Ecoregion Characterization for RACER Project - WWF

Ecoregions M46 and M47 – Northern Norway/Finnmark and Norwegian Sea

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DISCUSSION - NOTE

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Ecoregion Characterization for Racer Project - WWF

Ecoregions M46 and M47 – Northern Norway/Finnmark and Norwegian Sea

Summary:

Will be written after comments to the draft note.

Elaborated by: Ola M. Gausen and Leif Lillehammer	**Sign.:**
Controlled by: Leif Lillehammer	**Sign.:**
Responsible for contract/ dept.: Jannike Gry B. Jensen/ / Department for Environment	**Project Manager/ dept.:** Leif Lillehammer/ Department for Environment

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1. Introduction

WWF's International Arctic Programme is embarking on a new cutting edge project called RACER, a Rapid Assessment of Circumarctic Ecosystem Resilience. The results from this project are intended to help build awareness about those areas and features considered to be significant for building social-ecological resilience across the circumarctic (see Figure 1 for the boundaries of the circum arctic region) and that are likely to persist in future Arctic climate change conditions under different warming scenarios.

There is a growing concern that current conservation efforts may in future fail to achieve their goals, no longer safeguarding the natural values we are trying to protect. This has lead to the realization that conservation and planning approaches should be ecosystem-based (inclusive of humans) and focused on building resilience, if they are to be successful in helping us navigate through change. Given the rate at which we are racing to develop resources in the Arctic, there is also a need to provide interim products to inform what we can plan for and achieve in the short-term, while we simultaneously generate a deeper comprehension of what is required to fully build resilience in the Arctic. RACER takes a place-based approach to identifying features and areas important for building resilience, and seeks to assess at a very coarse level the vulnerability of these places to climate change. Fundamental to building resilience is maintaining function, and at the core of ecosystem function are the underlying bio-geophysical processes that support the continued expression of biological diversity, sustainable livelihoods for northern people, and ecosystem services for humanity.

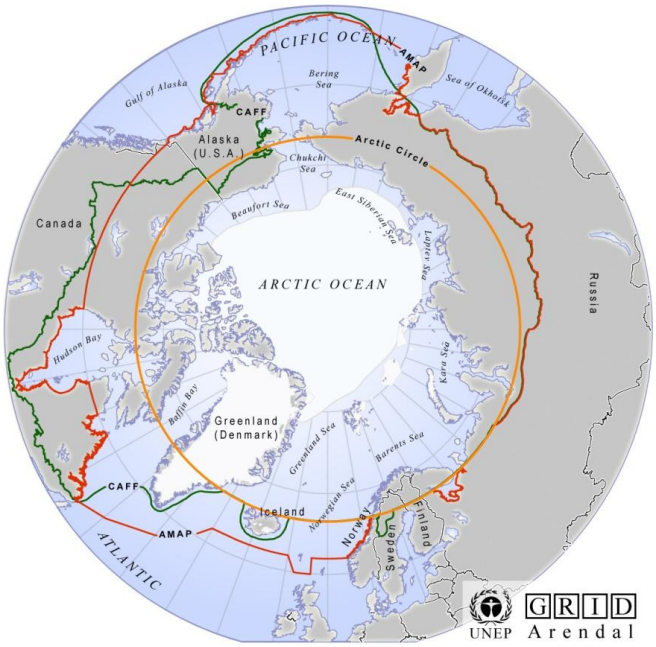

Figure 1. The Circum Arctic Region (the WWF ecoregions follows more or less the CAFF boundaries). Source: Grid Arendal.

For example, marine productivity is a fundamental process that supports the existence of higher order species such as marine mammals, and can be driven by such things as upwellings. There are several areas across the arctic where we can identify these spatially, but what is also important to know to better inform management of such areas is the features responsible for creating the upwelling phenomena itself. Highly productive areas can be driven by the meeting of thermal fronts driving nutrient rich bottom water up, or for example by ocean currents hitting against a topographic feature such as a shelf edge, pulling bottom water up.

Thus the focus of the RACER analysis is to identify the underlying drivers of key ecosystem processes, as these geophysical variables will be what is modeled into the future to determine how a system will respond to climate change, and how that will translate into the future biological expression found across the Arctic (WWF – RACER ToR 2010).

As a result of the above, WWF hired Sweco Norway to undertake the characterization of two of the ecoregions in the RACER programme, namely Northern Norway/Finnmark (M46) and Norrwegian Sea (M47). Focus of the work was to describe (i) Geophysical process-drivers-features; (ii) Ecosystem and biological features; as well as (iii) Socio-Cultural features. An important aspect for these two regions is that they are affected by human activity in some of the most densely populated areas in the arctic.

2. General characteristics of the Northern Norway/Finnmark and The Norwegian Sea areas

The Northern Norway/Finnmark Ecoregion (M46)

The ecoregion M46 stretches from the Northern Norwegian coast, and westward into the Atlantic Ocean. The shelf is approximately 300 meters deep near the coast, but goes down to depths up to little more than 3000 meters along the steep descending continental slope Eggakanten outside of Lofoten. The continental slope bends off north towards off the coast of Troms, making the border to the Barents Sea. Off the coast of Finnmark and the Kola Peninsula the area is less deep. The coast consists of many fjords along Lofoten and Finnmark. However, these fjords are much less frequent along the coast of the Kola Peninsula. Islands are frequent from Lofoten up to mid part of the Finnmark coast. No major riverine input are found in these areas, however several minor ones are found along the coastline and within the fjord systems. Sand, sediments and gravel dominates the bottom surface of the ocean floor in the region. Occasionally, hard rock surfaces can also be found. The costal Norwegian current goes northward, while the North Atlantic current brings warm saline water from the Norwegian Sea and into the Barents region making area M46 ice free all year around.

The Norwegian Sea Ecoregion (M47)

The borders of the Norwegian Sea vary in the literature[1]. Description given here is for the area covering WWF's ecoregion M47. M47 constitutes a narrow and shallow continental shelf (50-300 meters in depth), but is dominated by deep sea areas (down to 4000 meters). The average depth is 1800 meters. The Norwegian Sea is dominated by two basins: the Norwegian Sea Basin and the Lofoten Basin. The North Atlantic Current brings warm water through the Norwegian Sea, while the Icelandic East Current brings cold water from the Icelandic sea in the south-western parts of the area, making this part colder than the rest. Great variation in climate persist, both seasonal and annually, due to; (i) variations in temperature from the incoming Atlantic water; (ii) the amount of water input from Arctic waters from the west; and (iii) heat loss to the atmosphere. Warm Atlantic water also makes the Norwegian Sea ice-free throughout the year. Mixing of Atlantic water and costal water along the continental slope creates areas of water circulation, mixing and upwelling. The Arctic front, where warm Atlantic water meets cold Arctic water and creates upwelling varies in south-west, while it's more stable in the north.

The North Atlantic Current (NAC) and the Norwegian Coastal Current (NCC) are the two main features/drivers that interconnects geophysical and ecological processes between the two ecoregions (see also Figure 2).

[1] The area is much bigger for the management plan for the Norwegian Sea for example extending all the way down to the North Sea.

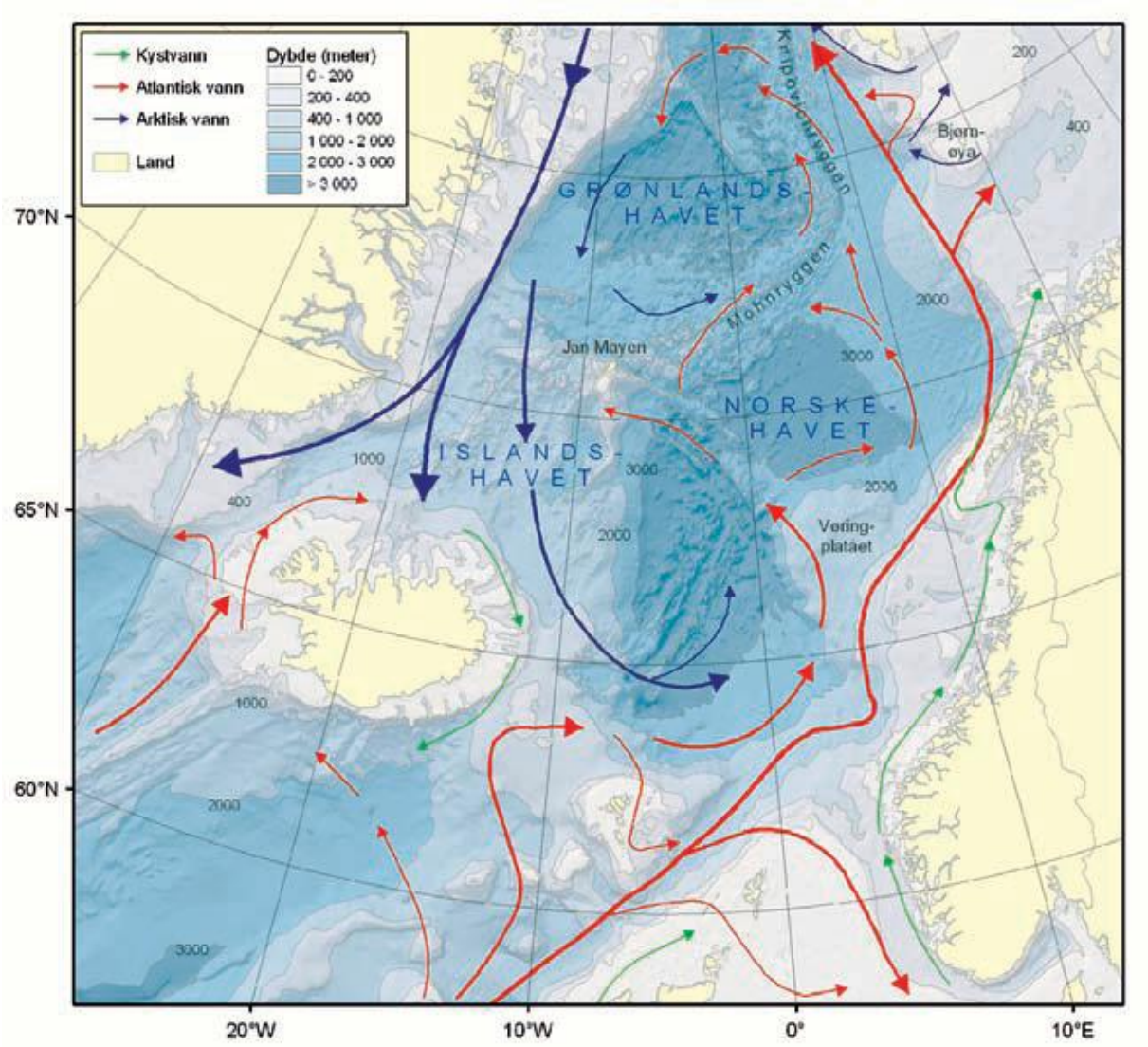

Figure 2. The main oceanic currents affecting the ecosystems in ecoregions M46 and M47 (from Stortingsmelding nr. 37 2007). (Green is the Norwegian Coastal Current, Red is the North Atlantic Current while blue is Arctic Water Currents).

3. Main Processes and Drivers

3.1. Northern Norway/Finnmark

Thermo Haline Circulation

Related to THC in the ecoregion the NAC brings warm water from south-west, while the NCC goes along the Norwegian coast from the south and along the Kola peninsula. Cold Arctic water can mix from North - North-East, however Arctic water does not reach the coastal parts (Sakshaug et al 2009).

P-E

The annual mean P-E is between -1 - 4cm. In winter this ranges between -2,5 to 3,5 cm, in spring -2 to 3 cm, in summer 0 to 4 cm while in autumn its between -1 to 4 cm. Highest P-E rate (4cm) is found at the Finnmark Coast. Generally in the marine areas the P-E is zero or negative, and positive along the coast. Lowest P-E is in the northernmost part of region M46 (Mid Barents Sea between Finnmark Coast and Svalbard) (Arctic Climate Research at the University of Illinois 2011)

Temperature

Temperatures from along the Finnmark coast and to mid northern coast of Kola peninsula, ranges between 3-7 at 100 m depth (Sakshaug et al. 2009).

Wind

During warm periods south-westerly wind conditions persist. During cold periods the wind is dominated by north-eastern arctic winds. The south-westerly winds follows an oscillation as follows: Low pressure in Barents Sea --> Westerly winds in the inflow area --> Increased Atlantic inflow --> Warmer water --> Increased heat flux from the sea --> Low pressure. This system stops under colder conditions, and high-pressure builds up in the Barents Sea (Sakshaug et al. 2009).

Nutrient inputs

Nutrient input mainly from NCC and the NAC. The NCC brings nutrients from the North Sea and from the Norwegian Coast. Nutrient inputs from aquaculture, agriculture, industry and municipal waste often exceeds the background levels. Some rivers also contribute, however good water exchange caused by 2-3 meter tidal difference, makes it very unlikely that the nutrient input can cause detectable local elevated nutrient concentration. The most important rivers are; Barduelva, Andselva, Pasvikelva, Alta River, Tana River (Finnmark) and Tulmoa (Kola). Phosphorus input is mainly from aquaculture (Lofoten-North Cape) being more than 5 times the background value (~175 tons/yr). From North Cape to the Russian-Norwegian border the background value is 200 tons/yr, and the aquaculture input is 175 tons/yr (Aure et al. 1997). Additionally, advection along the coast and shallow water caused by tidal and inwards/downwards currents causes nutrient input from deeper waters to pelagic zones

Topography

The M46 follows the continental slope in the east. This area of the slope has several marine canyons (10 large and several smaller). The continental shelf is relatively narrow in the Lofoten-Tromsø area (10-50 km) with depth down to 500 meter. The continental shelf sea floor is dominated by sediments, hard rock can also also be found, creating areas with a combination mountain hard rock, sand, gravel and large rocks in place of loose sediments. Important land forms on the shelf is moraine ridges, shallow marine valleys, sand waves, pockmarks, glacial ridges and ice mountain plow marks (Buhl-Mortensen et al. 2001).

Further east along the coast of Finnmark the area is relatively shallow, reaching 200 m very close to the coast and further off the coast its dominated by depths of 300-400. Nordkapp fish bank is the biggest fish bank northin the area. Sea floor sediments varies from sludge in trenches, to mud, sand, gravel av rocks on the most shallow banks. Some fjords can be found along the coast of Finnmark, while no fjords are situated along the coast of the Kola Peninsula. The M46 area along the Kola Peninsula has depths between 70-240 meters (MAREANO 2011).

3.2. The Norwegian Sea

Thermo Haline Circulation

TheNAC is a continuation of the North Atlantic Drift and brings warm saline water from the Gulf Stream. Coming in from between Iceland and the Faroe Island NAC goes through the main parts of Norwegian Sea in the upper layers and up to the Barents Sea where it meets cooler Arctic water. Heat transport is highest during winter when also the speed of the current is at its highest. The NAC is separated from the Arctic waters by the Arctic Front and Mohn Ridge. The NAC in the Norwegian Sea actually splits up in several branches. Two examples are the branches going towards Jan Mayen and The North Sea respectively. The main branch still goes up towards the Barents Sea (see also Figure 2).

The NCC, going northward along the Norwegian coast, brings colder, less saline water from the North Sea in the easternmost parts of M 47.

The East Iceland Current (EIC) transports cold saline water south from the Norwegian Sea towards Iceland and then east, along the Arctic Circle. Lastly the current flows north towards Jan Mayen. The description of the EIC here described refers to a "Norwegian Sea" with other border settings than used for the M 47 area. In this case the "Saline water south from the Norwegian Sea" is the east part of the M 36 ecoregion. The EIC may affect the position of the Arctic Front by the variations of volume of Arctic waters that the EIC transports between Iceland and Jan Mayen (Sakshaug et al 2009, ICES 2009, Blindheim 1986 and Norwegian Polar Institute 2011).

Cold and less saline deep water flows into the Norwegian Sea from the Greenland Sea, creating the Norwegian Deep Sea Water (>2000m). This is the main body of water in the Norwegian Sea and is relatively homogenous.

The warm Atlantic water makes the Norwegian Sea ice free throughout the year. However, sea ice from the Polar Sea can occasionally be transported by the Greenland Current together with sea ice mountains into the west Norwegian Sea (Sælen 2011). These occurrences are most frequent in April and least in September (Stortingsmelding nr. 37 2007).

P-E

The annual mean P-E in the ecoregion ranges between -1 to 2 cm. In winter its between -2 to 1 cm, in spring 0 to 3 cm, summer 0 – 2 cm and in autumn 0 to 3 cm. Lowest P-E rates are found in the north-eastern part of M47, bordering to M46, while the highest are found in south-western parts of M47, close to Iceland. (Arctic Climate Research at the University of Illinois 2011)

Temperature

The ecoregion has a 7 degree Celsius mean temperature in the water. It is further relatively cold in the south-west compared to the rest of the Norwegian Sea (Sakshaug et al. 2009).

Salinity

The Atlantic water upper layers have a salinity of 35.25 when entering the Norwegian Sea The Norwegian Coastal Current varies in salinity, but is generally low. The East Iceland Current has values between 34,7-34,9 (Blindheim 1985). The warm saline Atlantic water mix with less saline costal water south-east part of the sea (Stortingsmelding 37 2007).

Wind

South-western winds are associated with northward transport of heat into the Norwegian Sea (Sakshaug et al. 2009).

Nutrient inputs

There are no adjacent terrestrial/riverine sources in this ecoregion, so nutrient input is by the THC (Kuznetov 2005). Mixing at the arctic front releasing nutrients to the upper layers makes the foundation for the primary production in the area. Mixing of water layers also occur at the continental slope where coastal and Atlantic water meets. Where the warm Atlantic water meets cold arctic water we have the Arctic Front, which varies seasonally and annually. Ii is however most stationary in northern parts of the sea.

Topography

The area constitutes two major basins: the Norwegian Sea Basin and the Lofoten Basin with depth up to 3000-4000 m. The Vøring Plateau is found in the south east Norwegian sea, surrounded by deepwater. Shallower grounds are found closer to Iceland in the south-west and Jan Mayen in north-west. The sea floor dominated by sediments. The deep sea floor meets the steep continental slope in north-eastern parts of M47. The Norwegian Sea is separated from the Greenland Sea by the Mohn Ridge northeast of Jan Mayen, and to the

west by the Jan Mayen Ridge. Both ridges are about 2000m. The Continental slope has been included in M46 (Stortingsmelding 37 2009).

3.3. Interconnected processes and characterization of drivers

The main interconnected processes between the ecoregions are the THC constituting the North Atlantic Current, the Norwegian Coastal Current. These two currents also cross both ecoregions. Both of these currents are also affected by Arctic water currents. The two currents can be seen a prime/hub drivers for the ecoregions. Less clear is the picture of P-E in this region although there is a linkage between P-E and the THC as well. It seems that P-E however becomes more paramount as a prime driver along the coastline. Temperature, salinity, CO2 circulation and nutrient input can be seen as secondary drivers in the ecoregions as they largely are the effect of THC. Likewise wind is a secondary effect of the climate system that is largely driven by P-E. Sea bed topography however can be a main stationary “driver” that also affects especially the sea currents as well of a well of ecological drivers, including biodiversity.

4. Important Ecosystem Characteristics and Species – Keystone species and organisms in the areas

4.1. Northern Norway/Finnmark

Main underlying drivers for the ecosystems

As has been reported in the previous chapter the NCC has lower salinity and seasonal temperature variability than the NAC. The biological production is supposed to be highest in the areas where the sea currents meet, e.g. along the "fronts". Along with P-E these currents are the main underlying drivers in the system especially having huge impact on primary productivity. Secondary drivers are nutrient salts and CO2 in the water column giving energy to primary productivity. The sea currents are also transporting phytoplankton, zooplankton as well as eggs and larva of various organisms along the coast, thus contributing to and affecting the food web and its functions and services.

Primary productrivity and Phytoplancton

The primary production is medium high along most of the coast. Areas of very high productivity are bordering the Barents Sea region in the northernmost part. At average for the ecoregion PP rates (gC m-2 y-1) ranks relatively high. Overall median is 56.0 which is rank 3 of the 27 regions in the Arctic. Main phytoplankton taxa are diatoms, dino-flagelates and ciliates (ACTUS and WWF 2001, Stortingsmelding nr. 10 2009)

Important taxa

Benthic microalgae and macroalgae

Large areas of kelp forest dominate along the coast. *Laminaria* and Norwegian kelp is the most common. Transfer of carbon from water column to benthos affects these systems through pelagic-benthic coupling.

Aquatic macrophytes

Little or no information has been found related to this taxa.

Bacterioplankton

Dominated by Heterothtopic prokaryotes, e.g. bacteria and archaea (Sakshaug et al. 2009).

Zooplankton

Amongst herbivorous zooplankton *Calanus* spp. And copepods are numerous (Forsgren et al. 2009). Amongst carnivourus zooplankton *Paruchaeta norvegica* and *Medridia longa* are common. Krill are also numerous in the area (Sakshaug et al. 2009).

Ichthyoplankton

Eggs/larvae of various fish species but especially capelin dominates in the northernmost part (Hjermann et al 2009).

Benthos

Numerous sponge, cold water coral reefs and sea pen communities can be found along the coast and continental shelf. The coldwater coral reefs are an important ecological driver for biodiversity by creating diverse habitats for other species. Besides this they play a role in the CO2 balance in the ocean, through the carbonate - lime formation process. Amongst large crustaceans king crab, *Chionoecetes* and deep water prawn are common. King Crab and Ciniochetes are newly introduced specie to the area.

Fish

The area is characterized by north east arctic cod, herring and capelin and their trophic interactions during especially spring/summer. Other important species are haddock, herring, spotted wolfish and Greenland halibut. The capelin is a keystone species in the system and with the cod and herring their population dynamics are an important ecological driver in the area. The three species - capelin, cod and herring - are strongly interlinked through processes of predation, competition and cannibalism (Hjermann et al. 2009). See also Figure 3 and 4.

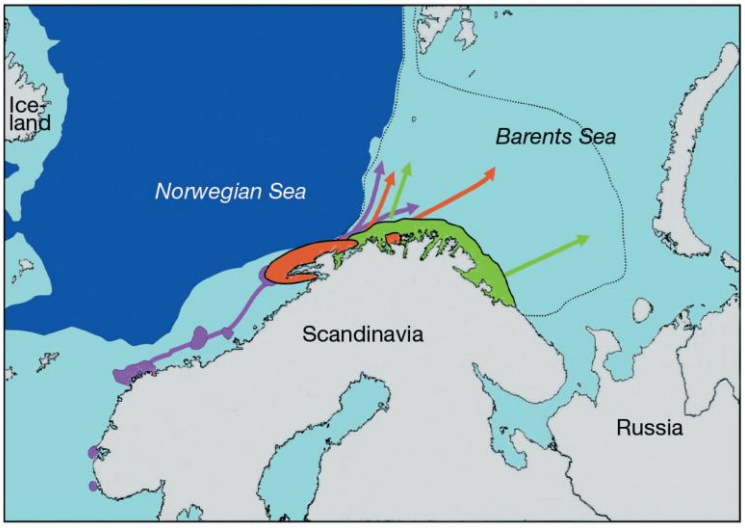

Figure 3. The Lofoten–Barents Sea cod-herring-capelin dominated system with spawning locations and advection routes of eggs and larvae of 3 fish stocks; red: North-east Arctic cod; purple: Norwegian spring-spawning herring; green: capelin (Aglen et al. 2005). Dotted line: maximum extension of the 3 species in the Barents Sea in the first summer following spawning. Light blue: continental shelf (<250 m); dark blue: deep sea. Larvae and eggs drift passively with the Norwegian Coastal Current (NCC), which runs northwards to the Barents Sea at depths down to 150 m. Further offshore and parallel to it runs the Norwegian Atlantic Current (NAC), a branch of which enters the Barents Sea. From Hjermann et al. 2009.

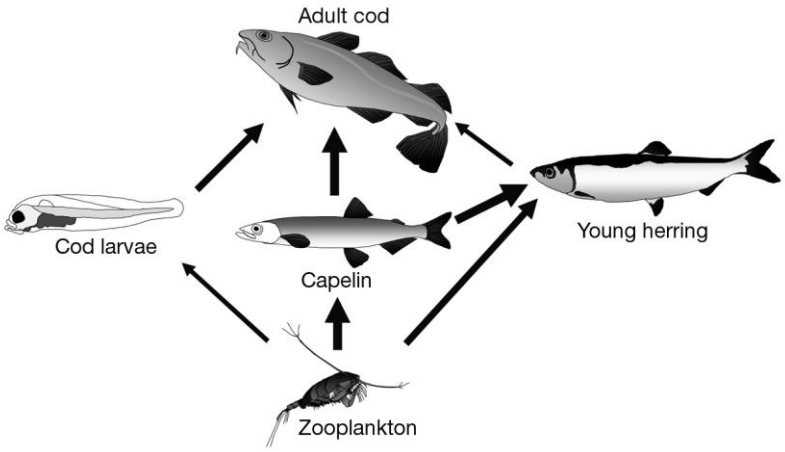

Fig 4. Trophic relationships between the main components of the food web, including cod cannibalism (From Hjermann et al. 2009)

Marine mammals

The marine mammals in the area constitute harbor seal, grey seal, white whale, narwhal, white beaked-dolphin and harbor porpoise. All these mammals are found along the coastline. The great whales and dolphins also use a wider area. The presence of capelin, herrings and krill are important ecological driver for sea-mammals and their migration (Sakshaug et al. 2009).

Marine Birds

The most common marine/sea birds in the area is; common murre, Atlantic puffin, yellow-billed loon, tystie, common eider, cormorant spp., black guillemots, guillemots species, little auks, northern fulmars and glaucous gulls. Variation in fish populations affects the seabird populations, e.g. like the Atlantic Puffin. There is a huge variety of identified valuable sea-bird populations along the whole coast of M46 (Stortingssmelding nr. 10 2009). Especially the presence of juvenile herring (0+) is a key ecological driver for the sea-bird population including the more coastal dwellers (Anker Nilsen et al. 1997, Barret et al. 2006 and Sandvik et al. 2005.).

4.2. The Norwegian Sea

Main underlying geophysical drivers

The NAC mainly arrives the area between Faroe Islands and Iceland and spread in the Norwegian Sea. In the southern part of the Norwegian Sea more cold and less salty water also enters from the Iceland Sea. The biological production is supposed to be highest in the areas where the sea currents meet, e.g. along the "fronts", e.g. NAC-EAC and NAC-NCC for the Norwegian Sea. Along with P-E, these currents are the main underlying drivers in the system especially having huge impact on primary productivity. Secondary drivers are nutrient salts and CO_2 in the water column giving energy to primary productivity. As for ecoregion M46 the sea currents are also transporting phytoplankton, zooplankton as well as eggs and larva of various organisms in and out of the Norwegian sea, thus contributing to and affecting the food web (Stortingmelding nr. 37 2007).

Primary productrivity and Phytoplancton

The primary production is medium high in the open ocean, whilst high productivity can be found along the continental coast and shelf and Jan Mayen (ACTUS and WWF 2001, Stortingsmelding nr. 37 2007). At average for the ecoregion PP rates (gC m-2 y-1) ranks relatively high. Overall median is 44.1 which is rank 5 of the 27 regions in the Arctic (Actus and WWF 2011). Diatoms are the most important taxa together with, dino-flagelates, flagelates and coccolithophores (Forsgren et al. 2009).

Important Taxa

Benthic microalgae and macroalgae

Large areas of kelp forest are found along the continental shelf. *Laminaria* and Norwegian kelp is the most common. Transfer of carbon from water column to benthos affects these systems through pelagic-benthic coupling.

Aquatic macrophytes

Little or no information has been found related to aquatic macrophytes in the Norwegian Sea.

Bacterioplancton

Dominated by heterothtopic prokaryotes, e.g bacteria and archaea.

Zooplankton

Amongst herbivorous zooplankton *Calanus* spp and Copepods are numerous (Forsgren et al. 2009). Krill are also numerous in the area. These crustaceans are important link to higher trophic levels. The Norwegian Sea is considered to be the center of production of *C. finmarcus* (Forsgren et al 2009, Melle 1998, Dalapado et al. 1998).

Ichthyoplankton

Eggs/larvae of herring are dominant. The area also constitutes huge amounts of jellyfish. Dalapado et al. 1998 found that the total summertime biomass of the jellyfish *Periphylla periphyla* in the Norwegian Sea was 11 million tones.

Benthos

Sponge and cold water coral reefs are numerous along the continental shelf. Others benthos taxa constitute; bryozoa, serpulidae, mussels, enchinoderms and polychaeta. The coldwater coral reefs are an important ecological driver for biodiversity by creating diverse habitats for other species. Besides this they play a role in the CO_2 balance in the ocean, through the carbonate - lime formation process. Still a lot of research is needed regarding knowledge about the cold water coral reefs, and sponge areas function in the ecosystem (Stortingsmelding nr. 37 2007).

Fish

The Norwegian Sea is characterized by migratory pelagic species, e.g. herring and blue whitting. Other important species constitute; pollock, mackerell, cod, haddock, rose fish, deepwater redfish, Greenland halibut, greater argentine, lings, cusk and Atlantic salmon. As a keystone species the production and migration of the herring is a key ecological driver for the presence of other species in the Norwegian Sea.

The Norwegian Spring Spawning herring is the world's largest herring population and is the dominating fish species in the Norwegian Sea (Stortingsmelding nr. 37 2007). Post smolts of Atlantic salmon are migrating into the Norwegian Sea on their way to the feeding grounds in the Nordic Seas and West Greenland. These areas are the most important feeding grounds for the species (Haugland et al. 2006).

The European flying squid is an important prey for sea mammals and some fish species in the Norwegian Sea. Juveniles that live close to the surface are also preyed by sea-birds. It was earlier commercially harvested, but the population has seriously declined over the years.

Marine mammals

Marine mammals in the area constitute blue whale, fin whale, humpback whale, northern mink whale, sperm whale, northern bottlenose whale, porpoise, killer whale, grey seal, harbor seal, Greenland seal and hooded seal. The blue whale, fin whale, humpback whale, northern mink whale migrates through the area. The sperm whale and northern bottlenose whale can be found along the edge of the continental shelf. Porpoise and killer whale are common along the coast. Amongst the seals grey seal and harbor seal are common along the coast whilst Greenland seal and hooded seal are common around Jan Mayen (Stortingsmelding nr. 37 2007).

Marine Birds

The most common bird species in the Norwegian Sea are common mure, Atlantic puffin, northern fulmar, lesser black-backed gull , the black-legged Kittiwake , the great cormorant, European shag and common eider. The northern part of the Norwegian Sea is an important foraging area for North Atlantic bird species that breeds further north or east. Other species stay overwintering here; some migrate through the area, whilst other might stay most of the year. The most important breeding areas is Jan Mayen, since Runde and Røst falls within M46 (Stortingsmelding nr. 37 2007).

5. Areas of Specific Biological Importance

The following areas of biological importance in M46 and M47 have been identified in Stortingsmelding nr. 10 (2009) and Stortingsmelding nr. 37 (2007) that falls within the ecoregions M46 and M47.

5.1. Northern Norway/Finnmark

Tromsøflaket bank area including Eggakanten.

This is a bank area at the edge of the continental shelf. It is an important area for juveniles of herring and larvae and juveniles of cod and haddock. It is furthermore important spawning grounds for spotted wolffish. There are important sponge communities in the area which is also habitat for fish. Cold water coral reefs are found at the edge of the bank which constitute areas of high biological diversity (Stortingsmelding nr. 10 2009).

The main geophysical driver along Tromsøflaket and Eggakanten is the fact that it is the frontal zone between the NCC and the NAC, thus a lot of circulation, mixing and upwelling of water occur in the area. Eggakanten is partly within M46 and M47.

Lofoten - Røstbanken - Vesterålen.

This area (see also figure 5) is winter habitat for herrings, seabirds (especially coastal species) and killer whales. During spring its important spawning areas for Norwegian arctic cod and haddock, and at Røstbanken the herring spawns. During summer the area is important breeding area for various fish, sea birds and sea mammals. Lofoten is further an important area of *Calanus Finmarchus* production. At the edge of the continental shelf there are large areas of cold water coral reefs. As late as in 2003 the (so far) largest reef in the world was discovered just south of Lofoten, the Røst reef, covering ca 100 km^2.

The areas of Røst, Værøy and Bleksøy constitute large breeding colonies of seabirds like common murre and Atlantic puffin. Around Røst there are important breeding grounds for yellow-billed loon, tystie, common eider and various cormorant species.

As for Tromsøflaket area the main geophysical driver along Lofoten - Røstbanken-Vesterålen is the frontal zone between the NCC and the NAC, thus a lot of circulation, mixing and upwelling of water occur in the area.

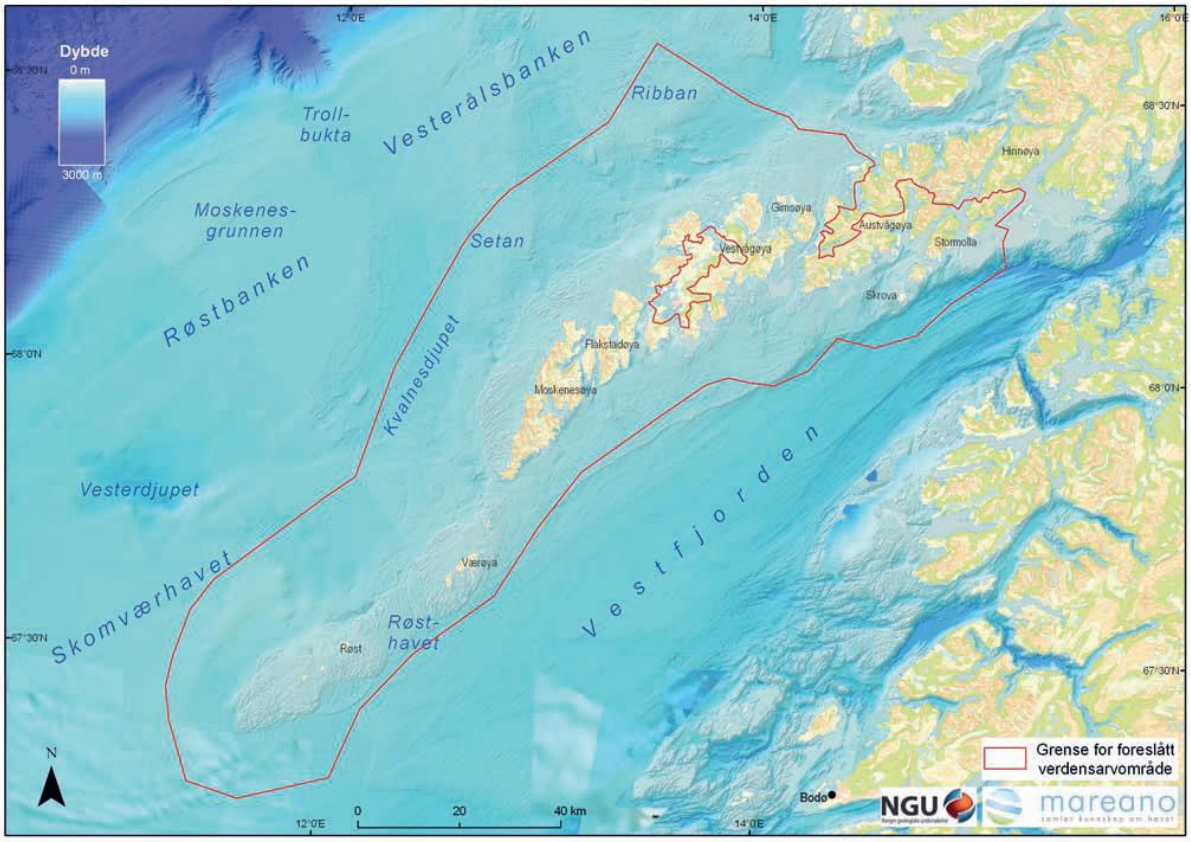

Figure 5. Proposed Nature Conservation site in the Lofoten - Røstbanken – Vesterålen area.

Coast of Finmark and Northern Troms counties.

These are important spawning areas of capelin, as capelin normally demands relatively shallow breeding grounds (20-75m), from Vesterålen in Troms to east of the Murman Bay, starting in March (see also figure 3 and Chapter 4.1). The larva and juveniles are transported by currents back to the Barents Sea in late spring and summer. Kongsfjorden, Varangerfjorden in Finmark and Tromsø-Balsfjorden important breeding grounds for coastal bird colonies. Besides capelin the area is also important for spawning and eggs of north east arctic cod, haddock and herring (extends naturally from the Lofoten-Vesterålen area (Stortingsmelding nr. 10 2009).

Main geophysical driver along large parts of the area is the fronts between NCC and NAC leading where mixing, circulation and upwelling also takes place. Nutrient input from rivers can be locally important along the fjords and near shore areas.

Main drivers for algal blooms are inshore by precipitation, offshore by wind (Sakshaug et al. 2009).

5.2. The Norwegian Sea

Eggakanten

This area constitute the areas along the edge of the continental shelf, and is partly also within M46. The area is highly productive, high in fish and sea-bird diversity and constitutes also quite a number of cold water coral reefs. It is high concentrations of zooplankton in the area and thus also an important area for baleen whales. The area constitute also important spawning grounds for deep water fish species like rose fish , deepwater redfish, Greenland halibut and greater argentine. It constitutes also important areas of cold water coral reefs and sponge communities (Stortingsmelding nr. 37 2007).

The main geophysical driver along Eggakanten is the frontal zone between the NCC and the NAC, thus a lot of circulation, mixing and upwelling of water occur in the area.

Jan Mayen

Jan Mayen is at the western fringe/edge of M47, but is included as part of it in this study due to its high biological importance. Its huge bird colonies (more than 300 000 breeding couple) also largely utilize the Norwegian Sea Area. There are huge colonies of northern fulmar, little auk, thick -billed murre and black-legged kittiwake in the area. The area has also high production and large densities of zooplankton, fish, sea-birds and sea-mammals (Stortingsmelding nr. 37 2007).

Jan Mayen is in an area where the NAC meets the southward East Greenland Current. This leads to circulation, mixing and upwelling of water that leads to high primary productivity giving basis of huge numbers of zooplankton and further in the food web, fishes, sea-birds and sea mammals (Stortingsmelding nr. 37 2007).

Other areas

The Coastal Zone, Mørebanken, Haltenbanken and Sklinnabanken and Sularevet and Iverryggen is part of "Helhetlig Forvaltningsplan" for the Norwegian Sea but is not within the boudaries of the WWF ecoregion. Furthermore, the deepwater areas of the Norwegian Sea are largely uninvestigated and thus knowledge about areas of biological importance.

6. Socio-Cultural Aspects

The socio-cultural aspects of these two ecoregions have been found to be largely inclined to commercial issues and less to cultural. Only harvest of Atlantic salmon at sea undertaken by the indigenous Sea-Laps (“sjøsamer”) has a cultural (as well as economic) aspect with it.

6.1. Northern Norway/Finnmark

The total value of the fisheries along coast of Finnmark, Troms and Nordland has been estimated to be about 5 billion NOK per year. From various fisheries places along the coast the following species are harvested (Helhetlig Forvaltningsplan for Barentshavet og Områdene rundt Lofoten 2009).

- Commercial fishing of ocean migratory cod ("skreifiske") and resident cod - (i) Lofoten - Tromsøflaket, January to April. (ii) Vest-Finnmark/Troms/ Vesterålen, November to April (iii) Coast of Finnmark, March to June.

- Commercial fishing for haddock - Coast of Finnmark, summer and fall.

- Commercial fishing for saithe (i) Line-fishing; (ii) Trawl - (i) Vest-Finnmark - Lofoten, September to January, (ii) Vest-Finnmark and Troms. Summer and fall.

- Commercial fishing of Grenland halibut - Along Eggakanten, June to August

- Commercial fishing of capelin - Winter fisheries in the Barents sea and along the coast of Finnmark and Troms in January and April.

- Commercial fishing of herring - Lofoten-Vesterålen-Ofotfjorden, September to February

- Commercial fishing of king crab, snow crab and deep water prawns - King crabs are caught mainly in fjords and along the coast in Øst-Finnmark, October to September (Sakshaug et al. 2004, Magnussen et al. 2009)

- Only Harp Seals and Mink Whales are harvested commercially in the Southern Barents Sea. Illegal hunting for other seals are occurring due to conflict with fisheries, etc (Sakshaug et al. 2009).

- Harvesting of Atlantic Salmon in the Sea. Undertaken in Finnmark and Troms by the Sea-Laps. Cultural and economic value (Borch et al. 2009).

- Leisure fishing, whale safari and bird hunting/peaking. Leisure fishing in all fjord systems along the coast, whale safari especially around Lofoten (Magnussen et al 2009).

6.2. Norwegian Sea

In 2007 the fishing fleet in Nordland, that are amongst them who utilize the Norwegian Sea constituted 3183 persons, whilst the associated fish industry at land constituted 2246 persons. The fishing fleet and associated industry are found along the Nordland County that is adjacent to M47. The most important commercial fishes are herring, blue whitting, cod, haddock, mackerel plus salmonid aquaculture species. The overall value of the fisheries plus aquaculture constituted close to 2,5 billion NOK in Nordland in 2005 (Sakshaug et al. 2009, Forsberg 2009, Stortingsmelding nr. 37 2007).

Harvesting of wild Atlantic salmon has been banned at sea (exempt for the Sea-Laps), although there are some indications that some Atlantic salmon are caught as a result of other fishery. NASCO is the main management unit for this species (Sakshaug et al. 2009, Haugland 2006, Stortingsmelding nr. 37 2007).

7. Summary of main drivers in the two ecoregions

Since the focus of the study has been on finding the main drivers in the two ecoregions and its associated biological characteristics the following table is an attempt to sum it up in an hierarchical manner. The two ecoregions are especially interconnected due to the THC and especially related to the NAC and the NCC.

Drivers/Features/Characteristics	**Ecoregion M46**	**Ecoregion M47**
Main Geophysical Driver(s)	1) THC: NAC and NCC 2) P-E 3) Topography	1) THC: NAC, NCC and EIC 2) P-E 3) Topography
Secondary Geophysical Drivers	1) Nutrient transport/ circulation 2) CO_2 circulation 3) Wind and temperature	1) Nutrient transport/ circulation 2) CO_2 circulation 3) Wind and temperature
Main Ecological drivers	Primary production *Calanus finmarcus* and krill production. Trophic interactions of cod-herring and capelin	Primary production *Calanus finmarcus* and herring production

For both ecoregions the THC is seen as the most important driver with its main features of NAC and NCC in M46 and NAC, NCC and EIC in M47. The seabed topography affects all these currents however the driver is stationary per se. The THC has profound impact on the nutrient and CO2 circulation in the systems while P-E has impact on wind and temperature. Lastly the two ecoregions are somewhat different related to the main ecological drivers. The M46 region is and its biological characteristic is besides primary production largely affected by *Calanus finmarcus* and krill production that affects higher trophic levels as well as the trophic interaction between cod-herring and capelin. The higher trophic levels in M47 are however largely affected by *Calanus finmarcus* and herring production as these are keystone species in this system.

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