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3. Status and Trends of Biodiversity and Ecosystem Function

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Box 3: Summary

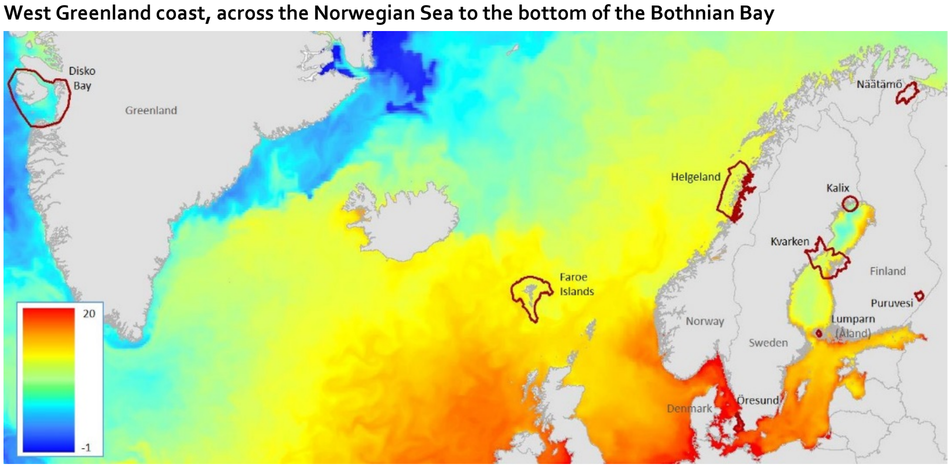
This chapter provides an overview of the status and trends in biodiversity and ecosystem function through assessment of key species and habitats, and summarizes the ecological status of selected Nordic regions. Important habitats across the Nordic coastal region include sea grass beds, kelp forests, blue mussel beds and soft sediments. Declines in sea grass have occurred since the 1970's, most likely due to eutrophication and overfishing. Norwegian kelp forests are recovering following severe losses in the 1960–1970's, most likely due to increased water temperature and changes in grazing pressure. Seabird populations have declined significantly during the last decades, reaching historical lows. Knowledge gaps are identified and a common biodiversity indicator system across the Nordic region is suggested. An indigenous local knowledge perspective is also presented.

3.1 Introduction

Changes in biodiversity and ecosystem services, or Nature's contributions to People (NCP), may result in a loss of benefits and values for present and future generations. The coastal ecosystems are among the most productive and dynamic ecosystems in the Nordic region, hosting some of the most rich and diverse habitats (McLean *et al.*, 2001). Nordic coastal ecosystems encompass a variety of habitat types essential to marine life and human wellbeing. These ecosystems are highly threatened because of the increase in human population and anthropogenic pressures (UNEP, 2006). Approximately 90 million people live in the catchment area of the Nordic marine region (85 million of these around the Baltic Sea). A part of this population however, lives in the non-Nordic neighboring countries. The chapter provides an overview of the status and trends in biodiversity and ecosystem function through assessment of key species and habitats, and summarizes the ecological status of selected Nordic regions as described in detail in (Tunón (Ed.), 2018).

The Nordic coastal region displays large variability in its geology, biology, and ecology. Geologically, it spans from the rocky coasts of North Greenland with large glacial inputs to the marine environments, across deep fjords in Norway and narrow sounds in Denmark, to the inner Bothnian Bay dominated by sandy and muddy sediments and wide-stretching shallow water areas. Water temperature spans from permanently around zero in North Greenland to temperatures above 20 °C during summer months in the Baltic Sea (Fig. 18). The marine physical environment is dominated by Arctic water masses around Greenland, Atlantic waters around Iceland and the Norwegian west coast, and temperate water masses in the south and Arctic conditions in the Northern part of the Baltic Sea, which is considered to be the largest brackish water sea in the world (HELCOM, 2009). Thus salinity (the content of salt in the sea water) ranges from full ocean water conditions (~35 PSU) on the Norwegian west coast to almost fresh water (<3 PSU) in the inner Bothnian Bay of the Baltic Sea. To a large extent, the ecology and biodiversity of the Nordic marine environment reflects these physical conditions (HELCOM, 2010) (Fig. 19).

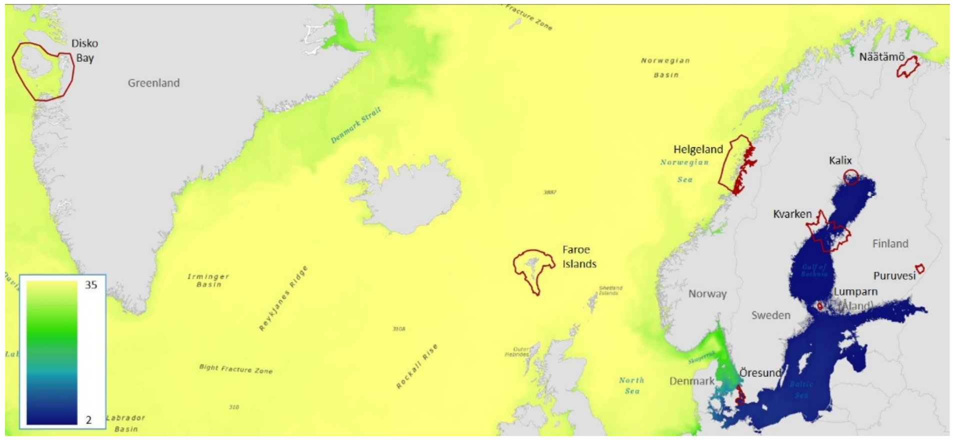
Figure 18: Map showing the gradients of sea surface temperature across the Nordic seas, from the West Greenland coast, across the Norwegian Sea to the bottom of the Bothnian Bay



Note: These physical gradients largely regulate marine biodiversity and ecosystem function in the region. Case study areas are marked with red lines.

Source: Copernicus Marine environment monitoring service (http://marine.copernicus.eu), downloaded for 16 June 2016. Maps by NIVA (Hege Gundersen).

Figure 19: Map showing the gradients of sea salinity across the Nordic seas, from the West Greenland coast, across the Norwegian Sea to the bottom of the Bothnian Bay



Note: These physical gradients largely regulate marine biodiversity and ecosystem function in the region. Case study areas are marked in red.

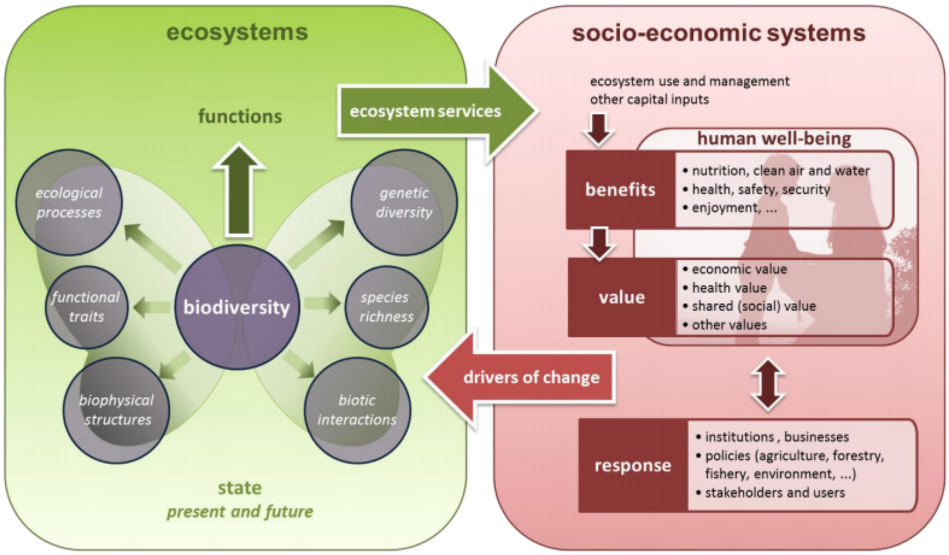
Source: Copernicus Marine environment monitoring service (http://marine.copernicus.eu), downloaded for 16 June 2016. Maps by NIVA (Hege Gundersen).

3.2 Defining biodiversity and its importance to Nordic marine life

Humankind is highly dependent on nature and NCPs. In the IPBES context, the word "nature" covers the full diversity of life: The living organisms including humans, along with their interactions with each other and their environment. Biodiversity, short for biological diversity, involves variation in life at all levels of organization and includes variability in ecosystems and their functions, in species richness and their functional properties, in genetic diversity and in biotic interactions (Fig. 20). The biodiversity of an ecosystem has implications for ecological processes, functional traits of the system and the biophysical structures. The IPBES definition of biodiversity is adopted from the UN Convention on Biological Diversity (Díaz *et al.*, 2015).

Many ecosystems are dependent on a few key species. Such key species enable the existence of many other species by modifying the environment, providing nursery areas, shelter and/or food. Such species are especially important for maintaining biodiversity due to their structural or functional abilities. Examples are tangle kelp (*Laminaria hyperborea*) and sugar kelp (*Saccharina latissima*), which are key species along the Northeast Atlantic coast line, where they form extensive underwater forests. These forests act as nursery grounds for fish and provide food for a variety of species (Christie, Norderhaug, & Fredriksen, 2009).

Figure 20: Conceptual framework for biodiversity and ecosystem functions with links to ecosystem services (see Ch. 2) and drivers of change (see Ch. 4)



Source: The EU ecosystem assessment MAES (Mapping and Assessment of Ecosystems and their Services).

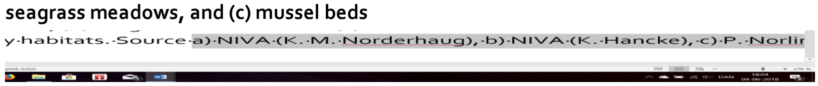
3.3 Defining Ecosystem function and value to human societies in Nordic countries

"Ecosystem function" defines the biological, geochemical and physical processes that occur within an ecosystem, including the rate at which processes occur, e.g. the cycling of nutrients and biomass production. Ecosystem function is dependent on biodiversity, so the loss of biodiversity often results in loss of ecosystem function (Bradley J. Cardinale *et al.*, 2012; Oliver *et al.*, 2015). Key habitats, such as seagrass meadows, promote multiple ecosystem functions (in this case, nursery grounds, food supply and stabilisation of the seabed) and maintain high biodiversity in marine areas. Functional diversity can be used to describe the types of species and the distribution and function they provide. For instance, deposit feeders (organisms feeding on material that have settled on the seafloor) are a functional group with importance for the turnover of nutrients and its transport between the seafloor and water column. (Gray, 1997; Strong *et al.*, 2015).

Ecosystems with "intact" levels of biodiversity hosting a high number of species use resources more efficiently (B. J. Cardinale *et al.*, 2011), whereas depauperate systems are often considered associated with lower functionality (lower resource use, lower biogeochemical fluxes and lower biomass production) (Gamfeldt *et al.*, 2015). Ecosystem function is linked to Nature's contributions to People (NCP) in terms of supporting, regulating, provisioning and cultural services (Fig. 20, Chapter 2). To maintain, or even enhance these ecosystem services, human-induced pressures on ecosystems and the drivers behind them need to be managed in a knowledgeable manner, based on sound sustainable principles. This is further elaborated on in Chapter 4.

Key habitats promote multiple ecosystem functions and maintain high biodiversity in marine areas. For example, kelp forests are key habitats along the Atlantic coast, forming dense underwater forests that provide shelter, nursery grounds and food sources for hundreds of habitat-specific species. This myriad of organisms provides essential ecosystem services such as fish biomass production, areas highly valued for recreation, along with carbon fixation and sequestration (Fig. 21) (Araujo *et al.*, 2016; Gundersen *et al.*, 2016). Other Nordic key habitats include seagrass meadows, seaweed beds, mussel beds and soft sediment habitats. Other important habitats are mudflats, shell sands, bird cliffs and coastal heaths.

Figure 21: Examples of key habitats in the Nordic coastal marine regions are (a) kelp forests, (b) seagrass meadows, and (c) mussel beds



Note: See text for additional details on Nordic key habitats.

Source: a) NIVA (K. M. Norderhaug), b) NIVA (K. Hancke), c) P. Norling.

Box 4: Glossary

- *Biodiversity*:* Biodiversity (contraction of biological diversity): The variability among living organisms from all sources including terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are a part. This includes variation in genetic, phenotypic, phylogenetic and functional attributes, as well as changes in abundance and distribution over time and space within and among species, biological communities and ecosystems;
- *Biosphere*:* All the ecosystems of the world considered together. It includes the organisms living on Earth, the resources they use and the space they occupy on part of the Earth's crust (the lithosphere), in the oceans (the hydrosphere) and in the atmosphere;
- *Ecosystem*:* A dynamic complex of plants, animals and microorganism communities and their non-living environment interacting as a functional unit. Ecosystems can be defined at a variety of scales, from a single pond, a fjord, an ocean or the entire globe. Humans and their activities are part of ecosystems as well;
- *Ecosystem function*:* The flow of energy and materials through the arrangement of biotic and abiotic components of an ecosystem. It includes many processes, such as biomass production, trophic transfer through plants and animals, nutrient cycling, water dynamics and heat transfer;
- *Habitat-forming species*: Species that form structures that act as habitats for other organisms. For example, bladder wrack is a seaweed that forms dense communities in the littoral zone and offers habitat for multiple other organisms;
- *Functional diversity*: Diversity of common characteristics or functions in the ecosystem, e.g. feeding and reproductive behavior, mobility, size, productivity and capacity to conduct certain biogeochemical processes. Functional diversity can also include differences between populations' or species' response to various stress factors.

* modified from (Díaz *et al*., 2015).

3.4 Biodiversity of the North East Atlantic coast

This section describes key species, key habitats, trends in biodiversity and the ecological status of the coastal region of the North East Atlantic coast, based on the case studies from Helgeland at the Norwegian west coast and the Faroe Islands (see Tunón (Ed.), 2018).

3.4.1 Key species

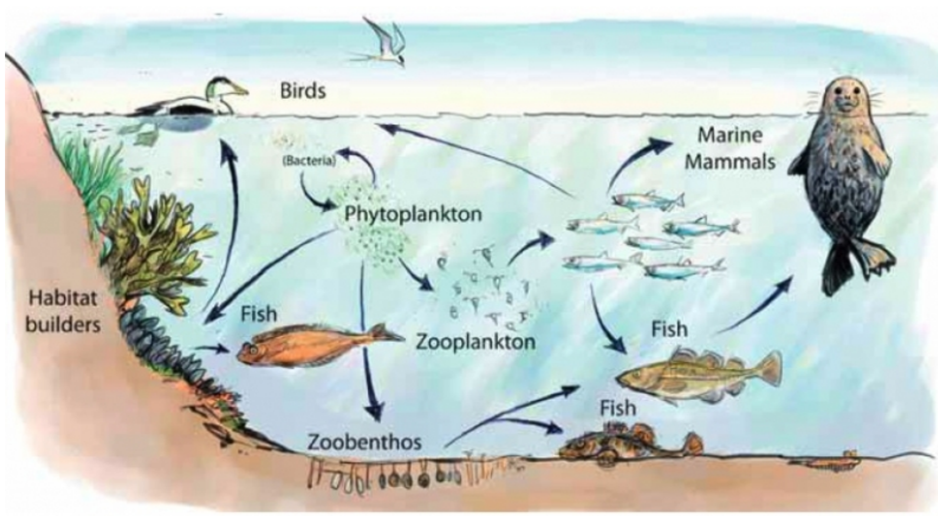
Along the rocky shores of the North East Atlantic coast, including Helgeland (NO) and the Faroe Islands, seaweeds dominate on rocks and stones in the photic zone. Seaweeds provide substrate, shelter and food for a rich associated flora and fauna, which in turn provide food for a large variety of animals including many fish species. In the tidal zone, small brown, green and red algal species dominate the flora. In the subtidal region, large kelp species such as sugar kelp (*Saccharina latissima*) and tangle kelp (*Laminaria hyperborean*) grow dense underwater forests with canopy-like structures (Christie *et al.*, 2009). In bays and inlets, eelgrass (*Zostera marina*) often dominate on sandy/muddy sediments and form extensive meadows (Bekkby *et al.*, 2008; Bostrom *et al.*, 2014). In the open water masses along the coast and in the off-shore pelagic zone, microalgal species are the dominant primary producers (e.g. *Skeletonema, Thalassiosira, Chaetoceros* spp.). These microorganisms form the base of the pelagic food web. Key zooplankton species feeding on pelagic algae are generally the same across the North East Atlantic, with copepods (e.g. *Calanus hyperboreus*, *C. glacialis*, and *C. finmarchicus*) and krill (*Euphausiacea crustaceans*) forming trophic links from phytoplankton to fish (Fig. 22) (Skjoldal, 2004). Droppings from the zooplankton provide food for a species-rich seafloor community of bivalves, echinoderms, sea anemones, crabs and fish. This way, life on the seafloor is strongly linked to and dependent on the foodweb and the production of organic matter in the open water (pelagic) community above, with implications for ecosystem function and resilience of the benthic system and key species (Renaud, Morata, Carroll, Denisenko, & Reigstad, 2008).

The commercially most important fish species in the North East Atlantic coastal waters are the demersal species cod (*Gadus morhua*), saithe (*Pollachius virens*), haddock (*Melanogrammus aeglefinus*) and ling (*Molva molva*). In the open waters, Atlantic mackerel (*Scomber scombrus*), Atlantic herring (*Clupea harengus*) and blue whiting (*Micromesistius poutassou*) are caught commercially. Along the coast in shallow habitats, flat fish species of commercial value are Greenland halibut (*Reinhardtius hippoglossoides*), monkfish (*Lophius piscatorius*) and Atlantic halibut (*Hippoglossus hippoglossus*).

Sea birds play an important role as top predators in coastal marine environments and the diversity is high in this region. Key species of the coastal region includes common eider (*Somateria mollissima*), geese (*Anser* and *Branta*), guillemots (*Uria* and *Cepphus*), puffin (*Fratercula arctica*), cormorants (*Phalacrocorax*) and gulls (*Laridae*), including black-legged kittiwake (*Rissa tridactyla*). In the open ocean and Faroe Islands, key species include Northern fulmar (*Fulmarus glacialis*), storm petrel (*Hydrobates pelagicus*) and common guillemot (*Uria aalge*).

Solely aquatic marine mammals (cetaceans) in the North East Atlantic include seal and whale, whereas whale are most dominant in the North East Atlantic (Skjoldal, 2004). Most seals are fish eaters, but they also feed on crustacean, octopus and mollusk. The most commonly observed seal species of the North East Atlantic coastal region are observed close to the coast in areas with seaweeds and kelp forests, and include the harbour seal (*Phoca vitulina*), grey seal (*Halichoerus grypus*) and ringed seal (*Pusa hispida*) (Bjørge, Øien, & Fragerheim, 2007). These three species are present in the Baltic region as well (see below). More than ten species of whales are known to feed in the North East Atlantic coastal region. The most commonly observed species are members of the small tooth whales, e.g. harbour porpoise (*Phocoena phocoena*), bottlenosed dolphin (*Tursiops truncates*) and white-beaked dolphin (*Lagenorhynchus albirostris*) (Bjorge, Skern-Mauritzen, & Rossrnan, 2013). Larger tooth whales in the region include the killer whale (*Orcinus orca*), which are commonly observed along the coast. Occasionally sperm whale (*Physeter macrocephalus*) are seen off shore. Tooth whales feed mainly on fish, but are also known to feed on seal, octupus and shark. In the outer coastal region, visiting baleen whales migrate northward toward the productive Barents Sea during summer months, where they feed on the large abundance of zooplankton and smaller fish species. These species include the humpback whale (*Megaptera novaeangliae*), minke whale (*Balaenoptera acutorostrata*) and fin whale (*Balaenopters physalus*).

Figure 22: Schematics explain key ecosystem components of the food web for the Baltic Sea and NE Atlantic coastal zones



Note: See text and the case studies from the Baltic Sea, Helgeland (Norway) and Faroe Islands for details on key species and habitats.

Source: Figure is adopted from HELCOM (2010).

3.4.2 Trends in biodiversity and ecosystem function

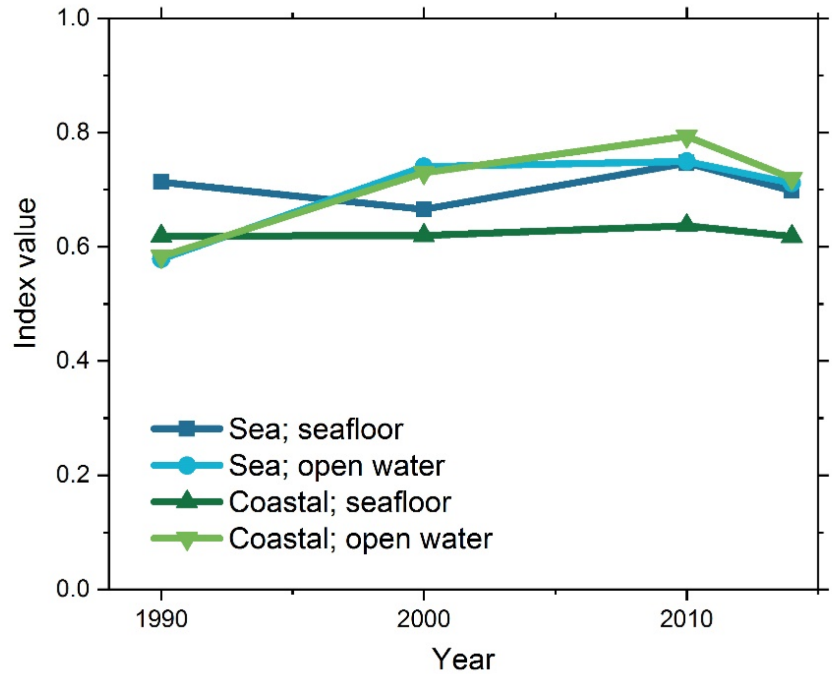
Trends in biodiversity and ecosystem function are assessed here based on a complied assessment of the Helgeland region, as a representative example of a Norwegian region with high coastal biodiversity, an intact ecosystem and a low human population density (see Hancke *et al.*, 2018). It is beyond the scope to provide a complete overview of trends in biodiversity and ecosystem function of the entire North-East Atlantic region here.

The Nature Index of Norway (Nybø, 2010) shows the state and development of biodiversity in Norway and provides an overview of the status of the environment for selected species groups and ecosystems. Indicators within the Nature Index of Norway represent populations of characteristic indigenous species, and the indicator values are based on data from monitoring, model estimates and expert assessments. The indicators in the Nature Index of Norway are particularly sensitive to the influence of climate on harvesting of marine ecosystems (Framstad, 2015). According to this index, there have been no major changes nor but a slight improvements in the biodiversity of the coastal zone of Mid-Norway during the last 25 years (Fig. 23). The slightly improved condition towards 2010 is due to improved phytoplankton biomass and numbers of harbor seal (*Phoca vitulina*), while the weak decline since 2010 is due to a small decline in the stocks of Atlantic herring, sand eel (*Ammodytes* ssp.) and some seabirds species along the coast (Gundersen *et al.*, 2015).

A recent assessment of the status of kelp forests in European waters concluded that a general decrease in abundance of native kelp is apparent in some areas (partly in areas considered as southern distribution limits), while other areas have experienced increases (Araujo *et al.*, 2016). The expanding kelp forests in Helgeland give hope for the future.

The stocks of herring, cod and crab are reported to have declined during the last decade. Estimated numbers of coastal cod show that populations are close to a critical limit; and their decline significantly linked to poor recruitment (Bakketeig, Gjøsæter, Hauge, Sunnset, & Toft, 2015).

Figure 23: Overall trend in biodiversity in the coastal region of Mid-Norway



Note: Data are from the Nature Index of Norway and show an overall slight improvement in the biodiversity of the coastal region in Mid-Norway during the last 25 years. The index includes the offshore seafloor (dark blue) and open waters (light blue), along with the coastal specific seafloor (dark green) and waters (light green). The index is compiled to represent the biodiversity of the represented habitats by compiling indicator values of relevant indigenous species on a scale between 0 and 1, where 1 describes an unaffected status with close to intact biodiversity. Both common and rare species are included in the indicators. Indicator values are based on data from monitoring, model estimates and expert assessments.

Source: www.naturindeks.no, (Gundersen *et al.*, 2015).

Kelp forests (Fig. 24) are currently recovering northwards from the south of Helgeland following large declines in Norwegian kelp forest cover in the 1960–1970s. Despite recoveries over the last decade, an area as large as 8,000 km^2 with suitable kelp habitat is still devoid of kelp and has potential for reforesting (Gundersen *et al.*, 2011). Reforestation of currently barren rocky seafloor will increase the amount of kelp biomass and enhance the biodiversity and primary production associated with kelp forests (Christie *et al.*, 2009). Drivers of the initial disappearance and the current reforestation are not completely understood, but changes in (i) water quality, (ii) grazing and predation pressure (urchins and cod) and (iii) competitive interactions (turf algae/epibionts vs. kelp) related to climate change are suggested (Araujo *et al.*, 2016).

Seagrass meadows (i.e. eelgrass *Zostera marina*) are distributed widely along the Norwegian coast and have many of the same functions as kelp forests (Bostrom *et al.*, 2014). How seagrass meadows contribute as a key habitat is described in more detail below (3.3 – the Baltic region section). The distribution and abundance of seagrass meadows has decreased in many areas throughout the North East Atlantic region.

Proposed mechanisms are reduced water transparency and increased eutrophication (see Hancke *et al.*, 2018).

Fish stocks of herring and cod are reported to have declined during the last decade. The stock of Norwegian spring-spawning herring is currently estimated to be below a critical level of 5 million tonnes, however opinions regarding the estimated stock size differ between fishers and researchers. The International Council for Marine Research (ICES) is currently renewing the stock estimation for herring (Bakketeig *et al.*, 2015). On the contrary, the stock of blue whiting has almost doubled in the North East Atlantic since 2010 and the stock is now in good condition (Bakketeig *et al.*, 2015). For populations of coastal cod the estimated numbers are considered close to a critical limit and their declines seem significantly linked to poor recruitment.

Bird cliffs and island shores provide areas for sea bird breeding, facilitating the rich biodiversity of sea birds in the Faroe Islands and along the Norwegian coast. Most of the seabird populations have declined during the last decades, except for Arctic skua (*Stercorarius parasiticus*). The populations of the northern gannet (*Morus bassanus*) and great skua (*Stercorarius skua*) are growing. See Hancke *et al.*, (2018) for details on the Helgeland case.

Marine mammals, such as populations of North Atlantic fin whale is presumed still recovering from earlier exploitation and is classified as least concern (LC) on the Norwegian red list (Kålås, Viken, Henriksen, & Skjelseth, 2010; Víkingsson *et al.*, 2009). Population sizes of killer whales are believed to have stayed relatively constant over the last three generations (Norwegian Biodiversity Information Centre, http://www.biodiversity.no/). Populations of harbor porpoise (*Phocoena phocoena*) are abundant and stable in the Helgeland area, but substantial amounts of bycatch are causing some concern (Bjorge *et al.*, 2013). Harbor seals are classified as least concern (LC, Kålås *et al.*, 2010) and are regulated through the harvesting quota. The population of otters (*Enhydra lutris*) along the coast of mid and north Norway has been decreasing over the last 25 years. They are now classified as vulnerable (VU) on the Norwegian red list (Norwegian Biodiversity Information Centre at http://www.biodiversity.no/).

Box 5: Marine carbon depositing in seagrass meadows and kelp forests

Kelp (Laminariales) species are large seaweeds that form underwater forests with canopy-like structures reaching several meters up from the seafloor. They occupy hard-bottom subtracts (rocks) and are among the most productive ecosystems on Earth, host an extremely high biodiversity (>100,000 individuals and >200 species per square meter) and provide important ecosystem services. Seagrasses meadows are marine plants that form underwater "grass fields" typically growing half a meter tall from the bottom, and thrives on soft sediments in shallow bays and estuaries. Seagrass are important food sources for animal grazers and host a high biodiversity, including large variety of fish and shellfish species. Seagrass meadows providing food, shelter and nursery grounds and thus eccential coastal ecosystem services.

Seagrass meadows and kelp forests have shown to be important in the process of sequestration, or permanent depositing, of organic carbon in the coastal zone. Seagrass meadows form thick layers of deposited and composed leaves and canopy-forming kelps constantly loose and export organic biomass to adjacent systems, a process through which both ecosystems contribute to depositing organic carbon, thus forming an "ocean sink" for atmospheric CO_2. With less than 4% total coverage of the sea surface area, they are estimated to contribute to almost 50% of all carbon deposition in the ocean (Duarte, Middelburg, & Caraco, 2005; Krause-Jensen & Duarte, 2016).

Figure 24: Kelp forest on the Norwegian west coast, which support unique ecosystems with pronounced biodiversity and ecosystem function

Source: NIVA (J. Gitmark).

3.4.3 Red listed and non-indigenous species

In Norway there are 56 red-listed marine species, which are threatened at various levels, from critical to vulnerable. Of these, nine species are considered critically endangered, including spiny dogfish (*Squalus acanthias*), European eel (*Anguilla anguilla*), common guillemot (*Uria aalge*) and bowhead whale (*Balaena mysticetus*). Another 23 species are categorized as strongly threatened, including black legged kittiwake (*Rissa tridactyla*), blue ling (*Molva dypterygia*), hooded seal (*Cystophora cristata*) and narwhal (*Monodon monoceros*) (Kålås *et al.*, 2010).

Non-indigenous species, also referred to as Alien species or Black-listed species in Norwegian management plans, are species that have spread beyond their natural limits through human activity and occupy habitats where they may displace native species. These species can potentially affect ecosystem structure and function, thus threatening pre-existing and native species. Non-indigenous species are categorized into different risk categories according to their assumed impact on habitats and native species.

Approximately 50 of these non-indigenous species (out of a total of 217 in Norway considered to impose "very high ecological risk" or "high ecological risk") are found in coastal and marine habitats of Norway. These species include Pacific oyster (*Crassostrea gigas*), Japanese wireweed (*Sargassum muticum*) and red king crab (*Paralithodes camtschaticus*) (Gederaas, Moen, Skjelseth, & Larsen, 2012).

3.4.4 Ecosystem health

According to the Water Framework Directive, the ecological status of Helgeland is generally good, as 88% of the more than 200 water bodies making up the marine region, and 99% of the total area, is classified as "Good" or "Very good" (Directorate-group, 2013). The water bodies include kelp forest and seagrass beds, as well as the pelagic environment. As mentioned above, the overall biodiversity rating is good for the coastal zone of mid Norway according the Nature Index of Norway (Gundersen *et al.*, 2015). Expansion of kelp forest and associated species has led to an increase in the index, however a decline in coastal populations of (e.g. coastal cod), mammals (e.g. grey seal, *Halichoerus grypus*) and birds (e.g. common eider), has led to an index decrease (Gundersen *et al.*, 2015).

Currently, no ecological or biodiversity status index exists for the Faroe Islands, however the overall status is evaluated as good, according to local authorities (Jan Sørensen, Natural History Museum, Faroe Islands, Pers. Comm. October 2017).

3.5 Biodiversity of the Baltic Sea region

This section assesses status and trends in biodiversity in the Baltic Sea, based on the cases studies from the Kalix, Kvarken, Lumparn and Øresund (see Tunón (Ed.), 2018).

The Baltic Sea is semi-enclosed and connected to the North-east Atlantic Ocean through three narrow straits with a maximum depth of 18 meters, which restricts water exchange with the wider ocean. The mean depth of the Baltic Sea is 55 meters and the deepest parts are approximately 400 meters. A strong salinity gradient effects both biodiversity and ecosystem function. The number of species decreases with increased distance from the North Sea. In the Baltic Sea, several essential ecosystem functions are supported by only a few species, which are of either freshwater or marine origin and live at the border of their physiological salinity tolerance (Figure 25) (HELCOM, 2010). For example, there is a decrease in diversity of benthic sediment communities with decreasing salinity, from 25 functional groups of benthic species in Skagerrak (K. Norling, Rosenberg, Hulth, Grémare, & Bonsdorff, 2007), to only 5 groups in the Baltic Sea sediments (Bonsdorff & Pearson, 1999).

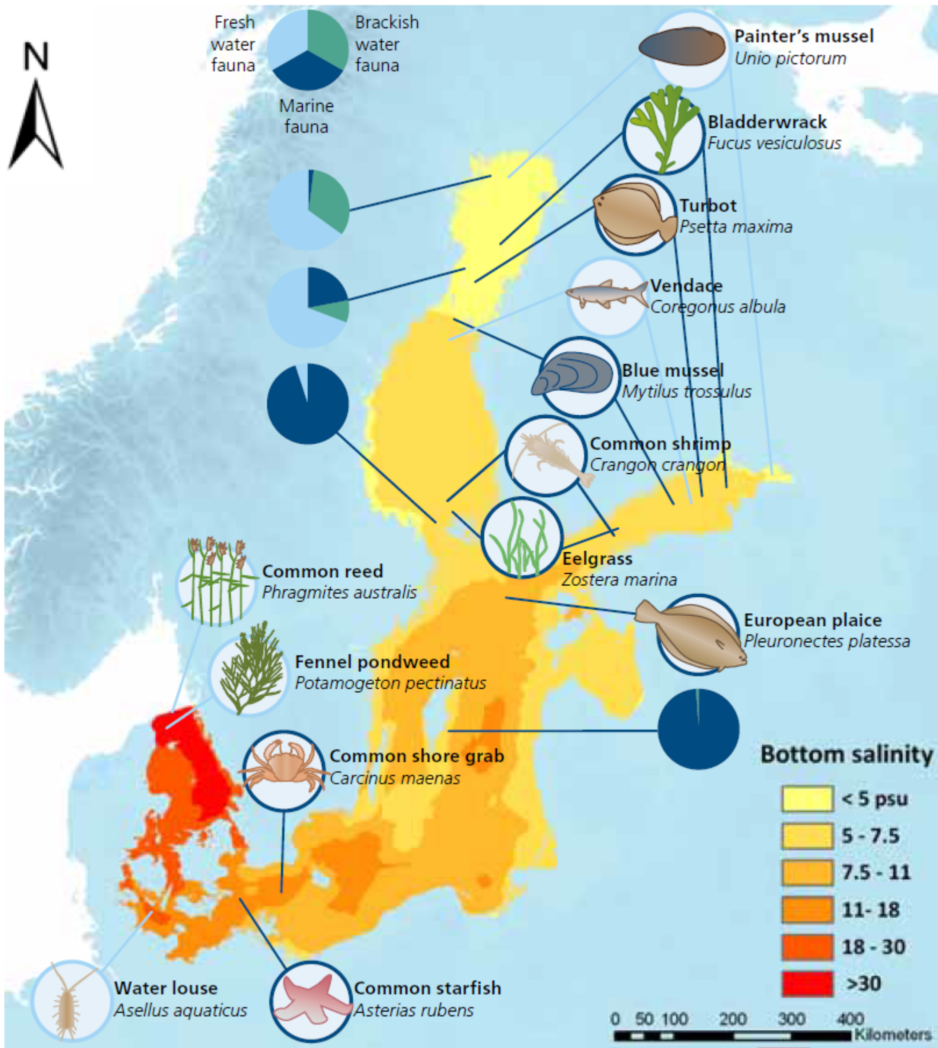
The Bothnian Bay differs from other parts of the Baltic Sea in many ways. It is characterised by low salinity, low water temperatures, a long period of ice cover, low primary productivity, low levels of nutrients (particularly phosphorus), and large amounts of riverine runoff adding organic matter and industrial-sourced nutrients (Kronholm *et al*., 2005). The Bay lacks many of the key species of the Baltic, such as bladder wrack, seagrass, blue mussels, cod and sprat. It is characterised by a combination of freshwater and salt-water species and has low biodiversity (Fig. 25).

3.5.1 Key species

Key species of the Baltic region include bladder wrack (*Fucus vesiculosus*), eelgrass (*Zostera marina*), blue mussel (*Mytilus trossulus*), Baltic macoma (*Limecola balthica*), European plaice (*Pleuronectes platessa*), turbot (*Psetta maxima*), vendace (*Coregonus albula*) and common shrimp (*Crangon crangon*) (see Figure 25). Common starfish (*Asterias rubens*) and common shore crab (*Carcinus maenas*) are only present in Kattegat and The Sound (Øresund). Other key species in the Baltic region are iconic species including salmon (*Salmo salar*), cod (*Gadus morhua*), great cormorant (*Phalacrocorax carbo sinensis*), white-tailed eagle (*Haliaeetus albicilla*), grey seal (*Halichoerus grypus*), harbour seal (*Phoca vitulina*) and ringed seal (*Phoca hispida*).

The Baltic Sea is one of the world's most important areas for overwintering sea ducks, not least for the globally threatened species velvet scoter (*Melanitta fusca*) and long-tailed duck (*Clangula hyemalis*). During the winter, approximately 90% of the sea ducks living in the Baltic Sea region gather in areas that constitute less than 5% of the Baltic Sea.

Figure 25: Distribution limits of key species in marine (dark blue), brackish (green) and freshwater (light blue) habitats, linked to bottom water salinity (color grade)



Source: HELCOM (2010).

3.5.2 Key habitats

Key species such as bladder wrack, seagrass and blue mussels are important habitat-forming species in the Baltic Sea.

Bladder wrack (*Fucus vesiculosus*) is the most widely distributed brown algae and a key species in the Baltic Sea, where it forms habitats and provides shelter for several crustaceans, isopods, snails, mysids and fish. Bladder wrack forms one of the most diverse Baltic Sea habitats down to 10–11 m depth. The lowest depth limit of bladder wrack (and other macroalgae) is widely used as one of the ecological quality indicators in the Water Framework Directive assessments in the Baltic Sea (Zettler *et al.*, 2017).

Blue mussel beds are key habitats in the Baltic Proper and have been shown to sustain high biodiversity in subtidal habitats (Pia Norling & Kautsky, 2008). The mussels modify the environment and support a rich diversity of associated species (P. Norling & Kautsky, 2007; Ojaveer *et al.*, 2010). Mussel beds uphold an important filter-feeding function: they regulate the availability and flow of resources such as nutrients and organic matter, thereby forming an important link between benthic and pelagic ecosystems. By doing this they counteract eutrophication and improve water quality.

Seagrass meadows are mainly found in relatively exposed and sandy areas in the Baltic Sea. They support a high diversity of associated species such as amphipods and snails and are an important nursery grounds for fish. The salinity gradient across the Baltic region creates functional differences in biodiversity and food webs in seagrass meadows, showing a decline in the number of species but an increase in the biomass of mesograzers. Meadows in the high end of the salinity gradient tend to be more productive (Bostrom *et al.*, 2014).

Soft sediment habitats are the most wide-spread habitat in the Baltic Sea. Key species of the macrozoobenthic community in the Baltic proper include *Macoma balthica, Halicryptus spinulosus, Marenzelleria arctia* and *Saduria entomon*, whereas in the Bothnian Sea, cold-water dominating species include *Monoporeia affinis*, *Pontoporeia femorata* and *Saduria entomon*.

3.6 Trends in biodiversity and changes in ecosystem function

Approximately 85 million people live in the catchment area of the Baltic Sea. Multiple pressures from agricultural landuse and maritime traffic (HELCOM, 2009) has resulted in large environmental changes during the last 100 years. Pressures include eutrophication, overfishing, pollution and changed hydrodynamic conditions. These are thought to have resulted in changes to the distribution of fish, vegetation and benthic fauna (Ojaveer *et al.*, 2010). Regime shifts from an oligotrophic to eutrophic state, with resultant changes in dominant species have also been observed (Österblom *et al.*, 2007), particularly during the last 30 to 40 years. The increased frequency and expansion of hypoxic and anoxic deep water has affected the structural and functional diversity of benthic communities. Phytoplankton productivity has increased and there has been a shift from dominance of diatoms to dominance of dinoflagellates in the phytoplankton spring bloom (HELCOM, 2009). Changes have also occurred in the zooplankton community where copepod biomass and the mean size of zooplankton have decreased, with consequences for the weight-at-age in herring stocks, Figure 26 (HELCOM, 2009). In the Bothnian Bay, eutrophication levels and phytoplankton productivity are lower than in the Baltic Sea in general.

Common eider (*Somateria mollissima*), long tailed duck (*Clangula hyemalis*), common scoter (*Melanitta nigra*) and velvet scoter (*Melanitta fusca*) are sea ducks that have similar ecological function and feed mainly on blue mussels during winter. These bird populations have severely decreased in the Baltic during the last 20 years. The number of over-wintering sea ducks decreased from approximately 7 million individuals in the beginning of the 1990s, to about 3 million birds in 2007–2009; a 30% decline in numbers (Skov *et al*. 2011).

The abundance of many fish-eating sea birds such as sandwich tern (*Thalasseus sandvicensis*), common guillemot (*Uria aalge*) and great cormorant (*Phalacrocorax carbo*) have increased during recent years. Reasons for this include protection schemes, declined concentrations of hazardous substances in prey and sea water, along with improved prey abundance due to over-fishing of large predatory fish(Herrmann *et al.*, 2015).

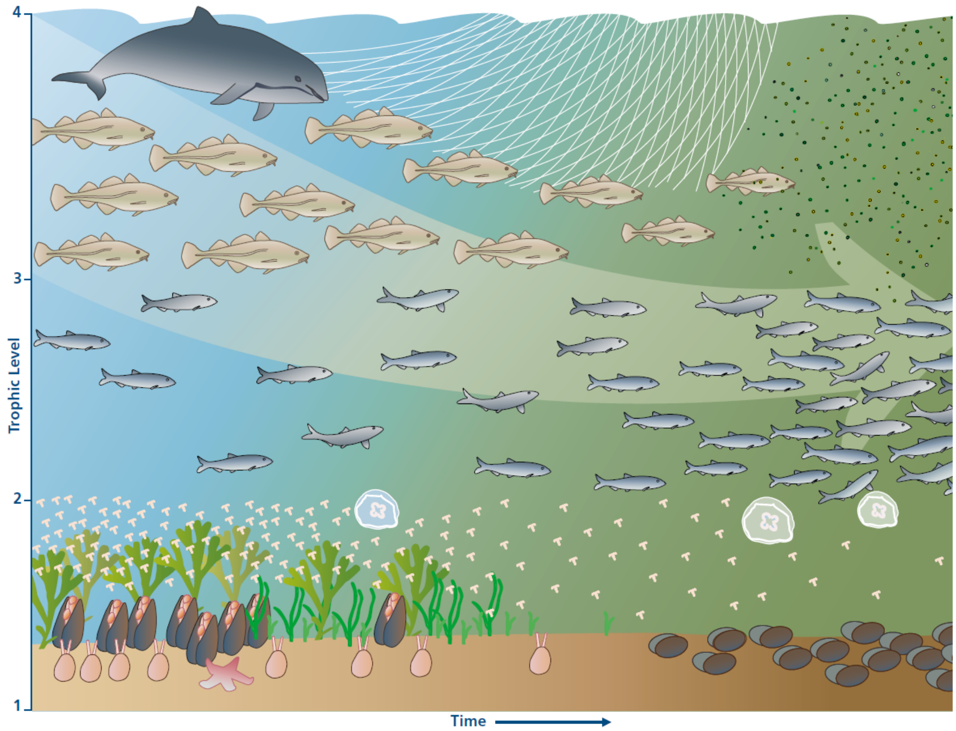
Oxygen deficiency has greatly reduced the benthic biodiversity in the Baltic Proper and decreased the abundance of benthic fauna in other regions of the Baltic as well (Karlson, Rosenberg, & Bonsdorff, 2002). As a consequence, an increase in hypoxia-tolerant species has been observed, most notably a dramatic increase in the abundance of the invasive species *Marenzelleria* spp. (Norkko *et al.*, 2012). Introduction of the invasive species *Marenzelleria* spp. has increased the functional diversity in soft sediments by increasing re-oxygenation of the surface sediments and hereby stimulating an increase in nutrient release from the seafloor to the water column.

During a regime shift in the late 1980s, the fish community underwent a change in the central Baltic Sea with a shift from dominance of demersal fish to dominance of pelagic clupeid fish, where the abundance of cod decreased and abundance of sprat increased remarkably. Reasons behind the change are thought to be climate variation and overfishing (Alheit *et al.*, 2005). Fish communities are also affected by other human pressures, for example, the abundance of perch and cyprinids have been associated with increased eutrophication in many coastal areas (Adjers *et al.*, 2006).

Seagrass meadows have suffered large declines in biomass and distribution in the Baltic regions, and in the Nordic region in general. Up to 60–100% of the vegetation has been lost over the last century in some areas, e.g. along the northern part of the Swedish west coast (Baden, Gullstrom, Lunden, Pihl, & Rosenberg, 2003; Waycott *et al.*, 2009). The biodiversity of seagrass communities are essential for ensuring high levels of ecosystem function (Duffy, Moksnes, & Hughes, 2013). Declines in seagrass abundance and distribution have negative effects on the biomass of fish and the sequestration of nutrients. Multiple stressors including eutrophication, sediment runoff, dredging and coastal development have been suggested as drivers of this negative development.

Since the 1980s, bladder wrack has decreased or even disappeared in several areas in the Baltic Sea (Torn, Krause-Jensen, & Martin, 2006). Although bladder wrack is now recovering in some areas (Kautsky, Martin, & Snoeijs-Leijonmalm, 2017; Laamanen, Korpinen, Zweifel, & Andersen, 2017), it is still declining at other locations (Vahteri & Vuorinen, 2016). During the last years, the depth distribution has increased, for instance at the Swedish coast of the northern Baltic proper and the Sea of Åland. Eutrophication is suggested to be the main driver for the historical decrease in bladder wrack (Torn *et al.*, 2006).

Figure 26: Ecological effects of eutrophication and over-fishing in the Baltic Sea, illustrated as changes in the food web structure



Note: The figure shows changes in trophic levels over time, from complex food webs to food webs with low biodiversity and simple functionally.

Source: Adopted from HELCOM (2010).

3.6.1 Non-indigenous species

About 130 non-indigenous species have entered the Baltic since the 18th century, mainly as an effect of human activities. Invasive species in the Baltic Sea include round goby (*Neogobius melanostomus*), red gilled mud worm (*Marenzelleria* spp.) and American comb jelly (*Mnemiopsis leidyi*). For a young sea like the Baltic Sea, the establishment of non-indigenous species is, to some extent, also a natural on-going process of succession and so far no non-indigenous species have resulted in the extinction of native species. Some non-indigenous species, such as *Marenzelleria* spp., may have increased functional diversity (Norkko *et al.*, 2012). However, the low number of species makes the Baltic Sea especially vulnerable, as the loss of one species may have a large effect on other parts of the ecosystem, as there may not be species to replace the niche of the lost species.

3.6.2 Ecosystem health

Ecosystem health of the Baltic Sea has been assessed by HELCOM based on biodiversity, eutrophication and hazardous substances (HELCOM, 2010). For most areas it is considered in a "non-acceptable" state, Figure 27 (HELCOM, 2010). When looking at biodiversity indices only, some areas in the northern parts of the Baltic Sea reach acceptable status (HELCOM, 2010).

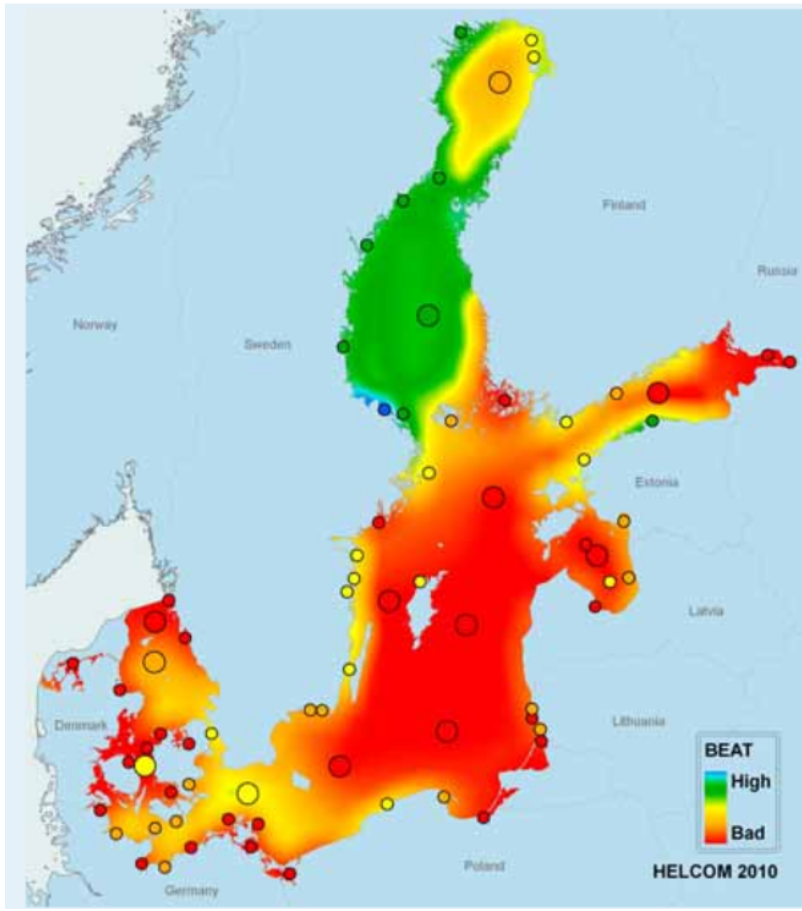
The HELCOM Red List reports have categorized at least 60 marine species and 16 marine biotopes in the Baltic Sea as threatened and/or declining, and the Swedish Environment Protection Agency lists 88% of marine biotopes as endangered. This suggests that the Baltic Sea is one of the most threatened marine ecosystems worldwide (HELCOM 2007, 2013e, SEPA 2009).

According to the 2012 International Union for Conservation of Nature (IUCN) Red list of threatened species update for birds, velvet scoter (*Melanitta fusca*) is now globally considered Endangered and long-tailed duck (*Clangula hyemalis*) is Vulnerable (http://sdg.iisd.org/news/iucn-releases-bird-update-to-red-list/).

These biodiversity losses threaten ecosystem function and resilience, as well as the provisioning of ecosystem services. It is thought that the relatively simple food webs and low biodiversity renders the Baltic vulnerable, since key functions may be supported by single species.

It is considered that the levels of sustainable use of the Baltic Sea ecosystem have been exceeded and apparent regime shifts of the Baltic Sea ecosystem have occurred as a result of overfishing and eutrophication (Alheit *et al.*, 2005; Osterblom *et al.*, 2007). However, improved efforts to reduce nutrient loading in various parts of the Baltic Sea have started to show signs of curbing eutrophication status, particularly for the pelagic indicators (J. H. Andersen *et al.*, 2017). The current preliminary HELCOM biodiversity assessment that summarize biodiversity status of several trophic levels and food webs, implies that despite the improvements in eutrophication, the effects are not visible at the level of biodiversity. Concurrently, the deterioration of many fish species and key habitats may result in welfare losses to society (HELCOM 2017).

Figure 27: An integrated biodiversity status of the Baltic Sea



Note: Areas in blue and green represent areas with an "acceptable biodiversity status", while areas in yellow, orange and red represent areas with an "unacceptable biodiversity status". Large circles represent assessment sites in open basins and small circles represent coastal assessment sites.

Source: HELCOM (2009) – where general assessment principles are described. BEAT is the HELCOM Biodiversity Assessment Tool (Jesper H. Andersen *et al.*, 2014) used to produce this figure. Additionally, HELCOM (HELCOM 2017), proposed a set of biodiversity indicators to asses the biodiversity status in the sub-basins of the Baltic Sea, (see Fig. 28).

Figure 28: HELCOM Status of biodiversity Indicators in the sub-basins of the Baltic Sea

** Core indicator agreed to be tested in this assessment*
*** Pre-core indicator agreed to be tested in this assessment*
**** The indicator 'Zooplankton size and stock' is under testing for the Gdansk Basin*

3.7 Biodiversity of the Arctic

The following overview of biodiversity, status and trends for the Arctic is provided using the case study from the Disko Bay area in West Greenland (see Poulsen, 2018).

3.7.1 Key species

Calanus copepods have a key position in the food web, grazing on phytoplankton. Copepods are food for organisms at higher trophic levels, such as fish, auks and Greenland whales, while copepods' faeces are food for benthic animals. Especially three species of copepods, *Calanus hyperboreus*, *C. glacialis*, and *C. finmarchicus*, create the basis for the high marine biodiversity in Disko Bay (Boertmann, Mosbech, Schiedek, & Dünweber, 2013; Garde, 2014). Important phytoplankton species include *Thalassiosira* spp. and *Chaetoceros* spp. (Krawcyk, Witkowski, Waniek, Wroniecki, & Harff, 2014). Benthic macrofauna species consume a significant proportion of the available production and, in turn, are an important food source for fish, seabirds, seals and whales. Sand eel (*Ammodytes* ssp.) and capelin (*Mallotus villosus*) form crucial links from lower to higher trophic levels (Boertmann *et al.*, 2013; Garde, 2014) (Fig. 29).

Commercially important species include Northern shrimp (*Pandalus borealis*), Greenland halibut (*Reinhardtius hippoglossoides*), Atlantic cod (*Gadus morhua*) and snow crab (*Chionoecetes opilio*) (FAO, 2016; Garde, 2014). In the seas off East Greenland, the first Atlantic mackerel (*Scomber scombrus*) was caught in 2011. In 2013, mackerel was documented for the first time along the West Greenland coast (ICES, 2014). In 2014, 78,000 tons of mackerel were caught, providing nearly a quarter of the Greenlandic export earnings (Jansen *et al.*, 2016).

3.7.2 Key habitats

Disko Bay has a diverse seabed terrain with areas of rather shallow waters near the coast, traversed by deep troughs. Kelp forests in the tidal zone, dominated by *Fucus evanescens* and *F. vesiculosus*, provide shelter and protection for many species.

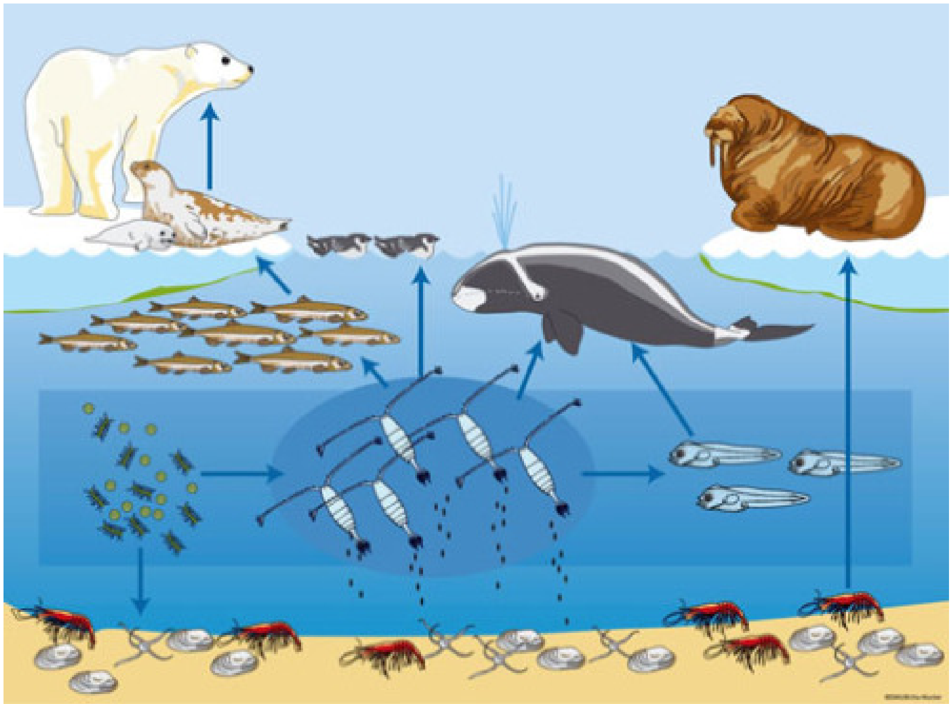
3.7.3 Trends in biodiversity and changes in ecosystem function

The anthropogenic drivers most relevant for changes in biodiversity in Disko Bay are climate change and exploitation of wild species. The number of fish species known from northwest Greenland is increasing (Boertmann *et al.*, 2013). The northern shrimp population has been declining in recent years, while there is an ongoing recovery of Atlantic cod (ICES, 2014; Jensen, 2003). Trends may be related to positive correlations between cod biomass and ocean temperature, along with strong negative correlations between shrimp and cod biomass (Worm & Myers, 2003). Among the bird species, especially common eider and thick-billed murre have suffered large population declines, which has been linked to hunting and egg collection. Eiders have responded positively as restrictions have been enforced, while murres have kept declining (Christensen, Mosbech, & Geertz-Hansen, 2015; Merkel, 2010).

3.7.4 Ecosystem health

The ecosystems of west Greenland are generally considered to be healthy. Lakes, rivers and marine waters are probably of good or very good ecological status. Habitat degradation is not regarded as a major issue in Greenland. However, climate driven changes in physical properties might alter the biological balance and regional biodiversity. For instance, northward retreatment of the sea ice edge has been linked to an increase in the distribution of kelp beds and increase in the seasonal productivity of seaweeds along the Greenland West coast (Krause-Jensen *et al.*, 2012). Wild species, and to some degree pollution and invasive species, may threaten the present good status.

Figure 29: Foodweb and biodiversity of an Arctic ecosystem



Note: Simplified view of the Disko Bay ecosystem with copepods in a central positon. *Calanus*-copepods have a key position in the food web (centered), where they graze on phytoplankton (phototrophic microalgae, middle left) and provide food for organisms at higher trophic levels such as fish, birds (auks) and whales (Greenland whale). In addition, copepod droppings constitute a food resource for bottom-living animals as they sink to the seafloor.

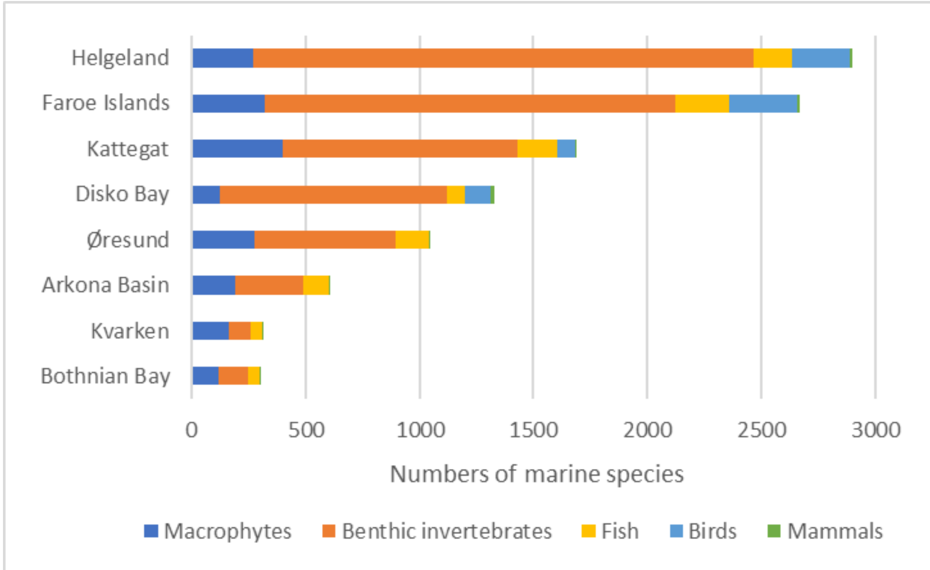
Source: B. Munter & T. G. Nielsen, 2005.

3.8 Differences and similarities between regions

3.8.1 Key species

Biodiversity gradients across the Nordic region are a reflection of the region's physical characteristics (Fig. 18 and 19). While biodiversity is relatively high in the North East Atlantic region, including the Helgeland coast and the Faroe Islands, the Baltic Sea species and functional diversity is relatively low. Consequently, even minor changes in species biomass and/or occurrence can have large effects on ecosystem function and services. The loss of a single species therefore has potentially higher impact in the Baltic Sea than in Helgeland and the Faroe Islands. Nordic coastal biodiversity is summarized in Figure 30, using the number of marine species in different functional groups and classes in each Nordic region.

Figure 30: Comparison of numbers of marine species of different groups and classes across the Nordic regions



Note: Only species associated with the coastal and/or marine waters are included. The birds and marine mammals included are those observed feeding off the marine environment.

Source: Helgeland: (Brattegard & Holthe, 2001), http://www.gbif.no/. Faroe Islands and Disko Bay: (Boertmann, 1994; Boertmann *et al.*, 2013; Hansen *et al.*, 2013). Kattegat, Øresund, Arkona Basin, Kvarken and Bothnian Bay: (HELCOM, 2012).

3.8.2 Key habitats

Key habitats of the Nordic coastal region are summarized in Table 3. Key habitats in the Atlantic region are kelp forest, smaller seaweed species, seagrass meadows, blue mussel beds and soft and sandy sediments. Entering the Baltic Sea, the large kelp species disappear (due to low salinity) leaving selected seaweed species, seagrass meadows, blue mussel beds and soft and sandy sediments as the most important habitats, with decreasing diversity along a decreasing salinity gradient (Fig. 19). Seagrass meadows are important across Scandinavia, including the Faroe Islands.

Table 3: Key marine habitats of selected Nordic regions. The selected regions represent Nordic IPBES case studies from which data has been compiled (Tunón (Ed.), 2018)

Key habitats	Helgeland	Faroe Islands	Disko Bay	Øresund	Lumparn	Kvarken	Kalix
Kelp forest	x	x	x				
Seaweeds	x	x	x	x	x	x *	x *
Seagrass meadows	x	x		x	x		
Mussel beds	x	x	x	x	x		
Maerl beds	x	x	x				
Sandy- and soft sediments	x	x	x	x	x	x	x

Note: * bladderwrack (*Fucus vesiculosus*) is not present (a key species in most of the Baltic Sea), but other small seaweed species are present.

3.8.3 Trends in ecosystem health and biodiversity

The Baltic Sea ecosystem, and to a lesser degree other parts of the Nordic region, have experienced considerable pressures from human activities over the past century, with particularly strong impacts on coastal biodiversity and ecosystem function. Pressures may affect only a few species, but due to the role of biodiversity and sometimes complex trophic interactions, the pressure may cascade through the system and have indirect effects on many other species and food web structures. An overview of the ecological status of the Nordic region is given in Table 4. In the table, color indicates the biodiversity status of each region, but note that the numbers in the table are derived from different assessment systems and thus cannot be compared between countries. While ecological status of the coastal ecosystems in the Baltic region is assessed using the WFD biological quality elements (phytoplankton, macrophytes and benthic invertebrates) and HELCOM biodiversity protocols (including pelagic invertebrates, fish, mammals, birds and key habitats), Norwegian waters are assessed using the Nature Index for Norway (NI), which includes trophic groups such as plants, fungi, algae, invertebrates, amphibians, birds, fish and mammals. The latter has a different scale, however, colors in Table 4 indicate how the status is assessed regionally or locally using regional assessment systems (Nybø, 2010).

Table 4: Biodiversity status assessment of selected Nordic coastal regions

Case region	Status *	Index
Norwegian Sea/Helgeland coast	Green	NI
NE Atlantic/Faroe Islands **	Green	**
Bothnian Bay/ Kvarken, Kalix coast	Green	HELCOM
Bothnian Sea/ Kvarken	Green	HELCOM
Gulf of Finland	Red	HELCOM
Baltic Proper	Red	HELCOM
Bornholm Basin	Yellow	HELCOM
Arkona Basin	Yellow	HELCOM
Kattegat	Yellow	HELCOM

Note: The colors green, yellow, red, indicate status classes: Good, moderate, and poor biodiversity status respectively, referring to the definitions of ecological status used in (HELCOM, 2010).

* Assessment status and number for the Norwegian Sea/Helgeland coast is from the Nature index of Norway (NI, Gundersen *et al.*, 2015). Numbers for the Baltic Sea are integrated values of biodiversity status and are means of normalized values assessed for habitats, communities, species and supporting services, based on the HELCOM (2010) classifications system and derived by (J. H. Andersen, Halpern, Korpinen, Murray, & Reker, 2015).
** No index exists for the Faroe Islands. Assessed as good quality (Jan Sørensen, Natural History Museum, Faroe Islands, Pers. Comm.).

Box 6: Nested tool for harmonized assessment of marine biodiversity

The Marine Strategy Framework Directive requires the environmental status of European marine waters to be assessed using biodiversity as one of 11 descriptors. Nested Environmental status Assessment Tool (NEAT) was applied to marine biodiversity data and indices to test the applicability and compare biodiversity assessments across the European Seas (Uusitalo *et al.*, 2016). The NEAT tool has been designed to overcome the complexity of marine biodiversity across salinity and latitudinal gradients and enable consistent methodology to integrate a broad range of indicators. The northern case studies included in the NEAT assessments were from the Baltic Sea (Gulf of Finland and Lithuanian coast), Kattegat and the Norwegian/Barents Sea and Lofoten areas in the Arctic. The outcome of the indicator based (quantitative) comparisons was very similar to the qualitative comparison in the current Nordic IPBES-like study, as the Barents Sea and Lofoten area had the highest score and the Gulf of Finland and the Kattegat, the lowest. In each of the areas, the most important ecosystem components that had the largest overall contribution to the integrated assessment were different. In the Barents Sea those were Harp seal and Kittiwake, in the Gulf of Finland benthic fauna and three species of fish (salmon, smolt and herring), at the Lithuanian coast the extent of benthic habitats affected by human impacts, and in Kattegat the winter abundance of three bird species (Fulmar, Kittiwake, and Guillemot). Although it was not possible to apply NEAT in the current study, assessments show that such tools have the potential to study comparisons of biodiversity status between areas of different scales, latitudes and salinity regimes (Uusitalo *et al.*, 2016).

Box 7: Restoration of marine ecosystems, an ongoing case

A new trend in marine ecosystem management are projects aimed to restore and reestablish harmed ecosystems, including the formal level of biodiversity and ecosystem function (Fig. 31). The MERCES (Marine Ecosystem Restoration in Changing European Seas) project is the first of its kind within the EU-framework (2016–2020, www.merces-project.eu.). The aim of MERCES is to restore different degraded marine habitats and quantify the returns in terms of ecosystems services and their socio-economic impacts.

By physically restoring harmed and/or destroyed marine habitats that are under threat due to anthropogenic activities including environmental pollution, human infrastructure and climate change, the hope is to reestablish lost biodiversity, ecosystem services and regain good environmental status of coastal ecosystems. In southern Norway, seagrass beds are being restored by planting juvenile plants in custom made physical constructions. At the Helgeland coast (a protected UNESCO World Heritage site in mid Norway) a restoration project is currently ongoing to reestablish kelp forests in areas where pronounced grazing pressure from sea urchins and eutrophication have expelled these key ecosystems (http://www.merces-project.eu/).

Figure 31: SCUBA diver working on a marine restoration project (www.merces-project.eu/) with re-establishing of a kelp forest (*Saccharina latissima*) on the Helgeland coast, Norway

Source: NIVA (J. Gitmark).

3.9 Local and indigenous knowledge

A recent trend in biodiversity assessment is to increasingly rely on citizen science, as it increases the coverage and number of observations. Another parallel methodology is community based monitoring (CBM), which places emphasis on the needs of local communities (Conrad & Hilchey, 2011; Tunón, Kvarnström, & Malmer, 2015). CBM activities are common among indigenous people and local communities in relation to IPBES-processes around the world. The *Atlas of Community-Based Monitoring & Indigenous Knowledge in a Changing Arctic* (http://www.arcticcbm.org/index.html) describes on-going community based monitoring-initiatives, reviewed in Johnson, Alessa, and Behe (2015). From a community perspective, it makes sense to keep track of the status and trends of surrounding biodiversity, especially the ones you are dependent on. The hypothesis is that local communities with an interest in a biological resource will gather reliable knowledge on, for instance, fish stocks and seabird populations. A study from Greenland shows that when the estimations from Inuit hunters and fishers were compared to researcher data on the status and trends of 24 different marine species (birds, fish and mammals) they largely agreed (Danielsen *et al.* 2014). Another example is from Swedish Saami villages where reindeer herders were accused of exaggerating the presence of bear predation on reindeer calves. However, when bear predation was measured using GPS-techniques, similar predation numbers were confirmed (Karlsson *et al.*, 2012). An increasing number of transdisciplinary collaborations between local communities and scientists could be a valuable result from the Nordic IPBES-like assessment.

3.9.1 Reflections from the ILK-process

As part of this IPBES-like report work, a Swedish and Finnish workshop to discuss ILK was held for local knowledge holders. Farmers, artisanal fishers, hunters and nature and culture tourism entrepreneurs from the coasts of Bohuslän, Östergötland, Gotland, Uppland, Stockholm archipelago, Åland and the Kalix archipelago were represented. The following is a summary of the findings related to the status and trends of biodiversity in coastal areas over the past two decades (Kvarnström & Tunón, 2018):

The white-tailed eagle (*Haliaeetus albicilla*), grey heron (*Ardea cinerea*), crane (*Grus grus*), several species of geese (*Anser anser*, *Branta canadensis* and *B. leucopsis*), otter (*Lutra lutra*) and seals (*Halichoerus grypus*, *Phoca vitulina* and *Phoca hispida bothnica*) have increased in number in the Swedish/Finnish archipelago and in the Bothnian Bay.

The populations of cormorant that increased rapidly since the 1970's seem to have stabilised. There is increasing bush encroachment on many islands in the archipelagos of Åland, Stockholm and Östergötland, and the number of pine seedlings (*Pinus silvestris*) has increased during the last few years. Nitrophilic species like stinging nettles (*Urtica dioica*) and cow parsley (*Anthriscus sylvestris*) have also increased. Sport fishing, fishing tourism and kayaking have increased, with both positive and negative impacts. Among species that have decreased are common eider (*Somateria mollissima*), gulls, pike (*Esox lucius*), blue mussels (*Mytilus* spp.) and bladder wrack (*Fucus vesiculosus*). Decreasing numbers of small-scale professional fishers and hunters have been noted. New regulations are leading to decreased quality of life in local communities in many coastal regions, e.g. Kalix, Östergötland and Gotland. Municipal services become more centralized leading to closure of local schools. In the Kalix archipelago household fishing is one of the single most important factors for a high quality of life in the local communities (see chapter 6 in this report and Kvarnström & Boström, 2018).

A few responses from Åland to a questionnaire on ILK, indicate that during the past decade, non-commercial fish species like common roach (*Rutilus rutilus*) and common bleak (*Alburnus alburnus*), as well as cod (*Gadus morhua*), have increased. Other species seem stable. This is in accordance with recent HELCOM assessments (HELCOM, 2017a). In Åland, there was agreement on observations of enormous increases in seals, particularly in the Baltic Sea – numbers reaching beyond those encountered in living memory. Furthermore, cormorant and swans (*Cygnus olor* and *C. cygnus*) have increased. The islands in the Åland archipelago are overgrown with vegetation and less people are at sea, except during the summer vacation.

The large increases in seal populations observed by participants in the workshop and responders to questionnaires, is in concert with the HELCOM assessment of seal species in the Baltic. These conclude that grey seal and harbor seal are increasing in numbers, while ringed seal populations in the Gulf of Finland are decreasing and currently only represented by around 100 animals (HELCOM, 2017b). Assessments of ringed seal populations in the Bothnian Bay show a large increase, from estimates of 2000 seals in the mid 80s (Härkönen *et al.*, 1998) to above 20,000 at present (Naturvårdsverket, 2017b). Participants were concerned about the strong negative impact of seals on fishing and fisheries. Research at the Swedish University of Agricultural Sciences highlights the different kinds of impacts seals have on fisheries, including damage to harvest and equipment, along with hidden damage through scaring off or removing fish without leaving traces. Impacts at ecosystem level include the impact of seals on fish populations and dispersal of parasites in fish (Lunneryd & Königson, 2017). Current efforts to reduce the negative impacts of seals on fishing include protective hunting and the development of new equipment (Lunneryd & Königson, 2017; Naturvårdsverket, 2017a, 2017b). Participants at the workshop commented that seal-proof equipment is expensive for small-scale household fishers and that protective hunting from a boat in open water is extremely difficult.

3.10 Case examples

Näätämö river watershed (see Mustonen, 2018a) is the home of the Skolt Saami Indigenous community and the first official collaborative management project in Finland. Näätämö is an Atlantic Salmon river with its source in Finland, flowing northward into Norway ending in the Barents Sea. Climate change, past land use and growing infrastructure plans are some of the present and future drivers of change to the basin. For the Skolt Saami, climate change is one of the most acute and relevant processes of indigenous knowledge led monitoring (Mustonen & Feodoroff, 2013; Pecl, Araújo, Bell, Blanchard, & Bonebrake, 2017). In 2010, extreme heat waves and torrential rains affected the water levels of the Näätämö river and the capacity of Atlantic Salmon to access the upstream spawning grounds. Recently, Saami have partnered with scientists to monitor the basin using ILK, which has resulted in the production of a database on salmon and water quality changes and an interesting first observation of a southern beetle species (*Potosia cuprea)* in the area (Mustonen, 2015). The community based monitoring work has also led to the identification of "lost" Atlantic salmon spawning areas, that are now subjects of a major restoration project (Mustonen, 2018a).

Puruvesi Lake (see Mustonen, 2018b) located in Savo and North Karelia provinces in eastern Finland, contains sea-like species and ecosystems. The Lake is part of the larger Saimaa Lake system. Endangered lake salmon and freshwater seal inhabit the lake. Puruvesi is also home to one of the most traditional fishing communities in northern Europe, who practice the winter seiners of Puruvesi (Mustonen, 2014). The population feed off the lake and remove approximately 400 tonnes of fish annually.

Salmon and seal are experiencing negative impacts from a range of drivers, including large-scale hydropower development and climate change. The lake it is subject to major eutrophication threats (Mustonen, 2014).

In the Faroe Islands (see Sørensen, Roto, & Tunón, 2018), seabirds have been reported to decrease during the last decade, including kittiwake (*Rissa tridactyla*), puffin (*Fratercula arctica*), guillemot (*Uria aalge*), Arctic tern (*Sterna paradisaea*) and seagulls. At the same time, species such as gannet (*Morus bassanus*), fulmar (*Fulmarus glacialis*), shag (*Phalacrocorax aristotelis*) and black guillemot (*Cepphus grylle*) have not seen the same decline. Since 1584, the local communities in the Faroe Islands have kept track of the annual harvest of pilot whales, most likely making it the longest running community based monitoring initiative in the world. There is also a more modern approach using a Facebook initiative where Faroese hunters register the number of hares hunted and researchers at the University of the Faroe Islands process the data. Small-scale professional fishing has gradually been substituted by industrial fishing and urbanisation is leading to fewer people in remote rural areas.

The PISUNA project in Disko Bay in Greenland (see case study text by Poulsen, 2018), highlights the status and trends of certain species. Local fishers and hunters monitor seals (fluctuating), Atlantic cod (increasing), common eider (increasing), humpback whale (*Megaptera novaeangliae*) (increasing), Greenland halibut (*Reinhardtius hippoglossoides*) (increasing), thick-billed murre (*Uria lomvia*) (declining), Canada goose (*Branta canadensis*) (increasing), narwhal (*Monodon monoceros*) (stable or increasing), and beluga (*Delphinapterus leucas*) (stable or increasing) (Danielsen, Frederiksen, & Mølgard, 2016).

In the Kalix archipelago of the Bothnian Bay (see Kvarnström & Boström, 2018), the local communities have mapped the abundance of fish stocks over the past three decades. Local community members and reindeer herders make regular observations of changes in abundance of fish, birds, seals and other mammals, as well as observations of changing weather patterns and changing ice cover. Special focus has been on mapping areas of presence and absence of brown trout (*Salmo trutta).* The local fishing communities hope that collaborative monitoring and co-management of fishing can support trout populations, as well as sustain and strengthen local fishing culture.

3.11 Knowledge gaps

- While HELCOM, OSPAR and other international and regional initiatives have been mapping biodiversity and ecosystem function during the last decade, no committed assessments have been made to obtain trends in biodiversity over time. However, recently some initiatives (e.g. BEAT) have been taken, aiming to quantify trends of biodiversity and improving understanding of the human impacts on NCP;
- Knowledge gaps regarding climate impacts (warming, ocean darkening, and acidification) on kelp forest and seagrass ecosystems are pronounced. Further research will help to develop an understanding of how anthropogenic and climate

driven forces impact trends in biodiversity and ecosystem function in these prestine ecosystems. A head start is the recent work on the role of kelp and seagrass in climate mitigation by the Norwegian Environment Agency and The Norwegian Blue Forest Network (www.nbfn.no). However, our quantitative understanding of these processes is limited and very coarse (Duarte *et al.*, 2005; Mazarrasa *et al.*, 2015);

- The development of common Nordic biodiversity indicators and assessment tools is recommended to aid future assessments of biodiversity and ecosystem function across the Nordic region. Some methodologies and tools are proposed locally and could be tested and modified for a common Nordic biodiversity assessment system, in line with the Norwegian Nature Index (Nybø, 2010), the Nested Environmental status Assessment tool for marine biodiversity (Uusitalo *et al.*, 2016), and the HELCOM Holistic Assessment tools for the Baltic Sea Biodiversity Assessment. HELCOM development for the Holistic assessment has developed several biodiversity indicators, agreed upon between the Baltic Sea countries. The lastest HELCOM assessment was carried out in July 2017;
- A major challenge is how to link biodiversity and ecosystem function with ecosystem services and their valuation. Currently, most qualitative assessments of ecosystem function are not operationally linked with biodiversity assessments. Also, tools that relate ecosystem function to ecosystem services should be developed for future management strategies;
- A closer link between ILK with monitoring and assessments of biodiversity is recommended. This would improve understanding of biodiversity and ecosystem function status and trends, and provide local and regional knowledge of ecosystem services and values.

3.12 Policy recommendations

- Implement multi-stressor impacts studies on coastal ecosystems. In particular, combined impacts of climate change (warming, elevated precipitation, acidification), eutrophication and human resource harvesting (e.g. fisheries) need to be better resolved and understood. Today, management programs largely focus on environmental challenges one at a time, e.g. separating climate impact studies from resource harvest monitoring;
- Identify and adjust policies that counteract incentives for conservation and the sustainable use of biodiversity in coastal areas;
- Increase political focus on the status of marine biodiversity and the influence of human activities on species and habitat diversity. This would be closely related to work with the UN Sustainable Development Goals (SDGs);
- Development of assessment tools for biodiversity and ecosystem function as part of established environmental monitoring programs (HELCOM, OSPAR, EU Habitat and Birds Directive, and the Marine Strategy Framework Directive);

- Include assessment of temporal trends in biodiversity and ecosystem assessment programs, like those recormended above, to improve future evaluations and possibilities for managers to take actions towards healthy coastal ecosystems;
- Include seagrass meadows and kelp forest contributions to carbon storage and climate mitigation in regional carbon budgets;
- Evaluate the impacts of climate pressures (sea level rise, warming, ocean darkening, and acidification) on biodiversity and ecosystem function in the coastal zone;
- Maintain a dedicated focus on scientifically sound and validated methods in applied assessment tools to secure high quality knowledge-based information for policy makers and management agencies;
- Scientific knowledge-based information should be combined with ILK in future management and policy planning, with the aim to improve quantification of NCP.

3.13 References

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Abstract [en]
This report describes the status and trends of biodiversity and ecosystem services in the Nordic region, the drivers and pressures affecting them, interactions and effects on people and society, and options for governance. The main report consists of two volumes. Volume 1 The general overview (this report) and Volume 2 The geographical case studies. This study has been inspired by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystems Services (IPBES). It departs from case studies (Volume 2, the geographical case studies) from ten geographical areas in the Nordic countries (Denmark, Finland, Iceland, Norway, Sweden) and the autonomous areas of Faroe Islands, Greenland, and Åland. The aim was to describe status and trends of biodiversity and ecosystem services in the Nordic region, including the drivers and pressures affecting these ecosystems, the effects on people and society and options for governance. The Nordic study is structured as closely as possible to the framework for the regional assessments currently being finalized within IPBES. The report highlights environmental differences and similarities in the Nordic coastal areas, like the inhabitants´ relation to nature and the environment as well as similarities in social and policy instruments between the Nordic countries. This study provides background material for decision-making and it is shown that Nordic cooperation is of great importance for sustainable coastal management and should be strengthened in future work.

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Nordic Council of Ministers

Biodiversity and ecosystem services in Nordic coastal ecosystems: an IPBES-like assessment

Volume 1

The general overview

Biodiversity and ecosystem services in Nordic coastal ecosystems: an IPBES-like assessment. Volume 1. The general overview

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Contents

Summary

This study has been inspired by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystems Services (IPBES). The aim of the assessment was to describe the status and trends of biodiversity and ecosystems in the Nordic region, including the drivers and pressures affecting these ecosystem components, as well as the effects on people and society and options for governance. Ultimately, this study provided an opportunity to aid the process of utilizing scientific results in the policy and decision-making realm, thus forwarding the science-policy interphase. The Nordic study is structured as closely as possible to the framework for the regional assessments currently being finalized within IPBES. This assessment has been based on information provided by the following case study areas in the Nordic countries: Näätämö/ Neiden basin, Kalix Archipelago, Kvarken/the Quark, Puruvesi Lake in North Karelia, the Lumparn area, Öresund, Helgeland coast, Faroe Islands (Føroyar), Broddanes West Fjords and the coastal areas of Húsavík (Iceland) and Disko Bay (Greenland).

The objectives of the assessment were to address the following questions:

- What are the main drivers and pressures affecting biodiversity, ecosystem services and ecosystem function?
- How does global, regional and national policy influence biodiversity, ecosystem services and human well-being in the Nordic region? What opportunities exist in policy-making?
- How can we better integrate indigenous and local knowledge (ILK) perspectives on biodiversity, ecosystem services and nature's contributions to people (NCP) in decision-making? How can we apply their culture and traditional management methods to support decision-making?
- What opportunities exist for sustainability and nature-dependent human well-being in Nordic societies?
- What biodiversity and ecosystem values define NCP in the Nordic coastal region?
- How can data sources such as Earth Observation and GIS spatial data be used in assessments to support decision-making?
- What are the major gaps in data, knowledge, management and decision-making systems? How can these gaps be minimized?

The outcomes from the assessment has been summarized in the following key messages:

- A. The Nordic coastal region has many natural assets and provides numerous ecosystem services:
  - A1. *The Nordic coastal region is unique due to the variability in nature types and biodiversity.* Its coastal areas support examples of many different habitats spanning the temperate to the Arctic zone. This diversity supports considerable biodiversity that people depend on for their livelihoods;
  - A2. *The Nordic coastal region contains several globally important species and habitats.* These include the wintering bird assemblages in the shallow seas around Denmark, the unique habitats of the Baltic Sea (the largest brackish water area in the world), the kelp forests and breeding seabird colonies on offshore islands and cliffs in northern regions along the Norwegian coast, the recovering populations of whales in the North Atlantic Ocean, the assemblages of Arctic species and the recovering stocks of cod and other species in the North Sea and further north;
  - A3. *Most of the region's biological value is in the form of large concentrations of fairly common species.* The region houses habitats and assemblages of species that are typical of temperate seas warmed by the Gulf Stream, along with the Arctic and the Baltic Seas, parts of which are seasonally frozen. The strong seasonality also results in long and short distance migration of many fish, birds and mammals using the coastal and marine systems in the region. These include globally important winter concentrations of migrant seabirds and shorebirds in the southern part of the region and similarly important summer concentrations in the northern and Arctic regions;
  - A4. *The ecological status in the North East Atlantic and Bothnian Sea is good.* The status is moderate in the Arkona Basin and the Sound, but poor in the Baltic Proper and Gulf of Finland;
  - A5. *Many biological values of the region are slowly recovering from very low values following past overexploitation.* These biological values include populations of fish-eating sea birds and white-tailed eagle, grey heron, crane and several geese species in the Baltic Sea. It also includes cod, herring, mackerel, ringed seal, grey seal, harbor seal, hooded seal, North Atlantic fin whale and bowhead whale along the Norwegian coast, along with wintering and breeding populations of geese and swans in Danish coastal areas. In the Baltic Sea, and particularly in the Bothnian Bay, there is a slow recovery from DDT and PCB pollution events. However, pollution from heavy metals and contamination from persistent toxic chemical and radiation events remains a challenge;
  - A6. *The network of marine and coastal protected areas is important for preserving biodiversity and ecosystem services in the Nordic region*. Regulations to accomplish sustainable use of these areas are under development;

- A7. *The coastal natural resources in the region have provided food for people living in the Nordic region for thousands of years.* They continue to provide this today, especially from fisheries in the shallow seas, but also from animals feeding on the coastal habitats and birds breeding on the coastal cliffs. These resources are under various management regimes; some traditional going back at least hundreds of years and others with a more recent natural science basis;
- A8. *The diversity of Nordic coastal and marine ecosystems continues to deliver goods and services that are vital to the livelihoods of many people in the region*. Beaches and other coastal areas are important leisure resources for tourists from other countries. Particularly holidaymakers and weekend visitors from within the Nordic countries frequent the southern parts of the region. There are also continuing traditions and systems of using coastal and marine resources across the Nordic region. These are integrated into the modern lives of people living both in the rural areas and, increasingly, in cities throughout the region;
- A9. *The Nordic coastal regions support communities with strong traditional ties to nature, which provides opportunities for resource management based on traditional use, management and governance regimes*. These communities include both Inuit/ Greenlandic and Saami peoples in the north, coastal communities along the seaboard of Norway, Sweden, Finland and Denmark, as well as populations in the Faroe Islands and Iceland;
- A10. *The coastal natural resources of the region provide inspiration for the people living in the Nordic countries.* Some are strongly embedded in cultural identities and ways of living. These cultural values provide a powerful bond between people and nature and are a major reason for the persistence, and in some cases recovery, of natural resources in these coastal regions.

- B. The coastal Nordic region is under pressure:
  - B1. *Some species are still in decline in the region despite conservation actions aiming to assist their recovery.* This includes the globally important populations of breeding auks (puffin, razorbill, common guillemot, Brünnich's guillemot) and some breeding seabirds (e.g. kittiwake). There has been a considerable decline in sea grass meadows, kelp forests and fucoid algae/or brown seaweeds in different parts of the region. Due to population crashes in the past century, species like sturgeon and lamprey in the Baltic Sea remain at very low populations;
  - B2. *The Arctic – also the parts within the Nordic region – is the part of the planet most heavily affected by climate change and is warming at a far higher rate than any other region on earth*. This is having and will continue to have dramatic impacts on ecosystems and their services, including through ocean acidification. Throughout the region, there are emerging impacts of climate change. Northern species of birds, fish and bivalves cease to breed in southern countries like Denmark, migrating northward and expanding their

breeding grounds along the coasts of Norway, Sweden and Finland. Fish e.g. mackerel, herring and tuna, are moving to more northern waters around Iceland and Greenland. There are changes in the coastal food web, potentially impacting food sources for some of the largest marine creatures in the region, e.g. humpback whale. Ocean warming is having negative impacts on the extensive kelp forests in the western oceans off Norway;

  - B3. *Chemical pollutants, eutrophication and plastics are affecting the coastal waters of the region.* The historical heavy industrial and nuclear radiation pollution is still affecting parts of the Baltic Sea. The situation has greatly improved over the past 30 years. In other parts of the region, there is considerable run-off of agricultural fertilizers and pesticides, although the amount has been reduced from past levels. Eutrophication of the coastal waters remains a problem, evidenced by impacts to species composition in many areas. In recent years, fears have emerged on what consequences the high quantities of plastics and nanoparticles in the oceans may lead to. It will take many centuries for these particles to degrade in the regions' colder northern waters, and their impact on marine life is negative;
  - B4. *Invasive species pose serious challenges to parts of the Nordic coastal ecosystems.* Significant challenges arise from the Japanese rose (*Rosa rugosa*) on coastal foreshores and sand dune areas in Denmark and southern Sweden. Challenges also arise as a result of a variety of invasive marine animals and plants, including the round goby in the Baltic Sea and in the North Sea, and king crab in the Bering Sea. Measures against alien invasive species may mitigate the effects of these species. Such measures may include the implementation of legislation and/or physical measures to remove already established species;
  - B5. *Infrastructure development in marine and coastal areas poses challenges.* The Nordic region is a global frontrunner in near- and offshore wind turbine technological development and installation. However, wind power plants have impacts on e.g. migratory birds and bats. In addition, there are impacts associated with the construction of the large bridges between Denmark and Sweden, and Denmark and Germany. The trend to set aside coastal or near-coastal areas for building summer cottages brings challenges of reduced access, increased disturbance and the need for water treatment. There is oil and gas exploration and mining industry in the northern seas that has potential to impact these areas. Of particular concern is the slow break-down of pollutants in cold waters of low biological capacity.
- C. Building resilient futures in the Nordic coastal region:
  - C1. *The political and governance systems of the Nordic region are transparent and fair.* There is a broad interest within the Nordic countries to pursue development pathways to reduce local and global impacts on natural resources. There is good access to coastal areas and strong emphasis on the use of nature and natural areas for livelihoods and recreation. These values

and traditions need to be maintained to continue to provide space for nature and to allow people to benefit from natural coastal areas. Nordic countries are able to implement and maintain systems for improved coastal management and sustainable harvesting of species, habitats and resources;

- C2. *There are good examples of indigenous and local peoples participating in coastal nature management in the northern regions.* This is critically important for continued subsistence use and for maintaining ecosystem services in the north. Better integration and support of indigenous and local knowledge within conservation management and in governance of resource use in the region would be beneficial;
- C3. *Ongoing progress to clean up pollution and reduce eutrophication in rivers, lakes, coastal areas and open seas needs to be continued*. This relates to all the countries in the Nordic region and is equally important on national, regional and international scales. This can be achieved through catchment-based management approaches, as eutrophication is mainly caused by run-off from land. There have been intensive efforts to reduce the secondary environmental impacts from the large marine aquaculture industries (e.g. salmon farmed in the Norwegian fjords), shell fish farming (e.g. blue mussels on poles and other structures in Danish and Swedish seas), along with the emerging seaweed farming industries;
- C4. *Some fish stocks and populations of marine mammals are recovering in the region.* Further recovery can be accomplished through careful review and changes to policies as required. However, some populations (e.g. seals) have recovered to the point where they are causing problems. For those fisheries and populations of marine mammals that are still in decline, further efforts are required to help return populations to a healthy state;
- C5. *Cooperation among the Nordic countries is needed to improve coastal zone planning and management.* Policies and their implementation need to balance the needs of the natural system and human development in coastal areas (e.g. summer houses, urban areas, industry). Examples can be drawn from ongoing marine spatial planning initiatives;
- C6. *Coastal resilience to rising seas needs to be enhanced, e.g. through nature-based solutions offered by natural or moderately modified ecosystems*. Changes in the coastal regions may be dramatic in the future due to climate change and related sea level rise, flooding, extreme weather events and increased run off from inland water bodies and melting ice;
- C7. *The legal frameworks in most Nordic countries have national laws, EU directives and regulations and follow regional marine conventions including HELCOM and OSPAR*. These are often developed from agreed targets of international non-binding agreements, such as those under the Convention on Biological Diversity and the United Nations Framework Convention on Climate Change. This legislative framework is strong, but can always be

further developed to enhance the outcomes for nature and people in the coastal regions.

The following options for policy makers have been proposed:

- Evaluate the costs and benefits of existing environmental policies, prioritise and streamline them to help overcome the high density of policies;
- Where possible, coordinate the implementation of policies across the Nordic region to reduce policy conflicts;
- Identify and adjust policies that counteract incentives for conservation and the sustainable use of biodiversity in coastal areas;
- Increase political focus on the status of marine biodiversity and the influence of human activities on species and habitat diversity. This is closely related to work with the UN Sustainable Development Goals (SDGs);
- Involve science-based assessments and priorities in policymaking in terms of identifying most needed conservation and management policy initiatives;
- Safeguard the right to public access of coastal areas as access to nature maintains access to a number of non-material nature's contributions to people, such as identity, physical and psychological experiences, knowledge and inspiration, as well as material benefits such as food and ornaments. This collectively helps maintain society's sense of duty to protect the environment;
- Implement ecosystem-based adaptation to increase the coastal region's resilience to climate change;
- Draw benefits from technological developments that reduce the region's ecological footprint; and
- Identify pathways to achieve the 2050 vision of the Strategic Plan for Biodiversity and implement the Sustainable Development Goals and their targets.

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