotland Basin Estonian Coastal waters	NA	NA	NA	NA	NA	NA
Eastern Gotland Basin	Latvia	Eastern Gotland Basin Latvian Coastal waters	Jurkalne	Cyprinids	1	1	0	1
Eastern Gotland Basin	Lithuania	Eastern Gotland Basin Lithuanian Coastal waters	Curonian lagoon	Cyprinids	1	1	1	1
Eastern Gotland Basin	Lithuania	Eastern Gotland Basin Lithuanian Coastal waters	Karklė	Mesopredators	1	1	1	1
Eastern Gotland Basin	Lithuania	Eastern Gotland Basin Lithuanian Coastal waters	Mon/But	Mesopredators	0	1	1	1
Eastern Gotland Basin	Lithuania	Eastern Gotland Basin Lithuanian Coastal waters	Smiltynė	Mesopredators	0	1	1	1
Eastern Gotland Basin	Lithuania	Eastern Gotland Basin Lithuanian Coastal waters	Šventoji	Mesopredators	1	1	1	1
Eastern Gotland Basin	Sweden	Eastern Gotland Basin Swedish Coastal waters	Herrvik	Mesopredators	0.5	0.5	0	1
Eastern Gotland Basin	Russian	Eastern Gotland Basin Russian Coastal waters	NA	NA	NA	NA	NA	NA
Eastern Gotland Basin	Poland	Eastern Gotland Basin Polish Coastal waters	NA	NA	NA	NA	NA	NA
Gdansk Basin	Russia	Gdansk Basin Russian Coastal waters	NA	NA	NA	NA	NA	NA
Gdansk Basin	Poland	Gdansk Basin Polish Coastal waters	Zalew Pucki	Mesopredators	1	1	1	1
Gdansk Basin	Poland	Gdansk Basin Polish Coastal waters	Zalew Wiślany	Cyprinids	1	1	1	1
Gdansk Basin	Poland	Gdansk Basin Polish Coastal waters	Zatoka Pucka Zewnętrzna	Mesopredators	1	0.5	1	1
Bornholm Basin	Sweden	Bornholm Basin Swedish Coastal waters	Hanöbukten	Mesopredators	0	1	0.5	1
Bornholm Basin	Sweden	Bornholm Basin Swedish Coastal waters	Torhamn	Cyprinids	0.5	1	0.5	1
Bornholm Basin	Poland	Bornholm Basin Polish Coastal waters	NA	NA	NA	NA	NA	NA
Bornholm Basin	Denmark	Bornholm Basin Danish Coastal waters	NA	NA	NA	NA	NA	NA
Bornholm Basin	Germany	Bornholm Basin German Coastal waters	NA	NA	NA	NA	NA	NA
Arkona Basin	Sweden	Arkona Basin Swedish Coastal waters	Stavstendsudde	Mesopredators	1	0.5	0	1
Arkona Basin	Denmark	Arkona Basin Danish Coastal waters	NA	NA	NA	NA	NA	NA
Arkona Basin	Germany	Arkona Basin German Coastal waters	NA	NA	NA	NA	NA	NA
Mecklenburg Bight	Germany	Mecklenburg Bight German Coastal waters	NA	NA	NA	NA	NA	NA
Mecklenburg Bight	Denmark	Mecklenburg Bight Danish Coastal waters	NA	NA	NA	NA	NA	NA
Kiel Bight	Denmark	Kiel Bight Danish Coastal waters	NA	NA	NA	NA	NA	NA
Kiel Bight	Germany	Kiel Bight German Coastal waters	NA	NA	NA	NA	NA	NA
Belt Sea	Denmark	Belts Danish Coastal waters	NA	NA	NA	NA	NA	NA
The Sound	Sweden	The Sound Swedish Coastal waters	NA	NA	NA	NA	NA	NA
The Sound	Denmark	The Sound Danish Coastal waters	NA	NA	NA	NA	NA	NA
Kattegat	Sweden	Kattegat Swedish Coastal waters, including Limfjorden	NA	NA	NA	NA	NA	NA
Kattegat	Denmark	Kattegat Danish Coastal waters, including Limfjorden	NA	NA	NA	NA	NA	NA

Appendix results Table 8. Overview of trends for functional groups between current and previous assessment in year 2018 (HOLAS 2, including data until 2016). For each HELCOM assessment unit, it is noted whether the integrated status using the BEAT tool achieves of fails to achieve the threshold value. The current integrated status is compared to the pervious status with regards to any distinct increasing or decreasing trend. In case of changed integrated status, the outcome is briefly described focusing on the relevant changes compared to the previous assessment.

HELCOM Assessment unit name (and ID)	Threshold value: achieved/failed	Distinct trend between current and previous assessment	Description of outcomes
Archipelago Sea Coastal waters	failed	no change	
Bornholm Basin Swedish Coastal waters	achieved	no change	
Bothnian Bay Finnish Coastal waters	NA		Not included iin HOLAS 3
Bothnian Bay Swedish Coastal waters	achieved	no change	
Bothnian Sea Finnish Coastal waters	NA		Not included iin HOLAS 3
Bothnian Sea Swedish Coastal waters	achieved	no change	
Eastern Gotland Basin Latvian Coastal waters	failed	no change	
Eastern Gotland Basin Lithuanian Coastal waters	failed	decrease	Inclusion of 3 new monitoring locations, all with GS, but status is decreased due to nGS in Mon/But
Gulf of Finland Finnish Coastal waters	failed	no change	
Gdansk Basin Polish Coastal waters	achieved	NA HOLAS II	
Gulf of Riga Estonian Coastal waters	failed	no change	
Gulf of Riga Latvian Coastal waters	failed	no change	
Northern Baltic Proper Swedish Coastal waters	failed	decrease	Inclusion of two new monitoring locations, status has decreased due to inclusion of Vaxholm
The Quark Finnish Coastal waters	NA		Not included in HOLAS 3
The Quark Swedish Coastal waters	failed	no change	
Western Gotland Basin Swedish Coastal waters	failed	decrease	Due to inclusion of mesopredators in Kvädöfjärden, status has decreased
Åland Sea Swedish Coastal waters	failed	no change	

Size structure of coastal fish

Functional groups result Tables

Appendix result Table 9. Data and methods used for the status evaluation of the size distribution of key coastal fish species for the assessment. Column headings provide the following information: geographic location, the time period assessed, the key species used, the monitoring method, and the assessment approach applied.

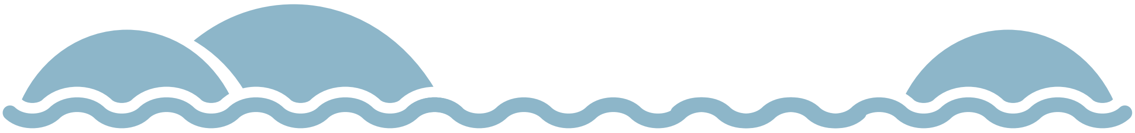
Sub-basin	Country	Coastal area name (assessment unit)	Coastal area code	Monitoring area	Time period assesed	L90 key species	Monitoring method	Assessment method
Bothnian Bay	Finland	Bothnian Bay Finnish Coastal waters	1	NA	NA	NA	Commercial statistics	NA
Bothnian Bay	Sweden	Bothnian Bay Swedish Coastal waters	2	Råneå	2002-2020	Perch	Fisheries independent data	THV
Bothnian Bay	Sweden	Bothnian Bay Swedish Coastal waters	2	Kinnbäcksfjärden	2004-2020	Perch	Fisheries independent data	THV
The Quark	Finland	The Quark Finnish Coastal waters	3	Finnish ICES rect 23	2017-2019	Perch	Commercial statistics	THV
The Quark	Sweden	The Quark Swedish Coastal waters	4	Holmön	2002-2020	Perch	Fisheries independent data	THV
The Quark	Sweden	The Quark Swedish Coastal waters	4	Norrbyn	2002-2020	Perch	Fisheries independent data	THV
Bothnian Sea	Finland	Bothnian Sea Finnish Coastal waters	5	Finnish ICES SD 30	2010-2020	Perch	Commercial statistics	THV
Bothnian Sea	Finland	Bothnian Sea Finnish Coastal waters	5	Finnish ICES SD 30	2010-2020	Pikeperch	Commercial statistics	Trend
Bothnian Sea	Sweden	Bothnian Sea Swedish Coastal waters	6	Gaviksfjärden	2004-2020	Perch	Fisheries independent data	THV
Bothnian Sea	Sweden	Bothnian Sea Swedish Coastal waters	6	Långvindsfjärden	2002-2020	Perch	Fisheries independent data	THV
Bothnian Sea	Sweden	Bothnian Sea Swedish Coastal waters	6	Forsmark	2002-2020	Perch	Fisheries independent data	THV
Åland Sea	Finland	Åland Sea Finnish Coastal waters	7	NA	NA	NA	NA	NA
Åland Sea	Sweden	Åland Sea Swedish Coastal waters	8	Galtfjärden	2002-2020	Perch	Fisheries independent data	THV
Åland Sea	Sweden	Åland Sea Swedish Coastal waters	8	Lagnö	2002-2020	Perch	Fisheries independent data	THV
Archipelago Sea	Finland	Archipelago Sea Coastal waters	9	Finbo	2002-2020	Perch	Fisheries independent data	THV
Archipelago Sea	Finland	Archipelago Sea Coastal waters	9	Kumlinge	2003-2020	Perch	Fisheries independent data	THV
Archipelago Sea	Finland	Archipelago Sea Coastal waters	9	Finnish ICES SD 29	2010-2020	Perch	Commercial statistics	THV
Archipelago Sea	Finland	Archipelago Sea Coastal waters	9	Finnish ICES SD 29	2010-2020	Pikeperch	Commercial statistics	Trend
Northern Baltic Sea	Finland	Northern Baltic Proper Finnish Coastal waters	10	NA	NA	NA	NA	NA
Northern Baltic Sea	Sweden	Northern Baltic Proper Swedish Coastal waters	11	Vaxholm: Askrikefjärden	2016-2020	Perch	Fisheries independent data	THV
Northern Baltic Sea	Sweden	Northern Baltic Proper Swedish Coastal waters	11	Askö	2005-2020	Perch	Fisheries independent data	THV
Northern Baltic Sea	Sweden	Northern Baltic Proper Swedish Coastal waters	11	Muskö	1992-2020	Flounder	Fisheries independent data	Trend
Northern Baltic Sea	Estonia	Northern Baltic Proper Estonian Coastal waters	12	NA	NA	NA	NA	NA
Gulf of Finland	Finland	Gulf of Finland Finnish Coastal waters	13	Brunskär	2002-2020	Perch	Fisheries independent data	THV
Gulf of Finland	Finland	Gulf of Finland Finnish Coastal waters	13	Tvärminne	2005-2020	Perch	Fisheries independent data	THV
Gulf of Finland	Finland	Gulf of Finland Finnish Coastal waters	13	Helsinki	2005-2020	Perch	Fisheries independent data	THV
Gulf of Finland	Finland	Gulf of Finland Finnish Coastal waters	13	Finnish ICES SD 32	2010-2020	Pikeperch	Commercial statistics	Trend
Gulf of Finland	Estonia	Gulf of Finland Estonian Coastal waters	14	NA	NA	NA	NA	NA
Gulf of Finland	Russia	Gulf of Finland Russian Coastal waters	15	NA	NA	NA	NA	NA
Gulf of Riga	Estonia	Gulf of Riga Estonian Coastal waters	16	Hiiumaa	1998-2020	Perch	Fisheries independent data	THV
Gulf of Riga	Latvia	Gulf of Riga Latvian Coastal waters	17	Daugavgriva	2016-2020	Perch	Fisheries independent data	THV
Western Gotland Basin	Sweden	Western Gotland Basin Swedish Coastal waters	18	Kvädöfjärden, summer	2002-2020	Perch	Fisheries independent data	THV
Western Gotland Basin	Sweden	Western Gotland Basin Swedish Coastal waters	18	Kvädöfjärden, autumn	1989-2020	Flounder	Fisheries independent data	Trend
Western Gotland Basin	Sweden	Western Gotland Basin Swedish Coastal waters	18	Vinö	2007-2020	Perch	Fisheries independent data	THV
Eastern Gotland Basin	Estonia	Eastern Gotland Basin Estonian Coastal waters	19	NA	NA	NA	NA	NA
Eastern Gotland Basin	Latvia	Eastern Gotland Basin Latvian Coastal waters	20	Jurkalne	2016-2020	Flounder	Fisheries independent data	Trend
Eastern Gotland Basin	Lithuania	Eastern Gotland Basin Lithuanian Coastal waters	21	Mon/But	1998-2020	Flounder	Fisheries independent data	Trend
Eastern Gotland Basin	Lithuania	Eastern Gotland Basin Lithuanian Coastal waters	21	Šventoji	2006-2020	Flounder	Fisheries independent data	Trend
Eastern Gotland Basin	Lithuania	Eastern Gotland Basin Lithuanian Coastal waters	21	Karklė	2006-2020	Flounder	Fisheries independent data	Trend
Eastern Gotland Basin	Lithuania	Eastern Gotland Basin Lithuanian Coastal waters	21	Smiltynė	2006-2020	Flounder	Fisheries independent data	Trend
Eastern Gotland Basin	Lithuania	Eastern Gotland Basin Lithuanian Coastal waters	21	Curonian lagoon	1998-2020	Perch	Fisheries independent data	THV
Eastern Gotland Basin	Sweden	Eastern Gotland Basin Swedish Coastal waters	22	Herrvik	2018-2020	Flounder	Fisheries independent data	Trend
Eastern Gotland Basin	Russian	Eastern Gotland Basin Russian Coastal waters	23	NA	NA	NA	NA	NA
Eastern Gotland Basin	Poland	Eastern Gotland Basin Polish Coastal waters	24	NA	NA	NA	NA	NA
Gdansk Basin	Russia	Gdansk Basin Russian Coastal waters	25	NA	NA	NA	NA	NA
Gdansk Basin	Poland	Gdansk Basin Polish Coastal waters	26	Zatoka Pucka Zewnętrzna	2014-2020	Perch	Fisheries independent data	THV
Gdansk Basin	Poland	Gdansk Basin Polish Coastal waters	26	Zatoka Pucka Zewnętrzna	2014-2020	Flounder	Fisheries independent data	Trend
Gdansk Basin	Poland	Gdansk Basin Polish Coastal waters	26	Zalew Pucki	2014-2020	Perch	Fisheries independent data	THV
Gdansk Basin	Poland	Gdansk Basin Polish Coastal waters	26	Zalew Pucki	2014-2020	Flounder	Fisheries independent data	Trend
Gdansk Basin	Poland	Gdansk Basin Polish Coastal waters	26	Zalew Wiślany	2014-2020	Perch	Fisheries independent data	THV
Bornholm Basin	Sweden	Bornholm Basin Swedish Coastal waters	27	Torhamn	2002-2020	Perch	Fisheries independent data	THV
Bornholm Basin	Sweden	Bornholm Basin Swedish Coastal waters	27	Hanöbukten	2015-2020	Flounder	Fisheries independent data	Trend
Bornholm Basin	Poland	Bornholm Basin Polish Coastal waters	28	NA	NA	NA	NA	NA
Bornholm Basin	Denmark	Bornholm Basin Danish Coastal waters	29	NA	NA	NA	NA	NA
Bornholm Basin	Germany	Bornholm Basin German Coastal waters	30	NA	NA	NA	NA	NA
Arkona Basin	Sweden	Arkona Basin Swedish Coastal waters	31	Stavstendsudde	2018-2020	Flounder	Fisheries independent data	Trend
Arkona Basin	Denmark	Arkona Basin Danish Coastal waters	32	NA	NA	NA	NA	NA
Arkona Basin	Germany	Arkona Basin German Coastal waters	33	NA	NA	NA	NA	NA
Mecklenburg Bight	Germany	Mecklenburg Bight German Coastal waters	34	NA	NA	NA	NA	NA
Mecklenburg Bight	Denmark	Mecklenburg Bight Danish Coastal waters	35	NA	NA	NA	NA	NA
Kiel Bight	Denmark	Kiel Bight Danish Coastal waters	36	NA	NA	NA	NA	NA
Kiel Bight	Germany	Kiel Bight German Coastal waters	37	NA	NA	NA	NA	NA
Belt Sea	Denmark	Belts Danish Coastal waters	38	NA	NA	NA	NA	NA
The Sound	Sweden	The Sound Swedish Coastal waters	39	NA	NA	NA	NA	NA
The Sound	Denmark	The Sound Danish Coastal waters	40	NA	NA	NA	NA	NA
Kattegat	Sweden	Kattegat Swedish Coastal waters, including Limfjorden	41	NA	NA	NA	NA	NA
Kattegat	Denmark	Kattegat Danish Coastal waters, including Limfjorden	42	NA	NA	NA	NA	NA

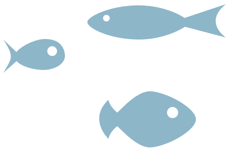
Appendix result Table 10. Status evaluation outcome for size distribution of key coastal fish species per monitoring location and assessment unit for the assessment period 2016-2020. GS = good status, nGS = not good status. Column headings provide the following information: geographic location, the status during the reference period, the threshold value for good status (for the trend-based approach the + or – sign indicate the desired direction of the trend), the current indicator value (the current value is shown for perch. For flounder and pikeperch, the current value with accompanying direction of trend is shown (+: increasing, s: stable, -: decreasing)), the status of the monitoring area, and the aggregated status of the assessment unit. The status for each assessment unit is derived using the One-Out-All-Out principle across monitoring locations.

Sub-basin	Country	Coastal area name (assessment unit)	Monitoring area	L90 key species	Threhold value	Current value (trend)	status, monitoring location	Status, assessment unit
Bothnian Bay	Finland	Bothnian Bay Finnish Coastal waters	NA	NA	NA	NA	NA	NA
Bothnian Bay	Sweden	Bothnian Bay Swedish Coastal waters	Råneå	Perch	25	28	GS	
Bothnian Bay	Sweden	Bothnian Bay Swedish Coastal waters	Kinnbäcksfjärden	Perch	25	23	nGS	nGS
The Quark	Finland	The Quark Finnish Coastal waters	Finnish ICES rect 23	Perch	25	29	GS	GS
The Quark	Sweden	The Quark Swedish Coastal waters	Holmön	Perch	25	27	GS	
The Quark	Sweden	The Quark Swedish Coastal waters	Norrbyn	Perch	25	23	nGS	nGS
Bothnian Sea	Finland	Bothnian Sea Finnish Coastal waters	Finnish ICES SD 30	Perch	25	29	GS	GS
Bothnian Sea	Finland	Bothnian Sea Finnish Coastal waters	Finnish ICES SD 30	Pikeperch	NA	42(s)	NA	NA
Bothnian Sea	Sweden	Bothnian Sea Swedish Coastal waters	Gaviksfjärden	Perch	25	26	GS	
Bothnian Sea	Sweden	Bothnian Sea Swedish Coastal waters	Långvindsfjärden	Perch	25	27	GS	
Bothnian Sea	Sweden	Bothnian Sea Swedish Coastal waters	Forsmark	Perch	25	26	GS	GS
Åland Sea	Finland	Åland Sea Finnish Coastal waters	NA	NA	NA	NA	NA	NA
Åland Sea	Sweden	Åland Sea Swedish Coastal waters	Galtfjärden	Perch	25	23	nGS	
Åland Sea	Sweden	Åland Sea Swedish Coastal waters	Lagnö	Perch	25	23	nGS	nGS
Archipelago Sea	Finland	Archipelago Sea Coastal waters	Finbo	Perch	25	28	GS	
Archipelago Sea	Finland	Archipelago Sea Coastal waters	Kumlinge	Perch	25	24	nGS	
Archipelago Sea	Finland	Archipelago Sea Coastal waters	Finnish ICES SD 29	Perch	25	30	GS	nGS
Archipelago Sea	Finland	Archipelago Sea Coastal waters	Finnish ICES SD 29	Pikeperch	NA	43(s)	NA	NA
Northern Baltic Sea	Finland	Northern Baltic Proper Finnish Coastal waters	NA	NA	NA	NA	NA	
Northern Baltic Sea	Sweden	Northern Baltic Proper Swedish Coastal waters	Vaxholm: Askrikefjärden	Perch	25	28.5	GS	
Northern Baltic Sea	Sweden	Northern Baltic Proper Swedish Coastal waters	Askö	Perch	25	23	nGS	nGS
Northern Baltic Sea	Sweden	Northern Baltic Proper Swedish Coastal waters	Muskö	Flounder	NA	23.5(s)	NA	NA
Northern Baltic Sea	Estonia	Northern Baltic Proper Estonian Coastal waters	NA	NA	NA	NA	NA	
Gulf of Finland	Finland	Gulf of Finland Finnish Coastal waters	Brunskär	Perch	25	21	nGS	
Gulf of Finland	Finland	Gulf of Finland Finnish Coastal waters	Tvärminne	Perch	25	22	nGS	
Gulf of Finland	Finland	Gulf of Finland Finnish Coastal waters	Helsinki	Perch	25	26	GS	nGS
Gulf of Finland	Finland	Gulf of Finland Finnish Coastal waters	Finnish ICES SD 32	Pikeperch	NA	50(+)	NA	NA
Gulf of Finland	Estonia	Gulf of Finland Estonian Coastal waters	NA	NA	NA	NA	NA	NA
Gulf of Finland	Russia	Gulf of Finland Russian Coastal waters	NA	NA	NA	NA	NA	NA
Gulf of Riga	Estonia	Gulf of Riga Estonian Coastal waters	Hiiumaa	Perch	23	24	GS	GS
Gulf of Riga	Latvia	Gulf of Riga Latvian Coastal waters	Daugavgriva	Perch	25	20	nGS	nGS
Western Gotland Basin	Sweden	Western Gotland Basin Swedish Coastal waters	Kvädöfjärden, summer	Perch	25	27	GS	
Western Gotland Basin	Sweden	Western Gotland Basin Swedish Coastal waters	Kvädöfjärden, autumn	Flounder	NA	27.5(s)	NA	NA
Western Gotland Basin	Sweden	Western Gotland Basin Swedish Coastal waters	Vinö	Perch	23	22	nGS	nGS
Eastern Gotland Basin	Estonia	Eastern Gotland Basin Estonian Coastal waters	NA	NA	NA	NA	NA	NA
Eastern Gotland Basin	Latvia	Eastern Gotland Basin Latvian Coastal waters	Jurkalne	Flounder	NA	29(s)	NA	NA
Eastern Gotland Basin	Lithuania	Eastern Gotland Basin Lithuanian Coastal waters	Mon/But	Flounder	NA	26(s)	NA	NA
Eastern Gotland Basin	Lithuania	Eastern Gotland Basin Lithuanian Coastal waters	Šventoji	Flounder	NA	30(s)	NA	NA
Eastern Gotland Basin	Lithuania	Eastern Gotland Basin Lithuanian Coastal waters	Karklė	Flounder	NA	31.2(+)	NA	NA
Eastern Gotland Basin	Lithuania	Eastern Gotland Basin Lithuanian Coastal waters	Smiltynė	Flounder	NA	31(s)	NA	NA
Eastern Gotland Basin	Lithuania	Eastern Gotland Basin Lithuanian Coastal waters	Curonian lagoon	Perch	23	22	nGS	nGS
Eastern Gotland Basin	Sweden	Eastern Gotland Basin Swedish Coastal waters	Herrvik	Flounder	NA	28(s)	NA	NA
Eastern Gotland Basin	Russian	Eastern Gotland Basin Russian Coastal waters	NA	NA	NA	NA	NA	NA
Eastern Gotland Basin	Poland	Eastern Gotland Basin Polish Coastal waters	NA	NA	NA	NA	NA	NA
Gdansk Basin	Russia	Gdansk Basin Russian Coastal waters	NA	NA	NA	NA	NA	NA
Gdansk Basin	Poland	Gdansk Basin Polish Coastal waters	Zatoka Pucka Zewnętrzna	Perch	25	22	nGS	
Gdansk Basin	Poland	Gdansk Basin Polish Coastal waters	Zatoka Pucka Zewnętrzna	Flounder	NA	24(s)	NA	NA
Gdansk Basin	Poland	Gdansk Basin Polish Coastal waters	Zalew Pucki	Perch	25	22	nGS	
Gdansk Basin	Poland	Gdansk Basin Polish Coastal waters	Zalew Pucki	Flounder	NA	29(s)	NA	NA
Gdansk Basin	Poland	Gdansk Basin Polish Coastal waters	Zalew Wiślany	Perch	25	26	GS	nGS
Bornholm Basin	Sweden	Bornholm Basin Swedish Coastal waters	Torhamn	Perch	25	24	nGS	nGS
Bornholm Basin	Sweden	Bornholm Basin Swedish Coastal waters	Hanöbukten	Flounder	NA	30(s)	NA	NA
Bornholm Basin	Poland	Bornholm Basin Polish Coastal waters	NA	NA	NA	NA	NA	NA
Bornholm Basin	Denmark	Bornholm Basin Danish Coastal waters	NA	NA	NA	NA	NA	NA
Bornholm Basin	Germany	Bornholm Basin German Coastal waters	NA	NA	NA	NA	NA	NA
Arkona Basin	Sweden	Arkona Basin Swedish Coastal waters	Stavstendsudde	Flounder	NA	31(s)	NA	NA
Arkona Basin	Denmark	Arkona Basin Danish Coastal waters	NA	NA	NA	NA	NA	NA
Arkona Basin	Germany	Arkona Basin German Coastal waters	NA	NA	NA	NA	NA	NA
Mecklenburg Bight	Germany	Mecklenburg Bight German Coastal waters	NA	NA	NA	NA	NA	NA
Mecklenburg Bight	Denmark	Mecklenburg Bight Danish Coastal waters	NA	NA	NA	NA	NA	NA
Kiel Bight	Denmark	Kiel Bight Danish Coastal waters	NA	NA	NA	NA	NA	NA
Kiel Bight	Germany	Kiel Bight German Coastal waters	NA	NA	NA	NA	NA	NA
Belt Sea	Denmark	Belts Danish Coastal waters	NA	NA	NA	NA	NA	NA
The Sound	Sweden	The Sound Swedish Coastal waters	NA	NA	NA	NA	NA	NA
The Sound	Denmark	The Sound Danish Coastal waters	NA	NA	NA	NA	NA	NA
Kattegat	Sweden	Kattegat Swedish Coastal waters, including Limfjorden	NA	NA	NA	NA	NA	NA
Kattegat	Denmark	Kattegat Danish Coastal waters, including Limfjorden	NA	NA	NA	NA	NA	NA

Appendix results Table 11. Confidence in the status evaluation of the size distribution indicator according to the criteria developed within HELCOM for the integrated biodiversity assessment.

Sub-basin	Country	Coastal area name (assessment unit)	Monitoring area	L90 key species	ConfA	ConfT	ConfS	ConfM
Bothnian Bay	Finland	Bothnian Bay Finnish Coastal waters	NA	NA	NA	NA	NA	NA
Bothnian Bay	Sweden	Bothnian Bay Swedish Coastal waters	Råneå	Perch	0.5	1	0.5	1
Bothnian Bay	Sweden	Bothnian Bay Swedish Coastal waters	Kinnbäcksfjärden	Perch	1	1	0.5	1
The Quark	Finland	The Quark Finnish Coastal waters	Finnish ICES rect 23	Perch	1	0.5	0.5	1
The Quark	Sweden	The Quark Swedish Coastal waters	Holmön	Perch	0.5	1	0.5	1
The Quark	Sweden	The Quark Swedish Coastal waters	Norrbyn	Perch	0.5	1	0.5	1
Bothnian Sea	Finland	Bothnian Sea Finnish Coastal waters	Finnish ICES SD 30	Perch	1	1	1	1
Bothnian Sea	Finland	Bothnian Sea Finnish Coastal waters	Finnish ICES SD 30	Pikeperch	NA	1	1	1
Bothnian Sea	Sweden	Bothnian Sea Swedish Coastal waters	Gaviksfjärden	Perch	0.5	1	0.5	1
Bothnian Sea	Sweden	Bothnian Sea Swedish Coastal waters	Långvindsfjärden	Perch	0.5	1	0.5	1
Bothnian Sea	Sweden	Bothnian Sea Swedish Coastal waters	Forsmark	Perch	0	1	0.5	1
Åland Sea	Finland	Åland Sea Finnish Coastal waters	NA	NA	NA	NA	NA	NA
Åland Sea	Sweden	Åland Sea Swedish Coastal waters	Galtfjärden	Perch	1	1	0.5	1
Åland Sea	Sweden	Åland Sea Swedish Coastal waters	Lagnö	Perch	1	1	0	1
Archipelago Sea	Finland	Archipelago Sea Coastal waters	Finbo	Perch	1	1	1	1
Archipelago Sea	Finland	Archipelago Sea Coastal waters	Kumlinge	Perch	1	1	1	1
Archipelago Sea	Finland	Archipelago Sea Coastal waters	Finnish ICES SD 29	Perch	1	1	1	1
Archipelago Sea	Finland	Archipelago Sea Coastal waters	Finnish ICES SD 29	Pikeperch	NA	NA	NA	NA
Northern Baltic Sea	Finland	Northern Baltic Proper Finnish Coastal waters	NA	NA	NA	NA	NA	NA
Northern Baltic Sea	Sweden	Northern Baltic Proper Swedish Coastal waters	Vaxholm: Askrikefjärden	Perch	1	1	1	1
Northern Baltic Sea	Sweden	Northern Baltic Proper Swedish Coastal waters	Askö	Perch	0.5	1	1	1
Northern Baltic Sea	Sweden	Northern Baltic Proper Swedish Coastal waters	Muskö	Flounder	NA	1	1	1
Northern Baltic Sea	Estonia	Northern Baltic Proper Estonian Coastal waters	NA	NA	NA	NA	NA	NA
Gulf of Finland	Finland	Gulf of Finland Finnish Coastal waters	Brunskär	Perch	1	1	1	1
Gulf of Finland	Finland	Gulf of Finland Finnish Coastal waters	Tvärminne	Perch	1	1	1	1
Gulf of Finland	Finland	Gulf of Finland Finnish Coastal waters	Helsinki	Perch	0.5	0.5	1	1
Gulf of Finland	Finland	Gulf of Finland Finnish Coastal waters	Finnish ICES SD 32	Pikeperch	NA	1	1	1
Gulf of Finland	Estonia	Gulf of Finland Estonian Coastal waters	NA	NA	NA	NA	NA	NA
Gulf of Finland	Russia	Gulf of Finland Russian Coastal waters	NA	NA	NA	NA	NA	NA
Gulf of Riga	Estonia	Gulf of Riga Estonian Coastal waters	Hiiumaa	Perch	1	1	0	1
Gulf of Riga	Latvia	Gulf of Riga Latvian Coastal waters	Daugavgriva	Perch	1	1	0	1
Western Gotland Basin	Sweden	Western Gotland Basin Swedish Coastal waters	Kvädöfjärden, summer	Perch	0.5	1	0.5	1
Western Gotland Basin	Sweden	Western Gotland Basin Swedish Coastal waters	Kvädöfjärden, autumn	Flounder	NA	1	0.5	1
Western Gotland Basin	Sweden	Western Gotland Basin Swedish Coastal waters	Vinö	Perch	0	1	0.5	1
Eastern Gotland Basin	Estonia	Eastern Gotland Basin Estonian Coastal waters	NA	NA	NA	NA	NA	NA
Eastern Gotland Basin	Latvia	Eastern Gotland Basin Latvian Coastal waters	Jurkalne	Flounder	NA	NA	NA	NA
Eastern Gotland Basin	Lithuania	Eastern Gotland Basin Lithuanian Coastal waters	Mon/But	Flounder	NA	1	1	1
Eastern Gotland Basin	Lithuania	Eastern Gotland Basin Lithuanian Coastal waters	Šventoji	Flounder	NA	1	1	1
Eastern Gotland Basin	Lithuania	Eastern Gotland Basin Lithuanian Coastal waters	Karklė	Flounder	NA	1	1	1
Eastern Gotland Basin	Lithuania	Eastern Gotland Basin Lithuanian Coastal waters	Smiltynė	Flounder	NA	1	1	1
Eastern Gotland Basin	Lithuania	Eastern Gotland Basin Lithuanian Coastal waters	Curonian lagoon	Perch	0.5	1	1	1
Eastern Gotland Basin	Sweden	Eastern Gotland Basin Swedish Coastal waters	Herrvik	Flounder	NA	0.5	0	1
Eastern Gotland Basin	Russian	Eastern Gotland Basin Russian Coastal waters	NA	NA	NA	NA	NA	NA
Eastern Gotland Basin	Poland	Eastern Gotland Basin Polish Coastal waters	NA	NA	NA	NA	NA	NA
Gdansk Basin	Russia	Gdansk Basin Russian Coastal waters	NA	NA	NA	NA	NA	NA
Gdansk Basin	Poland	Gdansk Basin Polish Coastal waters	Zatoka Pucka Zewnętrzna	Perch	0	1	1	1
Gdansk Basin	Poland	Gdansk Basin Polish Coastal waters	Zatoka Pucka Zewnętrzna	Flounder	NA	1	1	1
Gdansk Basin	Poland	Gdansk Basin Polish Coastal waters	Zalew Pucki	Perch	0	1	1	1
Gdansk Basin	Poland	Gdansk Basin Polish Coastal waters	Zalew Pucki	Flounder	NA	1	1	1
Gdansk Basin	Poland	Gdansk Basin Polish Coastal waters	Zalew Wiślany	Perch	0	1	1	1
Bornholm Basin	Sweden	Bornholm Basin Swedish Coastal waters	Torhamn	Perch	0	1	0.5	1
Bornholm Basin	Sweden	Bornholm Basin Swedish Coastal waters	Hanöbukten	Flounder	NA	1	0.5	1
Bornholm Basin	Poland	Bornholm Basin Polish Coastal waters	NA	NA	NA	NA	NA	NA
Bornholm Basin	Denmark	Bornholm Basin Danish Coastal waters	NA	NA	NA	NA	NA	NA
Bornholm Basin	Germany	Bornholm Basin German Coastal waters	NA	NA	NA	NA	NA	NA
Arkona Basin	Sweden	Arkona Basin Swedish Coastal waters	Stavstendsudde	Flounder	NA	0.5	0	1
Arkona Basin	Denmark	Arkona Basin Danish Coastal waters	NA	NA	NA	NA	NA	NA
Arkona Basin	Germany	Arkona Basin German Coastal waters	NA	NA	NA	NA	NA	NA
Mecklenburg Bight	Germany	Mecklenburg Bight German Coastal waters	NA	NA	NA	NA	NA	NA
Mecklenburg Bight	Denmark	Mecklenburg Bight Danish Coastal waters	NA	NA	NA	NA	NA	NA
Kiel Bight	Denmark	Kiel Bight Danish Coastal waters	NA	NA	NA	NA	NA	NA
Kiel Bight	Germany	Kiel Bight German Coastal waters	NA	NA	NA	NA	NA	NA
Belt Sea	Denmark	Belts Danish Coastal waters	NA	NA	NA	NA	NA	NA
The Sound	Sweden	The Sound Swedish Coastal waters	NA	NA	NA	NA	NA	NA
The Sound	Denmark	The Sound Danish Coastal waters	NA	NA	NA	NA	NA	NA
Kattegat	Sweden	Kattegat Swedish Coastal waters, including Limfjorden	NA	NA	NA	NA	NA	NA
Kattegat	Denmark	Kattegat Danish Coastal waters, including Limfjorden	NA	NA	NA	NA	NA	NA





Trends in size distribution compared to the previous assessment.

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