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7. Helgeland: An Atlantic archipelago (Norway)

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7.1 Setting the scene

The Helgeland archipelago stretches across 200 km, extending from Trøndelag in the south to Salten in the north. This iconic part of the Norwegian coast comprises a myriad of islands and islets (more than 12,000) and large shallow sea areas (fig. 61 and 62). All along the coast there are white beaches, sheltered coves, fjords and steep towering mountain walls rising straight from the open sea. A wealth of marine life thrives in the area, spanning from the smallest microalgae to the largest mammals. Harbor seals (*Phoca vitulina*), Atlantic puffins (*Fratercula arctica*), white-tailed eagle (*Haliaeetus albicilla*) and greylag goose (*Anser anser*) are among typical species encountered.

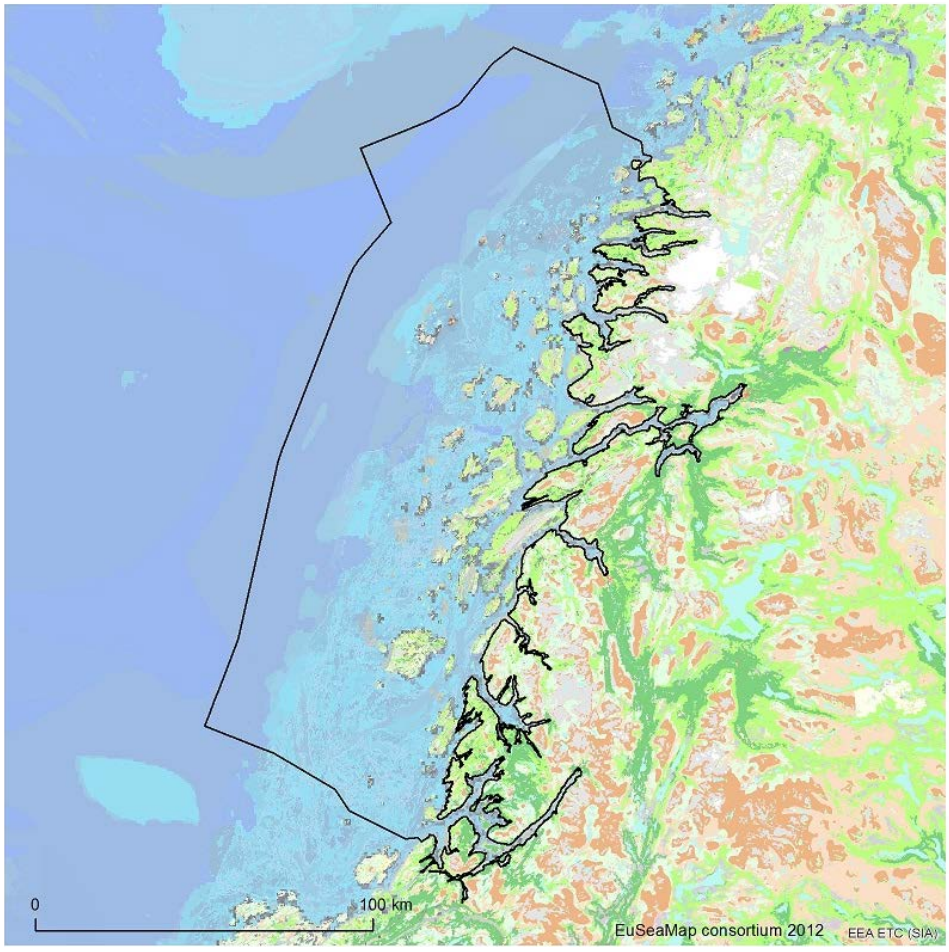
Figure 61: The Helgeland archipelago

Photo: I. Mahlum

The seabed is covered with soft sediments with seagrass beds and rocky substrate that are partly covered with kelp forest, some intact and some still suffering from severe grazing by urchins. The intact seagrass beds and kelp forests house thousands of species of invertebrates, fish and numerous other species.

People have harvested natural resources provided by nature in the Helgeland archipelago for more than 1,500 years (Box 8). Today, main livelihoods are agriculture and fishing, but hydropower, mining and industrial activities also influence the region. Approximately 85,000 people live in the Helgeland region today, distributed between several small municipalities.

Figure 62: Map of the Helgeland archipelago, Nordland County, at the north-western coast of Norway



Note: The archipelago lies in the Norwegian Sea, which is a part of the north-eastern Atlantic Ocean.

Source: EuSeaMap consortium 2012.

Box 8: Vegaøyan – A UNESCO World Heritage Site

A part of the Helgeland archipelago, "Vegaøyan", was inscribed as a cultural landscape in the UNESCO World Heritage List in 2004. This is a cluster of islands centered around the Vega island, just south of the Arctic Circle. The landscape covers approximately 100,000 ha, of which only 7% is land (fig. 62). In the past, several hundred people populated the small islands, while today, only three people live permanently within the World Heritage Site. Traditionally, locals have been self-sufficient fisher-farmer holdings, where gathering of eggs and down from eider ducks (Somateria mollissima) has been an important part of the islanders' income (fig. 63). The main reasons for its world heritage status is the maintenance of sustainable living practices over the past 1500 years, along with the significance of women contributing to eider down harvesting. The UNESCO status is also given due to the extraordinary landscape of Vega, the rich diversity of birds and high coastal biodiversity.

Figure 63: The small sheds in the foreground are for breeding eider

Note: In these, people used to harvest eggs and down from eider ducks. Today, only down is harvested.

Photo: Inger Hosen.

7.2 Key Ecosystem Services

The Helgeland coast gives rise to a number of ecosystem services, including provisioning, regulating, cultural and supporting services (Table 6). Among many, a few of the key ecosystem services are described in more detail below. It should be noted that this is not a complete list of ecosystem services from the area.

Table 6: Key ecosystem services of the Helgeland archipelago

Category	Ecosystem Services
Provisioning	
	Fisheries (fish, crabs)
	Kelp and algae for food, energy, and bioprospecting
	Genetic resources
Regulating	
	Carbon storage and deposition (sequestration)
	Water purification
	Nature protection, erosion control
Cultural	
	Recreation and nature based tourism
	Natural heritage
	Cultural heritage
	Aesthetic services

7.2.1 *Commercial fisheries*

Fisheries have been and still are a key source of income and an important basis for culture along the Helgeland coast. Seafood from fisheries and aquaculture is still a major industry in Norway. The industry also supplies technology and knowledge-based services that are important internationally. For many small settlements along the Norwegian west coast, the marine sector is a pillar in terms of settlement and employment (Meld. St. 37. 2008–2009).

Some fisheries and fish species are of particular importance in the area. The Norwegian spring-spawning herring (*Clupea harengus*) is one of the most important fish in the Norwegian Sea, ecologically as well as commercially. It provides food for higher-trophic level species such as seals, whales and humans. The Norwegian spring-spawning herring is migratory and at certain times of the year, herring can be found across large parts of the Norwegian Sea. Some of the main spawning grounds are in Helgeland, where they arrive in January/February and spawn between February and April.

Cod and haddock are, and have for a long time been, two of Norway's most important fish stocks and exported resources. The Northeast Atlantic cod (*Gadus morhua*) and Northeast Atlantic haddock (*Melanogrammus aeglefinus*) spawn on and along the edge of the continental shelf in the Norwegian Sea. There are several stocks of coastal cod distributed from Stadlandet at about 62°N northward to the Russian border.

The Northeast Atlantic cod and the coastal cod are the same species, but are considered separate strains. In contrast to the Northeast Atlantic cod, coastal cod does not migrate into the Barents Sea. It spawns in fjord systems, most frequently in the inner parts. It is present year-round and has thus been an important source of food to local people. Other commercially important species are saithe (*Pollachius virens*), Norwegian pollock *(Theragra finnmarchica),* pollack (*Pollachius pollachius*), shrimp and crab.

In mid-Norway and Helgeland (63°–67°N), the peak crab fishing season is from August to November. Some 75% of Norwegian landings of edible crab (*Cancer pagurus*) are from these regions, with nearly 90% of the landings going to processing factories. The number of reported landings have declined in the Helgeland area in recent years (www.imr.no). Crab play an important role in the kelp forest ecosystem (Box 9 and 10).

The Helgeland coastal region is also an important nursery area for salmon (*Salmo trutta*).

7.2.2 *Kelp and algae for food, feed, energy and other non-edible resources*

Norwegian kelp has the potential to be utilised in the production of fertilizer and bio-fuel (Gundersen *et al*., 2016). Currently, there is also growing interest in kelp for human consumption (Chapman *et al*., 2015).

As far north as Helgeland, about 200,000 tons of kelp is harvested for alginate extraction (Vea & Ask, 2011) with a first-hand value of more than EUR three million. As the kelp forest returns to these shores (Box 11), there is increasing interest in expanding the harvesting area northward, also into the Helgeland region. However,

this has led to massive concern, as the effects of kelp harvesting on cultural and natural values in the area are unknown. The red-listed eider population (Box 8) may be among the affected.

7.2.3 Nature protection, erosion control and purification of water

Kelp forests of *Laminaria hyperborea* are located in highly exposed areas, where they mitigate the forces of breaking waves (Løvås & Tørum, 2001), thus providing protection from wave impacts, storm surges and other oceanographic events that can cause harm to coastal communities. Seagrass (i.e. eelgrass *Zostera marina*) meadows are found in more sheltered areas, where they play an important role in reducing the risk of sediment erosion on soft and sandy bottoms.

Water purification and filtration services are also provided by kelp forests, sea grass meadows, and blue mussel (*Mytilus edulis*) banks. Improved water quality (in terms of transparency) is believed to infer enormous benefits for the production of food, along with for all aspects of ecosystems and their function.

7.2.4 Carbon regulation

Algae (e.g. kelp) and plants regulate the global climate by taking up carbon dioxide (CO_2) from the water (Box 9). Carbon in its organic form is stored in living algal and plant material, but eventually deposited on the seafloor sediments, where a fraction is permanently buried (deposited on geological time scales). Globally, kelp forests and sea grass meadows contribute to a burial of large amounts of organic carbon from the biosphere (Duarte *et al.*, 2010).

Box 9: Kelp – a potential important player in the blue carbon budget

Among many functions, kelp (fig. 64) regulate the global climate by taking up and using carbon dioxide (CO_2) for photosynthesis. Thus, kelp plants act as reserves for CO_2 when they are alive, whereas most of the carbon is released back to the system when the plant dies and decomposes, or when it is consumed. Because of the large and expanding (Box 11) areas of kelp forests along the Norwegian coast, the binding and release of carbon in kelp will have a great impact on the total carbon and greenhouse gas balance.

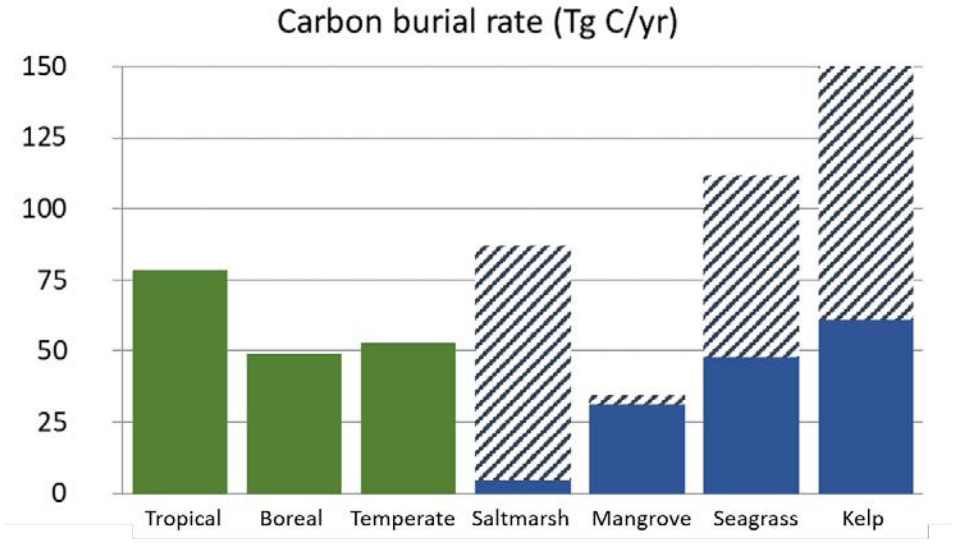
Many other marine ecosystems have been shown to be major contributors to carbon storage and sequestration (McLeod *et al.*, 2011). The general understanding for kelp however, has been that they "do not bury carbon, as they grow on rocky substrates where burial is impossible" (Nellemann *et al.*, 2009). But recent research shows that detached kelp materials are transferred to both shallow and deep-sea sediment areas where a fraction of it is permanently stored (in geological time scales). In fact, a recent study suggests that kelp and other macroalgae could represent a significant part of the carbon sequestered in marine sediments and the deep ocean (Krause-Jensen & Duarte, 2016).

Combining estimates from Krause-Jensen and Duarte (2016) with previous numbers from terrestrial and marine ecosystems (McLeod *et al.*, 2011, see fig. 65), reveals that the importance of kelp forests as carbon sinks have been largely overlooked, and that more studies on this subject are needed to map the pathways and role of kelp in the marine carbon circulation (see also Gundersen *et al.*, 2011).

Figure 64: Healthy kelp (*Laminaria hyperborea*) forest with young saithe fish swimming above it

Photo: Kjell Magnus Norderhaug/NIVA.

Figure 65: Estimates of carbon burial rates of different terrestrial and marine blue forest types in Tg (teragram) C per year globally, equivalent to millions of tons of carbon per year. Shaded areas indicate estimated potential (references in text)



7.2.5 Recreation and nature based tourism

Enger *et al*. (2013) describe the essence of tourism in northern Norway, including Helgeland, with the marketing slogan "Enter the world of natural wonders", referring to four themes of adventure and experiences: nature phenomena, the Arctic, the coast & coastal culture, and Saami culture. The ecosystems and the mix of services they provide are used in the marketing of Helgeland, and are visible in most descriptions of recreation and tourism in the area. One headline is, for instance, "White beaches and undiscovered islands". Others state "Rambling in high mountains", "Exploring thousands of islands and islets and white sandy beaches" and "Island-hopping with a bicycle or kayak in an area that many people see as the very best area in Norway for ocean kayaking".

Helgeland has areas ideal for recreational activities including fishing and scuba diving. Kelp forests, rocky slopes and maerl beds with myriads of species are scenic underwater habitats that are central for these activities, due to their rich biodiversity. These habitats' ability to purify water and mitigate eutrophication, further increases the Helgeland archipelago's value for scuba diving, swimming, kayaking and similar activities (Gundersen *et al*., 2016). In summer, the midnight sun makes outdoor life attractive both day and night. During winter the northern lights, another tourist magnet, can be seen on clear nights. Further, it is emphasised that the archipelago is a dream for bird watchers wanting to see eider ducks (Box 8), Atlantic puffins, Eurasian eagle-owl (*Bubo bubo*), white-tailed eagle (*Haliaeetus albicilla*), cormorants (*Phalacrocorax aristotelis* and *P. carbo*), ducks, geese and more than 200 other bird species (fig. 66–69).

Helgeland is also very attractive as a seasonal feeding ground for numerous larger species, some of which are considered tourist attractions in themselves, such as seals, killer whales (*Orcinus orca*) and minke whales (*Balaenoptera acutorostrata*).

Enger *et al*. (2013) estimated that the tourist sector in Helgeland was valued at amost EUR 100 million in 2011; EUR 65 million of these from the transport sector (airplanes, the Hurtigruten tourist ship, etc.), and EUR 30 million from other sectors including hotels and activities.

Recreational fishing at sea is an important activity in Helgeland, as well as in other areas along the coast. It was estimated that the economic value of recreational sea fishing in northern Norway, including turnover and wider economic effects, was about EUR 50 million in 2009 (Borch *et al*., 2011).

Figure 66: Charismatic birds in the Helgeland Archipelago: Atlantic puffins (*Fratercula arctica*)

Photo: Carron Brown.

Figure 67: Charismatic birds in the Helgeland Archipelago: White-tailed eagle (*Haliaeetus albicilla*)

Photo: Karl-Otto Jacobsen.

Figure 68: Charismatic birds in the Helgeland Archipelago: Greylag goose (*Anser anser*)

Photo: Michael Maggs.

Figure 69: Charismatic birds in the Helgeland Archipelago: Eurasian eagle-owl (*Bubo bubo*)

Photo: Karl-Otto Jacobsen.

7.3 Biodiversity and Ecosystem Characteristics

7.3.1 The Helgeland ecosystem

The Helgeland coast offers a range of natural habitats hosting a large number of marine species whose lifecycles are connected to terrestrial animals (birds and mammals), forming a diverse and complex ecosystem. Kelp and other macrophytes (both algae and plants), along with microalgae, drive primary production in the Norwegian Sea outside the Helgeland coast. A high number of "sun-hours" during summertime contribute to fuelling the system's primary production. Transforming the solar energy to organic matter, macrophytes provide both the food source and the habitat for all species higher up in the food-web, hereby playing a key role in the Helgeland marine ecosystem and people associated to it (Chapter 7.2).

7.3.2 Key ecosystems and typical habitats

The key marine ecosystems in the Helgeland region are kelp forests, maerl beds, sandy- and soft sediments, seagrass meadows, intertidal areas, islands and bird cliffs. These key ecosystems provide the physical and biological structures that support the living of key species and the rich biodiversity, that again provide the main functions and services of the ecosystem (Table 7).

Table 7: Key ecosystems and examples on corresponding key species groups making up the rich biodiversity of the Helgeland archipelago

Key ecosystems	Key species groups
Kelp forests	
	Brown, green and red algae
	Sea urchins, snails, small crustaceans
	Crabs, fish, birds, seals
Seagrass beds	
	Seagrass
	Bivalves, snails, small crustaceans
	Fish, birds
Maerl beds	
	Coralline red and other algae
	Bivalves, snails, small crustaceans, echinoderms
	Crabs, fish, birds
Sandy- and soft sediments	
	Bivalves, polychaetes and other infauna
	Crabs, fish, birds
Open water masses	
	Phytoplankton
	Zooplankton
	Fish, birds, seals, whales
Intertidal areas, islands and bird cliffs	
	Seaweeds
	Crustaceans, bivalves, snails
	Birds, seals

7.3.3 Key habitat forming species

The Helgeland region includes several key species that play essential roles in maintaining the structure and function of ecological communities. On the seafloor, kelp (e.g. *Laminaria hyperborea* and *Saccharina latissima*, Box 10) are important habitat forming species (Teagle *et al.*, 2017) that create large underwater forests. Under the canopy of these forests, several brown, red, and green algae of various sizes thrive, some even growing on the kelp itself (epiphytes). Together, these algae communities function as habitat for invertebrates such as bivalves and sea urchins, crustaceans such as crab, and benthic fish such as cod and wolf fish. The kelp plants grow more than two meters tall and their biomass can reach more than 30 kg per square meter. Kelp are among the world's fastest growing primary producers (Krumhansl & Scheibling, 2012) and in Helgeland, kelp are the most important primary producers, contributing more than 1,000 g carbon/m^2 annually.

Eelgrass is also found in the region, having many of the same functions as kelp forests (e.g. Fredriksen *et al.*, 2005). How sea grasses contribute as a key habitat forming species are described in detail in the "Øresund case study".

Shell sand is a common habitat that is found along the coast of Helgeland. Shell sand consists of partially disintegrated carbonate shells from marine organisms such as bivalves, barnacles, sea urchins, snails and skeletal calcareous algae. These habitats are important as they contain a large number of animals, providing good spawning grounds and growing areas for different fish species, shellfish and crustaceans. Shell sand is also harvested for limestone, chicken feed, artificial beaches, covering polluted seafloor and in wastewater filter treatment technology. Shell sand develops slowly and is regarded as a non-renewable marine resource.

Box 10: The blue forests – key habitats for thousands of species

Blue forests are underwater coastal ecosystems that are particularly important as primary producers and ecosystem engineers, and they play a central role in structuring coastal habitats (Teagle *et al.*, 2017). The Nordic blue forests consist of habitats such as kelp forests and sea grass meadows (fig. 70 and 71); these are key players in the coastal ecosystem. In addition to providing a high number of key ecosystem services, these habitats also provide extensive substrata for colonizing organisms, enhancing conditions for understory assemblages and provide three-dimensional habitat structure for a vast array of marine plants and animals, including commercially important species (Christie *et al.*, 2003). Recent studies have found a surprisingly rich fauna of mobile invertebrates. Such animal societies can consist of 200–300 different species at densities of more than 100,000 individuals of snails, crustaceans, clams, polychaetas and other invertebrates per square meter (Christie *et al.*, 2009).

In 2015, a network to strengthen the Norwegian understanding and knowledge of blue forests was established. The network aims to understand the full potential of blue forests in addressing the global climate challenge, along with their ability to provision ecosystem services nationally and abroad. More information on The Norwegian Blue Forests Network (NBFN) can be found at www.nbfn.no.

Figure 70: Typical kelp forest dominated by Tangle kelp (*Laminaria hyperborea*) and its richness of associated species, including fish seen above the kelp canopy

Photo: J. Gitmark/NIVA.

Figure 71: Eelgrass meadow (*Zostera marina*), also an important feeding and nursery ground providing a high biodiversity to coastal communities. Here with the common lion's mane jellyfish (*Cyanea capillata*) hovering over

Photo: Kasper Hancke/NIVA.

7.3.4 Lower-trophic key species

Lower trophic animals are important for maintaining ecosystem function. These include a range of fish and sea birds (e.g. eider ducks) that prey on invertebrates such as snails and bivalves (e.g. blue mussels). Some sea birds, such as geese, graze the seafloor vegetation (fig. 72).

In the open water masses (the pelagic zone) microalgae, zooplankton (e.g. copepods), and pelagic fish represent the key species. They have essential roles in the food-web, along with the turnover of carbon and nutrients in the marine ecosystem. Microalgae, which harvest light energy the same way as seaweeds and seagrass do, are the main food source for copepods, krill and other small crustaceans. These small animals provide a food source for fish, sea birds and mammals.

Figure 72: Image showing typical species at a semi-exposed tidal (littoral) zone

Note: The rocks are covered by barnacles (*Semibalanus balanoides*), Atlantic dogwinkle (*Nucella lapillus*) and seaweeds such as bladderwrack (*Fucus vesiculosus*), spiral wrack (*F. spiralis*) and red dulse (*Palmaria palmata*).

Source: Image from Arenholmen, Vega by NIVA.

Photo: Janne Kim Gitmark.

7.3.5 Fish of Helgeland

Cod and herring have played significant roles in the shaping of society in Helgeland. Stocks of herring and Northeast Arctic cod have declined since 2013. The coastal cod populations have declined substantially since the mid-90s due to poor recruitment (www.imr.no). Both cod and herring are important in ecosystems around Helgeland.

Herring is a food source for many larger fish and marine mammals, and along with crabs, cod may play an important role in the balance between kelp and sea urchins (Box 11). Other local fish may also be important by controlling the meso-grazer populations, thus maintaining trophic structures in habitats including eelgrass meadows and kelp forests (Baden *et al.*, 2012; Östman *et al.*, 2016; Andersen *et al.*, 2017).

7.3.6 Birds of Helgeland

The younger age classes of saithe and coastal cod are nutritionally important for cormorants (*Phalacrocorax* spp.) and black guillemot (*Cepphus grylle*) that forage on fish from the coastal zone. The Northern gannet (*Morus bassanus*) dives after somewhat bigger fish, such as herring and mackerel that are important prey. The gulls utilise fish for prey when available, but also eat other birds, molluscs, larger invertebrates like crabs, waste from fisheries and even garbage.

Like many of the larger fish in Helgeland, sea birds are important as predators in the biological communities associated with kelp forest and eelgrass meadows. Common species include greylag goose (*Anser anser*), common shelduck (*Tadorna tadorna*), red-breasted merganser (*Mergus serrator*), black guillemot and several species of gulls. The Atlantic puffin (*Fratercula arctica*) is also found in Helgeland, but only breeds on Lovund (fig. 66). The white-tailed eagle (*Haliaeetus albicilla*) has increased steadily since its protection by law in 1968, and is now an iconic species in Helgeland (fig. 67).

7.3.7 Marine mammals of Helgeland

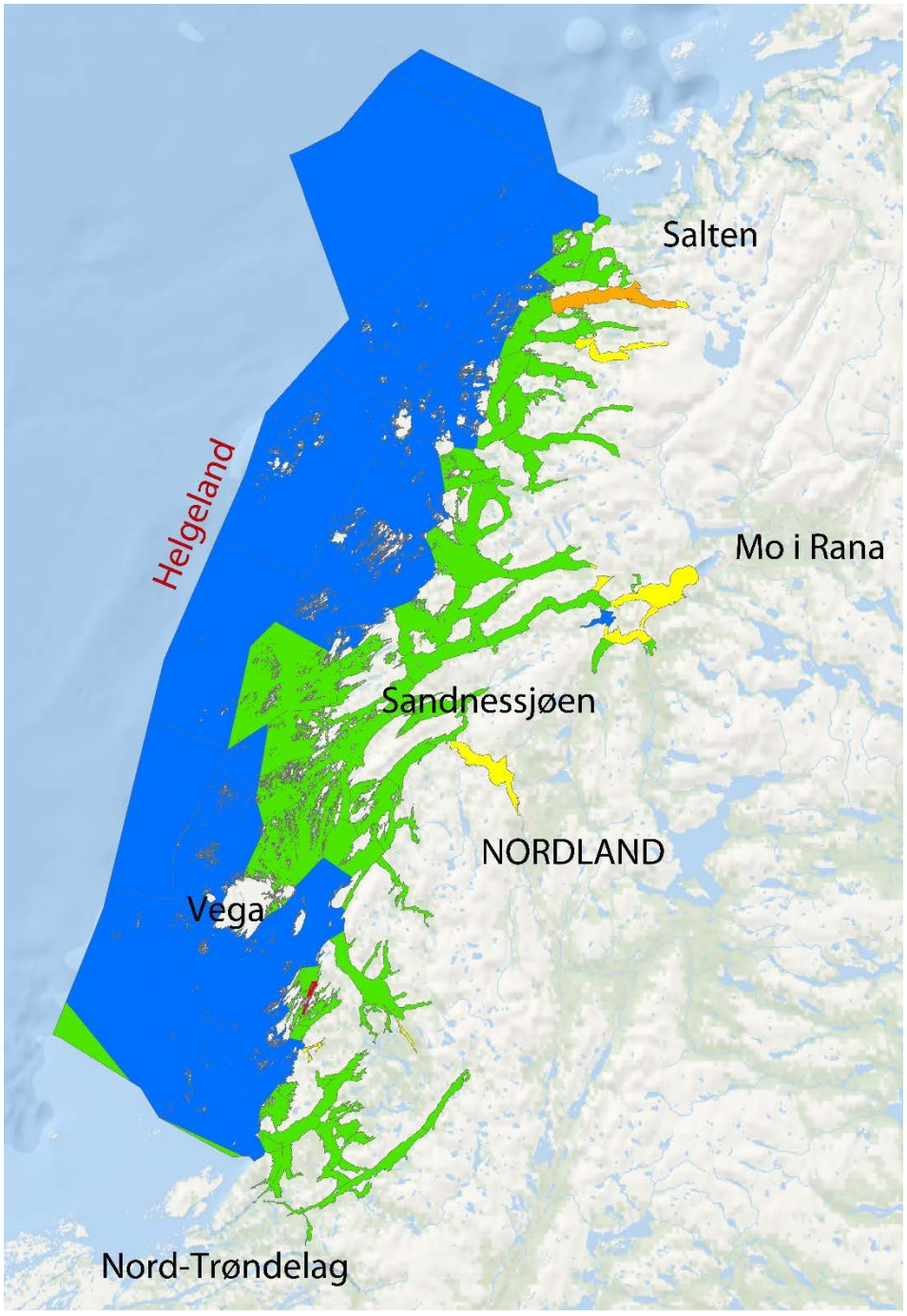
Seals are probably the most important mammals in the marine coastal ecosystems of Helgeland, feeding mainly on fish and crustaceans in areas where there is seaweeds and kelp. Eurasian Otter (*Lutra lutra*) and whales, such as killer whales (*Orcinus orca*), are also present, and may follow schools of herring along the coastline while foraging. Even minke whales and long-finned pilot whale (*Globicephala melas*) have occasionally been registered at Helgeland (www.biodiversity.no, 29.5.2017). Harbour porpoise (*Phocoena phocoena*), white-beaked dolphin (*Lagenorhynchus albirostris*) and the Atlantic white-sided dolphin (*Lagenorhynchus acutus*) are also relatively commonly observed in this area.

7.3.8 Ecosystem status

According to the Water Framework Directive, the ecological status of Helgeland is generally good. As much as 88% of more than 200 water bodies, and 99% of the total area, is classified as "Good" or "Very good" (fig. 73). The assessment applies to the benthic habitats as well as the pelagic environment (Directorate Group, 2013). Both physio-chemical and biological quality elements are included, of which some of the parameters also measure soft bottom biodiversity. In general, water bodies in the outer exposed sea are classified as "Very good", whereas closer to the coast and within fjords,

the status turns into "Good", "Moderate" and even "Poor" in a few cases. Areas with less than "Good" conditions are usually associated with eutrophication.

Figure 73: Ecosystem status in the Helgeland archipelago

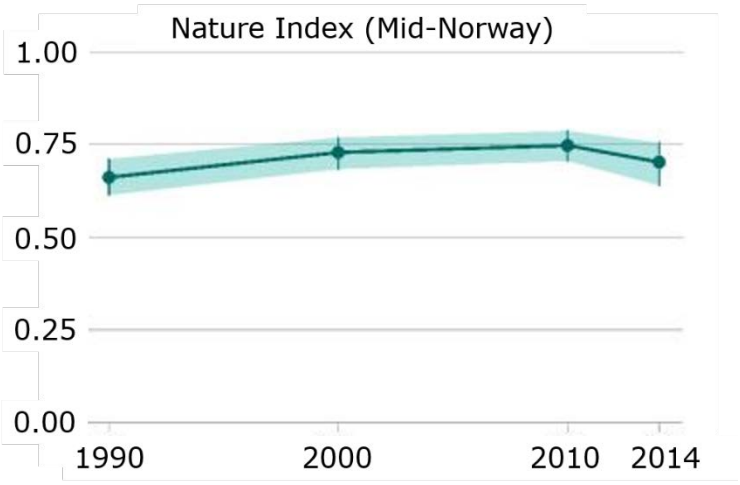


Note: Helgeland includes more than 200 water bodies in coastal waters, of which almost 90% of them are in Good (green) or Very good (blue) condition according to the Water Framework Directive. The last remaining conditions are Moderate (yellow), a few Poor (orange), and very few Very Poor (red).

7.3.9 *Status and trends in biodiversity and ecosystem function*

The Nature Index of Norway measures the condition of biological diversity in Norway and gives an oversight of the development of ecosystems for selected species groups and geographical regions. A report from 2015 (Gundersen *et al.*, 2015) divides the Norwegian coast into four different regions, and according to this index, there has been a steady improvement of the biodiversity in the coastal zone of Mid-Norway during the last 25 years (fig. 74). The index consists of many different indicators ranging from richness of phytoplankton to abundance of harbor seals.

Figure 74: The Nature Index of Norway calculated for the coastal seafloor and pelagic zone



Source: 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 (Araújo *et al.*, 2016).

Stocks of herring, cod and crab are reported to have declined in the last decade (Bakketeig *et al.*, 2015; Gundersen *et al.*, 2015). Estimated coastal cod population numbers are considered close to a critical limit and their decline seems highly linked to poor recruitment.

The European shag (*Phalacrocorax aristotelis*) population in central Norway is also strongly linked to kelp forests, especially during their nesting period. Recent studies (e.g. Bustnes *et al.*, 2013; Lorentsen *et al.*, 2015) show that many nesting parameters correlate strongly with the occurrence of young saithe. Changes in the kelp forest that affect the appearance of the youngest age groups of saithe, will therefore also likely affect the shag population.

Reforestation of kelp forests may have important positive effects on native populations and will certainly affect the species trends and biodiversity in a broader sense, by re-establishing habitats for a myriad of species of algae, invertebrates, fish, birds and mammals in the years to come.

Along with Atlantic puffins, several other red listed species are found in Helgeland (nine species of marine birds, eight species of fish and five marine mammal species according to the Norwegian Biodiversity Information Centre).

Bird populations in Helgeland have experienced large fluctuations in the last decades, with a few species in growth, but most of them in decline. Greylag goose has increased considerably along the entire coast during the last 20 years and is now a common species in Helgeland. Common eider (*Somateria mollissima*) was once very abundant and has been sustainably managed and exploited commercially through many decades (Chapter 7.6). The population has decreased markedly in Helgeland in recent years. Two other widespread duck species present also in Helgeland are common shelduck and red-breasted merganser. The trends in populations of these two species are uncertain (Shimmings & Øien, 2015).

In Helgeland, Atlantic puffin breed only on the island of Lovund. The population trend was negative for several decades, but in recent years there has been an increase in numbers. Razorbill (*Alca torda*) breed very sparsely in the region. Black guillemot is a rather common species, but suffers from predation pressures in areas where the American mink (*Neovison vison*) is present.

Several species of gull occur in Helgeland. Black-legged kittiwake (*Rissa tridactyla*) and lesser black-backed gull (*Larus fuscus*) have declined dramatically in Norway, including in Helgeland. There are now only a few colonies left of these two species in the area. The populations of great black-backed gull (*L. marinus*), European herring gull (*L. argentatus*), and common gull (*L. canus*) have also declined.

Both the European shag and great cormorant (*Phalacrocorax carbo*) nest along the coast of Helgeland, and after a period of increase, their populations are now presumed stable.

Peregrine falcon *(Falco peregrinus*) breed along the coast and have shown an increasing trend in population size. Previously, Eurasian eagle-owl was abundant in Helgeland, but is currently largely restricted to the municipality of Lurøy (Directorate for Nature Management, 2009; County Governor of Nordland, 2017). One of the reasons for its decline in the area is a reduction in the population of European water vole (*Arvicola amphibius*), which is its primary food source. Vole has declined largely in many areas due to predation from American mink.

7.4 Drivers and Pressures

Coastal habitats are among the most threatened due to the steadily growing human pressures from physical disturbance, fishing, pollution and nutrient input from terrestrial sources. A changing climate influence waves, water currents, water temperature, water acidity and transparency (e.g. UNEP, 2006), which may all drive biological changes at a global scale. However, compared to most Nordic and European coastal areas, the coastal habitats of Helgeland seem minimally impacted by local human activity, and are mostly influenced by the trends in global drivers. Drivers and pressures regulating biodiversity and ecosystem function and services in the Helgeland region are listed in Table 8. The drivers and pressures cause both short-term variability and long-term changes in biodiversity and ecosystem functioning, and are categorised as natural direct drives, anthropogenic direct drivers and anthropogenic indirect drivers (see Chapter 4 in Belgrano (Ed.), 2018). Selected drivers are described below, with particular focus on those regulating long-term changes in the ecosystem. However, the list should not be read as a complete list of the present drivers.

Table 8: Key ecosystem drivers of the Helgeland archipelago

Category	Ecosystem Services
Natural drivers	
	Weather and solar radiation
	Water physicochemical properties, incl. nutrients
	Major predator and prey species
Anthropogenic direct drivers	
	Fisheries and aquaculture
	Eutrophication and pollution
	Invasive species
	Climate change, incl. warming, ocean acidification and water darkening
Anthropogenic indirect drivers	
	Tourism
	Society development

7.4.1 Natural drivers

Natural drivers are independent of human activities. These include natural weather and climate patterns, physicochemical properties of water such as concentrations of inorganic nutrients, as well as natural prey- and predator pressures on key species. Also, natural extreme events such as big storms, landslides and major disease outbreaks are among the natural drivers that have formed ecosystems through time.

Temperature, light and the availability of inorganic nutrients are the main natural drivers in most ecosystems, shaping the biodiversity in the area, including that in Helgeland. Each year, when the sun light returns in the spring, solar radiation and nutrient availability fuels plants, microalgae and seaweed growth. With the growth of organic matter, more resources for ecosystems function and services are provided, e.g. for kelp harvest, fishing and hunting. As light, nutrient concentration and temperature show large annual and seasonal fluctuations, these natural drivers

impose large variability on key habitats and the species within them. In many ways, this natural variation complicates the assessment of anthropogenic drivers of long-term change to system biodiversity and ecosystem function (see Chapter 4 in the main report for details).

7.4.2 Anthropogenic direct drivers

Direct anthropogenic drivers are the consequences of human activities. These drivers have a *direct* impact on biodiversity and ecosystem function and services. They include marine construction and landscape modifications (e.g. harbors and marine fairways), boat traffic, mining, fishing, aquaculture and eutrophication on regional scales, while changing climate and pollution are drivers at a global scale.

Helgeland connects to the North-east Atlantic Ocean and major fish stocks migrate in and out of this coastal region. Over the past two centuries, overfishing has driven widespread declines of kelp forests along major parts of the Norwegian coast, through cascading effects on sea urchin and crab abundance (Araujo *et al.*, 2015). Whether this also is the case for the Helgeland region is unknown, but there are reasons to believe that over-fishing may be a part of the problem (Baden *et al.* 2012; Östman *et al.*, 2016; Andersen *et al.*, 2017).

Over 200 locations in the Helgeland region have licences for aquaculture and most of these sites are utilised, many for salmon production. Salmon farming is associated with several factors that may influence biodiversity and ecosystem function on both local and regional scales. The farms and connected infrastructure take up space and contribute to intensified boat traffic and human presence, which may disturb animal life locally. Furthermore, increased input of nutrients and organic matter to the marine environment may lead to increased sedimentation and eutrophication, which may also affect biodiversity and ecosystem function at larger scales. How and to what extent these different factors influence biodiversity and ecosystem function in Norway is not fully understood. Considering the national goal of future increases in sustainable aquaculture (Meld. St. 16, 2014–2015), there is a pressing need for a better grasp of these connections.

Helgeland is strongly influenced by the North Atlantic water currents and thus directly impacted by nutrient export and contaminants, including heavy metals, PCBs and micro/macro plastics, exported from western Europe and transported northward along the Norwegian coast with the coastal current (Gundersen *et al.*, 2016; Andersen *et al.*, 2016; Ferreira *et al.*, 2011; Borja *et al.*, 2013).

Seagrass ecosystems are threatened by human activity, including through the development of roads, bridges and harbour infrastructure along the coast. The response of seagrass ecosystems to coastal nutrient enrichment has shown to follow a "threshold pattern" when nutrient enrichment exceeded moderate levels, with a switch from positive to negative net leaf production. This shift is potentially driven by increased epiphyte load due to nutrient enrichment, which blocks light and reduces health of the seagrass leaves (Connell *et al.*, 2017). Effective management of land-

derived nutrient inputs from e.g. wastewater and agricultural runoff, could help to avoid threshold values being surpassed.

Invasive species have been reported in increasing numbers across the European and Nordic marine systems, with impacts on habitats and ecosystems, sometimes also with cascading effects (Katsanevakis *et al.*, 2014). One example is the introduction of American mink into the Norwegian fauna (in the 1920s) that has caused detrimental effects on local populations of sea birds. Since monitoring data on invasive species is virtually non-existent, very little is known about their expansion and impacts on the coastal systems of Helgeland.

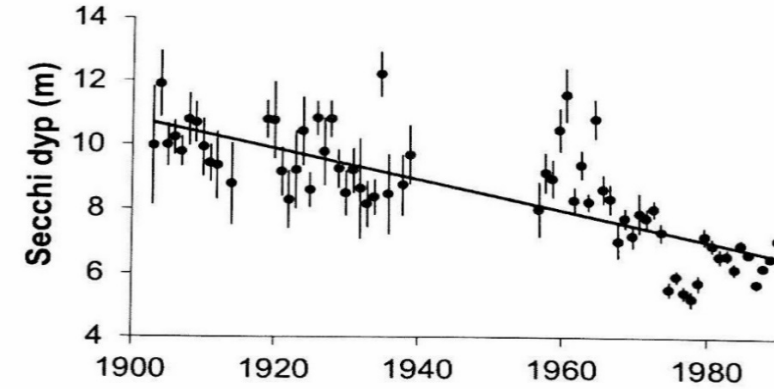
Climate change has, over the last few decades, led to pronounced changes to the marine ecosystem in Helgeland. Warming and changes in ecosystem function have, along with impacts from commercial fisheries, led to pronounced loss of kelp forest systems along the Norwegian Atlantic coast (Norderhaug & Christie, 2009; Wernberg *et al.*, 2010). In the 1970s, a nearly 2,000 km^2 area of kelp forest stretching from Møre on the Norwegian west coast to the Russian border, was completely grazed down by green sea urchins (*Strongylocentrotus droebachiensis*) (Box 11). This previously rich kelp forest ecosystem came to resemble a marine desert of barren grounds for decades. The mechanism behind the disappearance of the kelp forest is not completely understood, but the phenomenon is observed globally and has been prescribed to human impacts from fishing of predator species, eutrophication and poor resistance of kelp to changing environmental conditions (e.g. Ling *et al.*, 2015).

In recent years however, kelp forests have started reestablishing in the Helgeland region bringing back a rich kelp forest ecosystem with high biodiversity and ecosystem services (Box 11). The rise in seawater *temperature* may be part of the explanation, making unfavorable conditions for sea urchin larvae, with resultant decreased grazing pressure allowing for kelp forest recovery (e.g. Norderhaug & Christie, 2009; Rinde *et al.*, 2014).

The increase of pCO_2 in the atmosphere increases the concentration of inorganic carbon (including CO_2) in coastal waters. The consequence is a more *acidic underwater* world with direct, though variable, implications for the calcifying organisms that need to produce shells and skeletons (reviewed in Kroeker *et al.*, 2010). An increase in pCO_2 may also stimulate growth in kelp and other macroalgae and thus increased coastal primary production (Koch *et al.*, 2013). There is, however, no scientific consensus on this subject yet, as realistic experiments with elevated pCO_2 concentrations have shown complex to perform and interpret (Olischlager *et al.*, 2012; Iniguez *et al.*, 2016; Connell & Russell, 2010). The effects on ecosystems from ocean acidification are largely unknown. The application of ecological theory does however predict impacts on biodiversity and ecosystem function globally, with species interactions playing a major role in outcomes (Gaylord *et al.*, 2015).

Reductions in water quality from increased input of particulate and dissolved organic matter (POM/DOM) has continued during the last decade(s) leading to *ocean darkening* (fig. 75) (Dupont & Aksnes 2013; Aksnes *et al.*, 2009; Urtizberea *et al.*, 2013). Ocean darkening may affect photosynthesis (reduction in photon availability) as well as the behaviour of animals (reducing visibility) and physiology of both animals and algae (by changes in light cues).

Figure 75: Reduction in water transparency in the North Sea over the last century (measured as Secchi depth, which is the depth at which a specific black and white disk becomes invisible from the surface)



Source: Aksnes (2015).

7.4.3 Anthropogenic indirect drivers

Indirect anthropogenic drivers are the indirect consequences of human activities. These can be a consequence of how people and societies organise themselves and how they interact with nature at different scales. The effects can be both positive and negative. Examples are tourism, legislation, demographic changes and policies, along with economic-, technological-, and cultural developments. In Helgeland, examples of functional indirect drivers include all of these, however, little quantitative knowledge exists on the impact of indirect drivers on the ecosystem.

Ecotourism, a form of tourism involving visiting fragile, pristine and relatively undisturbed natural areas with focus on low-impact recreational activity, is popular in Helgeland (Chapter 7.2). Such activity is in line with the natural values of the area and the marketing of the landscape and pristine resources in the region. Among popular activities are kayaking tours, bicycle riding and hiking across the islands or inland mountain peaks, often with overnights in tents or small traditional boat houses (www.visithelgeland.com) (fig. 76–77).

Islands in Helgeland have been given the label "Sustainable Destinations" – a quality stamp given by Innovation Norway (www.innovasjonnorge.no) to destinations that work systematically to reduce negative impacts from tourism on the environment, along with to those who take care of nature, culture and guests.

Figure 76: Popular recreational activities are kayaking, bicycling, riding, hiking, fishing and hunting in Helgeland

Note: These ecosystem services are in principle indirect anthropogenic drivers, but attempts are made to impose minimal impact on nature and its ecosystem services through organised tours with a Sustainable Destinations trademark (www.innovasjonnorge.no).

Photo: KelpScotland.com ©.

Figure 77: Popular recreational activities are kayaking, bicycling, riding, hiking, fishing and hunting in Helgeland

Photo: KelpScotland.com ©.

Box 11: Kelp reforestation – climate impact on urchins, crabs and kelp growth

Since the early 1970s, more than 50% of kelp forests in the sheltered and moderately exposed areas from ~63 to 71°N have been grazed by green sea urchins (*Strongylocentrotus droebachiensis*, fig. 78). They have transformed the previous rich kelp forest areas along the Norwegian coast into marine deserts or so-called barren grounds (Sivertsen, 1997). The reason for this development is not fully understood, but might relate to both stochastic and cyclic events. However, in the last decade, a gradually northward recovery of kelp has been observed (Norderhaug & Christie, 2009; Rinde *et al.*, 2014). This recovery is partly *explained by the negative effects of warming on sea urchin recruitment* (Fagerli *et al.*, 2013) and to some degree from increased predation by northward expanding Cancer pagurus and Carcinus maenas crabs (Fagerli *et al.*, 2014).

Figure 78: Green sea urchins (*Strongylocentrotus droebachiensis*) on the seafloor between the remaining parts of kelp forest trunks (stipes) from the large Laminaria (*Laminaria hyperborea*)

Photo: Hartvig Christie/NIVA.

7.5 Governance of ecosystem services and influencing policies

In the water management plan for the Norwegian Sea (Meld. St. 35, 2006–2017), the coastal zone, which is 12 nautical miles beyond the low water mark, is considered an especially vulnerable area subject to external influences.

The management plan describes how the main source of pollution is non-local, involving borth air- and sea-born pollution. This is also assumed to be the case for the Helgeland coast. However, it is difficult to disentangle the impacts of local versus distant sources on ecosystem function and services. Therefore, management strategies aim to consider both distal and local sources.

Oil and gas activities in the Norwegian Sea create potential for oil spills with impacts on the coastline. Shipping along the coast, as well as further out at sea, causes emissions of combustion gases and creates potential environmental risks associated with shipping accidents.

Pollution from aquaculture is potentially increases the influx of nutrients and waste into rivers and the sea along most of the Norwegian coast. This subject gets increasingly more attention through, for instance, the H2020 TAPAS project and Norwegian Research Council funded KELPPRO project.

Anadromous fish, which live in both fresh and salt water, are exposed to a number of negative factors. In rivers and lakes these are mainly from hydropower developments and heavy loads of the parasite *Gyrodactylus salaris*. In the sea, escaped fish from the aquaculture industry may mix with wild fish and impoverish the natural gene pool. Farmed fish also contribute to the spreading of salmon lice (*Lepeophtheirus salmonis*), which are natural parasites in marine waters on the northern hemisphere that have caused reduced harvests in some places in Norway (Anon. 2017).

Fisheries have potential large-scale impacts on biodiversity through bycatch and overfishing. Lost fishing gear may drift or settle on the seafloor, continuing to catch animals, a phenomenon called ghost fishing. Hunting and marine mammals may also affect local populations and impact ecosystems in ways that may be difficult to foresee.

In order to maintain vital ecosystems along the coast, including those of Helgeland, it is important that primary producers, plankton, fish and bird populations are protected from negative impacts. This includes monitoring and managing nutrient inputs and pollutants from local activities, and assessing the impacts of kelp harvesting, recreational fishing and ghost fishing on local populations of important species, along with evaluating, improving and implementing potential management strategies.

Further measures may include reducing the risk for potential shipping accidents near the coast, from which large oil spills can have severe impacts on coastal communities. The same applies to reducing the risk of blow-outs and other accidents in oil and gas operations.

7.5.1 Influencing factors and policy

Norway has implemented the EU Water Framework Directive through the Water Regulation. The main purpose of the Water Regulation is to provide a framework for determining environmental goals that will safeguard the sustainable use of water resources. The Water Regulation covers all water bodies, from mountains streams, to fjords and out to one nautical mile beyond the low water mark. The regional water management plan for Nordland (including Helgeland) and Jan Mayen Island has been approved by the Norwegian Ministry of Climate and Environment. The regional water authority for Helgeland is Nordland County Council. Information about the Water Regulation in general, along with the Nordland water region in particular, can be found at www.vannportalen.no.

The fisheries represent some of the most important ecosystem services and natural resource providers in Helgeland. Fisheries are administered by the Ministry of Trade, Industry and Fisheries and its subordinate Directorate of Fisheries through the Marine Resources Act.

The Marine Resources Act applies to all living wild marine resources (whales, seals, fish, crustaceans, echinoderms, mollusks, snails, seaweed, kelp, etc.) and ensures that the resources belonging to the Norwegian society, are managed to secure sustainable and profitable exploitation in to the future. This includes preserving marine biodiversity and genetic material, as well as maintaining coastal communities through protecting coastal culture, traditions and employment. In essence, fishing for all stocks and

resources is permitted, but there are regulation-based limitations. Regulations apply to whom may fish, what methods may be used, quantities (quotas), in which time periods, as well as in which areas catch is allowed.

Following the reestablishment of large kelp forests in the southern parts of Helgeland a few years ago after 30 years of absence, the area has now been opened to one kelp trawling company. The company has been granted trial permits for harvesting that are conditional on surveys performed by the Institute of Marine Research in Bindal, Sømna, Brønnøy and Vega.

Fishing for anadromous species such as salmon, brown trout (*Salmo trutta*) and Arctic char (*Salvelinus alpinus*) both in salt water and fresh water, is administered according to the Salmon and Inland Fishing Act by the County Governor and the Norwegian Environment Agency. Fishing in rivers is mainly regulated by fishing seasons and stocks must be kept sustainable. River fishing is most commonly carried out in Vefsenfjorden (Vefsna) and Ranafjorden (Ranaelva).

In Helgeland, aquaculture is carried out lumpfish, mussels and for salmon harvesting and stocking. The practice is administered according to the Aquaculture Act by the Ministry of Trade, Industry and Fisheries and the Directory of Fisheries. Also, some aspects of permit application are delegated to the County Council. Permits are limited by national concessions for salmon and rainbow trout (*Oncorhynchus mykiss*), and all locations have to be approved by local authorities. Concessions are also controlled by the Aquaculture Act, the Harbour Act (Norwegian Coastal Administration), the Food Act (Norwegian Food Safety Authority) and the Pollution Control Act (the County Governor). Facilities for fish stocking are also subject to the Water Resources Act (Norwegian Water Resources and Energy Directorate, NVE – applies to land-based constructions).

Hunting is managed under the Natural Diversity Act and the Game Act. The administrative bodies are The Ministry of Climate and Environment and The Norwegian Environment Agency. The aim of the Natural Diversity Act is to sustainably uphold genetically viable species populations witin their natural distribution limits. Seal hunting is managed within and through the Marine Resources Act. While eider can be hunted in southern parts of the country, hunting eider is not allowed in Helgeland.

Important habitats associated with high biodiversity, like eelgrass meadows, softbed areas, kelp forests and shell sand areas, are largely administered by local authorities through the Planning and Building Act. Gravel and sand are resources that are managed according to the Continental Shelf Act and by the County Council.

The Vega islands have been placed on UNESCO's World Heritage list because of the eider and the millennia-old tradition of egg and eider down production (Chapter 7.6). Natural values are also managed in areas with protected area status according to the Natural Diversity Act, with either the local authority or the County Governor as the administrative authority.

Areas have also been secured for outdoor activities by being bought and secured for public use, pursuant to the Outdoor Recreation Act. The authorities are the County Governor and the Norwegian Environment Agency. The common right of access, pursuant to the Outdoor Recreation Act, ensures that people can go where they wish

at sea and ashore on uncultivated land all year and in farmed fields from 14th October to 14th April.

Development of wind energy is administered by the Ministry of Petroleum and Energy and its subordinate Norges vassdrags- og energidirektorat (NVE) according to the Marine Energy Act. Fifteen areas along the Norwegian coast have been identified as suitable for wind power production, including two in Helgeland: Træna West and Trænafjorden – Selvær according to the administration plan for the Norwegian Sea (Meld. St. 35, 2016–2017).

7.5.2 Past and present management

A coastal protection plan for Nordland was implemented in the 1990s. It involved the protection of valuable nature, land and marine areas through the creation of protected areas and nature reserves to best preserve the iconic coastal flora and fauna.

Work on a regional coastal plan for Helgeland is progressing, in which 13 local authorities have been asked to clarify local use. The purpose of the coastal plan is to regulate and facilitate the use of marine areas in Helgeland in terms of traffic, fishing, aquaculture, nature conservation, protection of cultural heritage, tourism and outdoor recreation. The regional council of South Helgeland is the responsible party.

A number of mammals and birds are being monitored along the Helgeland coast, including greylag geese, eagle-owls, golden eagles (*Aquila chrysaetos*) and otters. The County Governor has initiated a monitoring programme focusing on the salmon population and threat factors, including enhancing knowledge on the effects of aquaculture.

Rules on the minimum sizes for sea fish catch were expanded to also apply for leisure anglers with effect from January 1st 2010. Fishing for mackerel with hooks or nets, and for saithe for own use, are exempted from the rules for minimum sizes. There are also limits on the quantity of fish that can be taken out of the country by leisure anglers.

A national action plan for sea birds is expected to be ready in 2018, which will contain proposed measures against the continued demise of several species. Decimation of mink is one measure that may be enforced in protected areas, along with trials for reducing bycatch (of surface grazing birds such as fulmar, *Fulmarus glacialis*) by setting out bird scare lines.

7.6 Insights from indigenous and local knowledge

7.6.1 ILK in Helgeland "eider duck local knowledge"

Coastal communities are commonly dependent on fishing, but the Vega archipelago has a much more unique tradition. Already in the 9th century, the islands constituted an important centre for trade in down from common eider. Wild harvesting of eider down from nests has been a tradition all around the coastlines of Nordic countries, but the tradition in the Vega archipelago has been based on harvesting from almost semi-domesticated eiders (Andersson, 2001, p. 171). The UNESCO World Heritage Committee decided, based on its "cultural landscape based on cultural criterion", to accept the Vega archipelago as a World Heritage. In the decision, it is highlighted that the area qualified "based on the now unique practice of eider down harvesting, and it also celebrates the contribution made by women to the eider down process" (World Heritage Nomination and decision, WHC-04/28.COM/26 Paris, 29 October 2004, 14B.45). Beyond the down harvest, the Vega archipelago has had similar uses for local biodiversity as those of most Nordic coastal cultures. The cultural landscape is described in the nomination by the Norwegian government as follows:

> "This exposed seascape contains fishing villages with breakwaters, quays and warehouses, sites with eider houses where eggs and down were collected, the homes of fishermen-farmers with dwellings, outhouses, boathouses and islets where livestock grazed and hay was scythed, and navigational aids like lighthouses, lights and other beacons to aid seafaring in the perilous, foul waters. All told, these elements shaped by people relate a long history of use under exceptional living conditions controlled by the climate and the basis endowed by nature."
> (World Heritage Nomination and decision, WHC-04/28.COM/26 Paris, 29 October 2004, 14B.45, p. 5).

It was women who stayed on the outer isles of the archipelago and protected the female eiders while nesting in small eider houses. For centuries the inhabitants have gathered bladder wrack (*Fucus vesiculosus*), dried it and made nests in different driftwood shelters in small houses built of stones to attract female eiders. The eider tenders then chased away predators, like crows, ravens, gulls and foxes to gain the optimum amount of eggs, chicks, adult female eiders and primarily down. Even white-tailed eagle and Eurasian eagle-owl have been hunted for this reason for a long time – the latter species is still on the red list. The birds nest from May until late June, after which the tedious work cleansing the down from the impurities begins. High quality eider down has an extremely high price on the market, and has had so for at least a millennium. A duvet containing about a kilo of down from Vega costs approximately EUR 4,400.

The tradition was about to disappear in the 1990s due to depopulation and abandonment of the isles, leading to increased predator pressure on the bird population that resultantly decreased rapidly. Intense work documenting people's knowledge ensued and a pilot project on one of the isles to re-establish the eider

population was implemented. In 1997, a documentation and visitor centre was established in Nes on Vega ("The Nordland Ærfugllag", www.eiderducks.no).

The relationship between local communities and the birds did not only constitute a provisioning ecosystem service, i.e. eggs and down. It is often claimed that this symbiotic relationship also developed a sense of closeness and pleasure, and can thus also be described as a substantial cultural and spiritual ecosystem service. Previously, local women took time to tend the nesting birds, but today, volunteers also take part. It is possible to take a course in eider custodianship and learn more about the tradition, along with the management of eiders and down harvesting.

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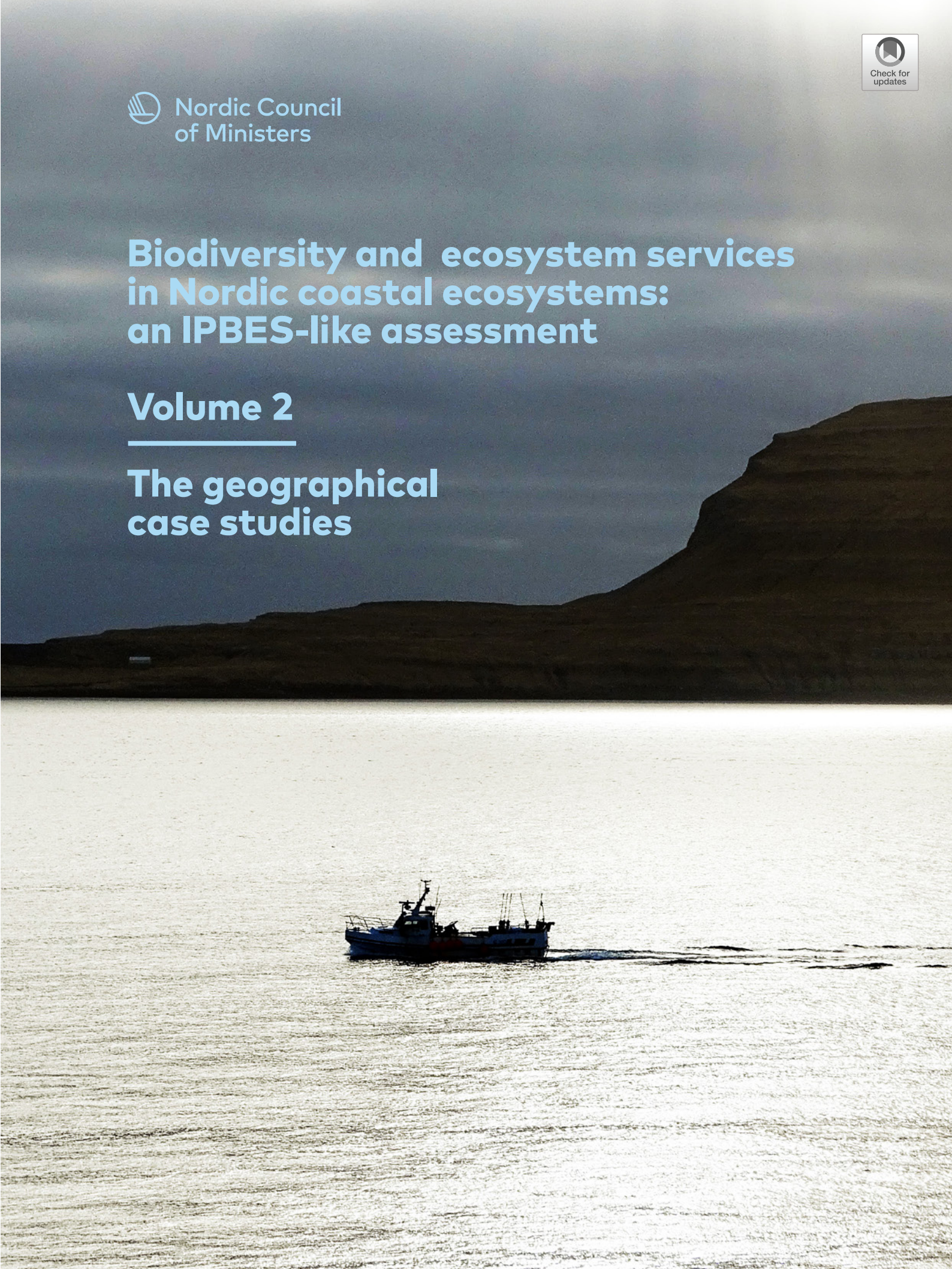

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Biodiversity and ecosystem services in Nordic coastal ecosystems: an IPBES-like assessment Volume 2. The geographical case studies

This report contributes to a Nordic IPBES-like assessment of biodiversity and ecosystem services in Nordic coastal areas. It is based on ten geographical cases in the Nordic countries (Denmark, Finland, Iceland, Norway, Sweden) and Faroe Islands, Greenland, and Åland. The purpose is to reflect upon local biodiversity and ecosystem services, e.g. status and trends, drivers of change and policies for governance, and what future we are to expect. The cases describe the situation in the Näätämö area, Kalix archipelago, Quark, Lake Puruvesi, Bay of Lumparn, Öresund, Helgeland archipelago, Faroe Islands, the northern coastline of Iceland, and Disko Bay. It stretches from fresh water areas to ecosystems in the Atlantic Ocean and from urbanised areas with heavy pressures on the environment, e.g. Öresund, to sparsely populated areas, like Greenland with a population of around 0.03 habitants/km^2.

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