Chapter 5. Environmental impact of oil and gas activity in the Arctic

This chapter presents detailed information on the special ecological features of the Barents region. The ecosystem structure in the northern seas is examined and food chain models are outlined. The chapter also discusses the increased vulnerability of the biota in the event of emissions of oil and petroleum products into the marine environment.

The chapter recounts how oil and petroleum products impact directly on living organisms and their vital activities and includes detailed description on environmental impact on birds, mammals and fish during various stages of their development. A list of the key areas for preserving bio resources in the Arctic shelf region is also provided

The readings of this chapter also include two articles in the appendix (number V-i and V-ii) about the Barents Sea written by Dr. Cecile H. von Quillfeldt. The articles *Special ecological features of the Barents Sea* and *Vulnerable areas* were first published in OTTAR nr. 260/ 2006, the journal of the University Museum of the University in Tromsø, Norway. Bellona is grateful for the permission to translate and reprint these articles. We also recommend to study in depth appendix V-iii. *Consequences of a large oil spill in the Arctic.* All this readings are advised as complementary reading to this chapter. We also remind the reader of appendix III *Climate Change.*

All the information presented in this chapter is accompanied by reference data, opinions from specialists, legal notes and illustrations.

5.1. The Barents Sea

This report will use the example of the Barents Sea to show the vulnerable nature and ecosystem of the Arctic. The reason for this is twofold, the Barents Sea is the most productive, and therefore most valuable in terms of resources, of the Arctic Seas. Secondly, in the Norwegian part of the Barents Sea, offshore oil and gas activity has come longer than in northwest-Russia. The Snow White field, operated by Statoil, is supposed to start exporting LNG in 2007. The Barents Sea is also the sea in the region which has undergone most research and monitoring.

The Barents Sea is situated in the boarder region of Norway and Russia. The Sea goes from the Norwegian coast to Spitsbergen in the west, and to Novaja Zemlja and Franz Josef's land in the East. The sea is shallow, the average deep is only 230 meters. More than 300 species of micro algae are registered in the Barents Sea. There are about 150 fish species, the most important commercial fish is cod, capelin and herring. Different types of top-predators such as seal, whale and ice bear are also important species in the Barents Sea.

5.1.1 The structure of the Barents Sea ecosystem

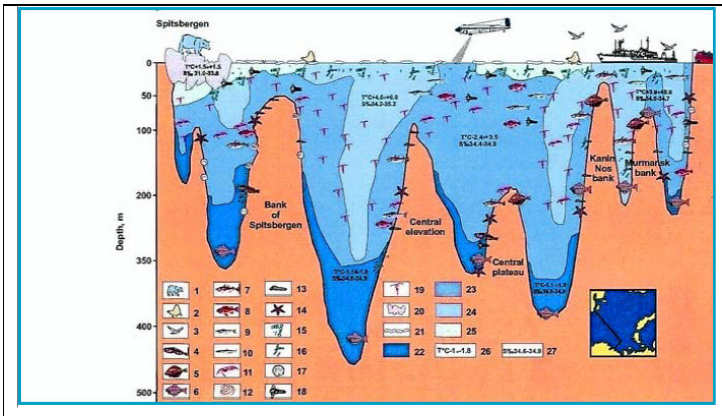


Fig.3 Ecosystem structure of the Arctic shelf (Barents Sea)[1]

Habitats:
1. Polar bear;
2. Marine animals;
3. Birds;
4. Atlantic wolffish;
5. Plaice;
6. Halibut;
7. Cod;
8. Perch;
9. European salmon;
10. Capelin;
11. Shrimps;
12. Scallops;
13. Polychaetes;
14. Starfish and brittle / basket stars;
15-16. Diatoms and protozoa;
17. Sea urchins;
18. Sea butterflies;
19. *Calanus* and *Copepoda*.

Other symbols: 20. Icebergs; 21. Sea ice; 22. Near-bottom Arctic waters; 23. Coastal waters; 24. Atlantic waters; 25. Arctic waters; 26. Barents Sea waters; 27. Salinity of the water.

[1] *"Ecosystems and biological resources of Russian European seas at the turn of the 21st century", G.G. Matishov, V.V. Denisov - Russian Academy of Sciences, Kola Scientific Centre, Murmansk Marine Biological Institute, Murmansk, 2000.*

5.1.2 Food chain models in the Barents Sea ecosystem

The biodiversity convention of 1992 defines an ecosystem as "a dynamic complex of plants, animals, and microscopic organisms interacting with each other and the non-leaving environment they live in". The functioning of every ecosystem is based on links between its organisms. The durability of these links determines the stability of the ecosystem. In an ecosystem all species of living organisms are linked to one another and disturbing one of them can create an imbalance in the system as a whole.

In the Barents Sea, biogenic materials (phosphorous, nitrogen, carbon, silicon, iron, manganese, cobalt, zinc and others) in the sea water form the basis for reproduction of primary organic material. Phytoplankton consumes these biogenic elements and absorbs the sun's energy, converting it into energy comprising chemical bonds of organic substances.

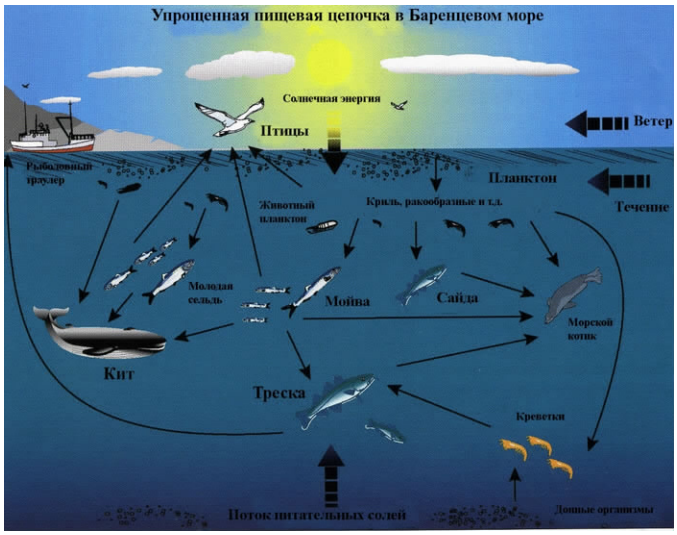


Fig.4 Simplified food chain in the Barents Sea[2]

The majority of plankton in the Barents Sea is made up of fine copepods and Crustacaea. In plankton, one will also encounter roe, fry of various fish species, larvae of benthic animals (molluscs, sea urchins, starfish, etc.). Roe, larvae and fry of various fish species are also found in open water. The main consumers of plankton are deep-sea fish such as herring, capelin, Polar cod, etc. In icy waters, phytoplankton serves as a basic food for Polar cod and sea birds.

Phytoplankton consumes zooplankton and is itself consumed by Benthos, which is subsequently consumed by higher organisms in the food chain. Many benthic organisms are also eaten by roundfish – haddock, wolffish, plaice, long rough dabs, cod and others. Phytoplankton, zooplankton and zoobenthos form the basis for food chains within the ecosystem of the Barents Sea. Fish, sea mammals and birds make up the upper levels of the nutrition pyramid. A significant part of the fish population, invertebrates, marine mammals and algae found close to the shore, are removed commercially.

During their life cycle, birds produce a large quantity of carbon and phosphorous which finds its way into deep-sea and coastal waters. These substances are required food for phytoplankton and zooplankton, macrophytes and benthos. Low contents of these substances will result in reduced bioproductivity of the seas.

In general, Arctic food chains are relatively short containing few species which have adapted to the unstable environment. In this way, rivalry between species is reduced. The further south you go, the lower the number of species encountered due to seasonal shifts and changes in the environment. Animals which live at great depths, however, experience relatively stable physical conditions and high diversity despite seasonal variations in food access.

5.2. Environmental impact of oil and petroleum products on plants and animals

Emissions of oil and petroleum products into bodies of water have a detrimental impact on all elements of an ecosystem. It results in a reduction in biological production connected with the breakdown in the exchange of energy, heat and gas between oceans and the atmosphere. Intense levels of pollution and formation of an oil film on the surface of the water lowers the penetration of oxygen from the atmosphere. The higher the concentration of oil, the greater is the reduction in dissolved oxygen content. A film of oil, like a shield, impedes the penetration of the sun's rays into the open water, thereby slowing the process of photosynthesis and disturbing the regeneration of oxygen reserves essential for life in the Sea.

The presence of oil and petroleum products not only changes the light, acidity, taste and smell of water. Its main impact is its toxic influence on those organisms which reside in the bodies of water. The harmful influence of oil is the result of the oil itself as well as the products arising from its chemical and microbiological oxidation. The toxicity of the oil and its components is evident even at low concentrations. Even insignificant

[2] *"Special ecological features of the Barents Sea", Cecilie H. von Quillfeldt, "OTTAR"*

quantities have a negative impact on the flora and fauna, and especially on commercially important aquatic organisms. It must be stressed that sea organisms and ecosystems regenerate extremely slowly following oil spills, up to 5-15 years. The time frame depends on the conditions under which the spill took place, the type and quantity of the oil spilled, and the intensity of the physical, chemical, geological and biological processes resulting in the dispersion and breakdown of the oil.[3]

Oil and petroleum products have the most significant impact on bottom-dwelling and planktonic aquatic organisms, fish, birds which live on or near the water and marine mammals. In the life cycles of many species within these groups, there are particularly sensitive periods when pressures caused by natural, climatic and man-made factors increase the probability of death. The causes of this increased vulnerability are as follows:[4]

- The restriction in mobility and consequently greater vulnerability of organisms during regular moulting of plumage or fur, or permanent attachment to places of reproduction during spawning/breeding (adults and more helpless young and cubs);
- The dependence on places where food is concentrated during periods of moulting, and at times when fat is being accumulated prior to migration or wintering.

Oil spills during extraction and transportation are the most serious and direct factor threatening aquatic organisms. Moreover, the level of threat increases tenfold during the sensitive periods in the species life cycle.

5.2.1 The impact of oil and petroleum products on birds

Marine colonies inhabit open areas and the waters of the Barents Sea, while the following species of nest-building birds reside on coastal islands: Fulmar, Kittiwake, Brunnich's Guillemot, Great Jaeger and Skua, and the Northern Gannet. The last two species mentioned are included in the Red Data Book for Murmansk oblast.

On areas adjacent to the ice barrier, one will find the White Gull, which is included in the Red Data Book of the Russian Federation. The spring and autumn migration routes of an estimated 150 species of gull and waterfowl also pass along the Murmansk coast.[6]

The red data book of the Russian Federation:

A state document documenting rare and endangered species in Russia. The federal Red Data book is complemented by regional Red Data Books, such as the Red Data book for Murmansk oblast.

Here's a thought…

It is estimated that as many as 450,000 sea birds die each year as a result of oil pollution in the North Sea and the North Atlantic.[5]

Oil causes contamination to birds' food supply, eggs, and habitat. External contamination by oil destroys plumage, mats feathers and causes eye irritation. Oily feathers hinder birds from flying and deprive them of their ability to retain warmth. .

Birds ingest oil when they clean their feathers, drink, consume contaminated food and breathe in the fumes. When a bird swallows oil, it rarely results in death immediately. Oil poisoning leads to a slow death from hunger and illness. As a consequence, predators die. Birds' eggs are very susceptible to the effects of oil. A small quantity of oil may prove sufficient to cause death during incubation.

For your information:

Moulting - changing plumage involves complete replacement of a bird's old plumage, including those feathers necessary to fly, over a period of one and a half months. Total moulting is characteristic of all species of seabirds.

Arctic sea birds are the most vulnerable during periods when they are changing their plumage, (moulting), nesting and migrating.

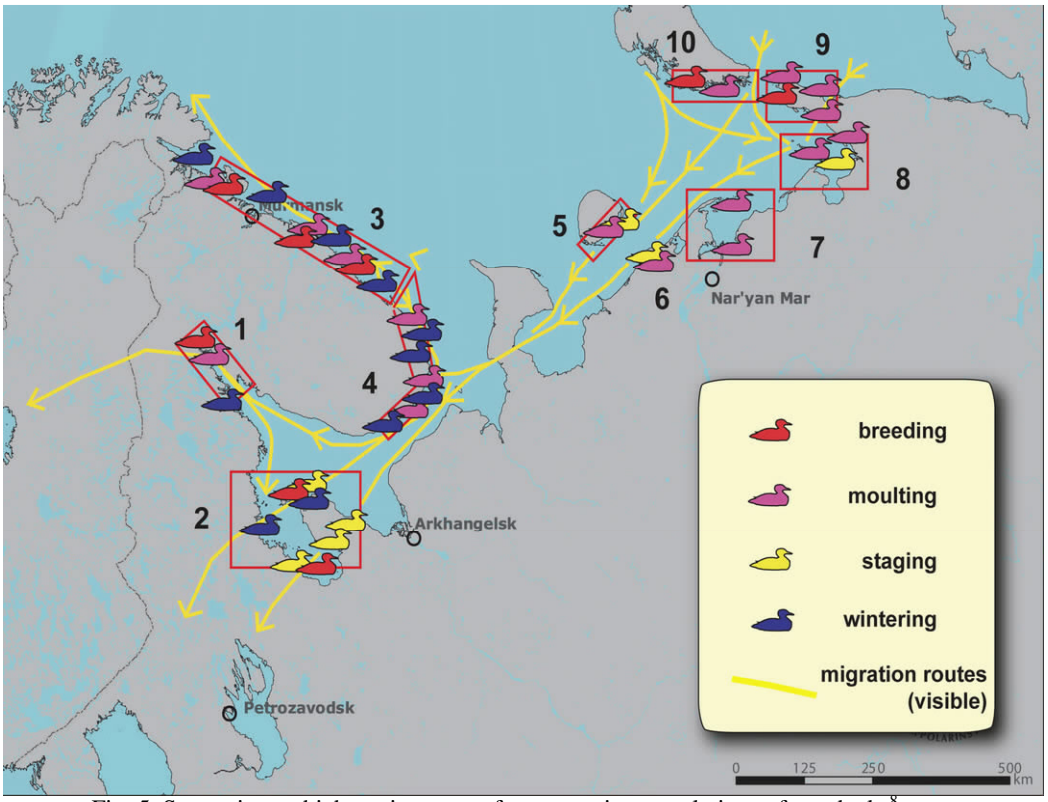
Here's a thought…

The Common Eider is a duck which spends most of its time by or in the sea during its entire life cycle. The Common Eider is a protected species which benefits from a hunting ban. Eiderdown is a valuable raw material. The most popular moulting and stopover sites on migration journeys for King Eiders in Russia are in the Pechora Sea.[7]

[3] *A. Sutyagin, project entitled "Monitoring the Baltic pipeline system"*
[4] *A. Sutyagin, project entitled "Monitoring the Baltic pipeline system"*
[5] *http://www.sakhalin.environment.ru/oil/oilrazliv/reagirovanie/opit.php*
[6] *"The basis for investment in the first phase of the Shtokman field infrastructure development project involving the production of liquefied gas and its transport by sea". Vol. II - Technical solutions for producing liquefied gas. Book 8. Evaluation of the effect on the environment. Section 8.1 Offshore structures. The "Giprospetsgaz" public company, St. Petersburg, 2005*

Since birds lose their ability to fly when moulting, moulting requires that they take special precautions. Over prolonged periods, they choose an area with a maximum amount of food which is not accessible to land-based predators and gather in dense flocks to maximise their defence. Since only a few water areas satisfy these special requirements, similar areas usually adjoin one another in the same sea sectors. The mobility of flocks of waterfowl is extremely low. On account of the porosity and low defensive properties of the incoming plumage, it is very easily contaminated by even small quantities of petroleum products. Consequently, the bird's body is unprotected from the cold water and it quickly perishes.[9]

The "worry" factor also results in increased bird mortality. Migration stopovers occur over the course of several days, with the appearance of one person sufficient to break up this gathering. Generally, many individuals never return to the previous location. With a permanent source of anxiety (industrial work, hunting, etc.), birds are forced to abandon the stopover without having achieved the necessary conditioning in terms of energy requirements. This results in seabird deaths in increased numbers during migration and wintering.



1 - Gulf of Kandalaksha,
2 - Gulf of Onezh'ye,
3 - Murman,
4 - Tersk coast,
5 - Kolguev Island,
6 - Sengeyskiy Strait,
7 - Pechora Bay,
8 - Dolgy Island - Khaipudirskaya Bay,
9 - Vaigatch Island,
10 - South Novaya Zemlya

Silhouettes of different colours reflect the importance of the waters for the populations of sea ducks at various times in the annual cycle: breeding, moulting, staging, and wintering. The yellow lines indicate the main migration routes for sea ducks.

Fig. 5. Sea regions which are important for supporting populations of sea ducks[8]

5.2.2 The impact of oil and petroleum products on mammals

During the icy period on the waters of the Barents Sea, the white bear, ringed seal, sea hare and walrus are common. Migration routes and grazing areas for the Greenland seal, common dolphin and porpoise are found here.

The majority of marine mammals in this region are rare, or protected, and are included in the Red Data Books of the Russian Federation and the International Union for the Conservation of Nature and Natural Resources.[10]

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[7] *A. Sutyagin, project entitled "Monitoring the Baltic pipeline system"*
[8] *Krasnov, Yu., Gavrilo, M., Nikolaeva, N., Goryaev, Yu. & Strøm, H. 2005. Main results of the studies of East-Atlantic flyway populations of sea ducks in the Barents Sea region. Abstracts of the Waterbirds Around the World Conference. Edinburgh, 2004*
[9] *"Special ecological features of the Barents Sea", Cecilie H. von Quillfeldt, "OTTAR"*
[10] *"The basis for investment in the first phase of the Shtockman field infrastructure development project involving the production of liquefied gas and its transport by sea". Vol. II - Technical solutions for producing liquefied gas. Book 8. Evaluation of the effect on the environment. Section 8.1 Offshore structures. The "Giprospetsgaz" public company, St. Petersburg, 2005*

Marine mammals which have fur (sea otters, polar bears, seals, new-born seal bears) are more vulnerable to oil spill than other sea mammals. Fur which is contaminated with oil starts to mat and loses its ability to retain heat and water. Adult seals and cetaceans are characterised by the presence of a layer of fat on which the oil impacts, aggravating heat consumption. In addition, oil can cause irritation to the skin and eyes and impede the animal's normal ability to swim.

Here's a thought…

"For the time being, no manmade influence on the ecosystem of the Barents Sea has been observed following oil and gas shipments. All the changes in how the ecosystem is functioning are insignificant and within stipulated norms", suggests A.A. Shavykin, scientific associate at the Marine Biology Institute in Murmansk.

Seals and cetaceans are more resistant to oil, than for example polar bears. However, the oil that enters the organism can cause gastrointestinal bleeding, renal failure, liver poisoning and blood pressure disruption. Fumes resulting from the evaporation of oil lead to problems in the respiratory organs of mammals which are located near to, or in the immediate vicinity of, large-scale oil spills.

5.2.3 The impact of oil and petroleum products on fish

The main species of fish identified in the waters of the Barents Sea are trans-border species and invertebrates: the north-east Arctic cod, north-east Arctic haddock, capelin, and the Arctic salmon, herring and navaga.[11]

Here's a thought…

More than two thirds of the fields which are earmarked for oil and gas development are situated in an area of increased biological productivity and active fishing.[12]

Oil pollution of sea waters can directly kill fish en masse and cause the gradual reduction in fish stocks by destroying the food base and spawning areas.

Spawn and fish larvae are particularly sensitive to the effects of petroleum products. Under the influence of hydrocarbons, the larvae of many aquatic organisms become poisoned and killed during the first 3 days after the oil spill. Unable to access oxygen from the atmosphere due to the film of oil, which prevents gas exchange between water and air, the larvae of many fishes suffocate and quickly die.

Contamination by petroleum products not only has a toxic effect on all species in the food chain within the marine ecosystem, but may also pose a real threat to human health due to the accumulation and retention of hydrocarbons in the bodies and fatty tissues of animals which man consumes. Fish containing hydrocarbons are unsuitable as food, even when the oil content in water measures only 0.1 parts per million. It acquires an unpleasant oil-like taste and smell. In addition, individual hydrocarbons are potentially carcinogenic.[13]

Comments by a legal expert:

To prevent the death of fauna, Russian legislation makes provisions for the protection of animals when implementing production processes. Generally speaking, these requirements are consolidated in Article 28 of Federal Law No. 52 dated 24.04.1995 "regarding the animal kingdom".

Resolution No. 997 of the Government of the Russian Federation dated 13.08.1996 "regarding approval of the requirements for preventing the death of fauna when carrying out production processes and also when utilising transport routes, pipelines and communication and power transmission lines" specifies in detail the obligatory rules directed at protecting fauna. For example, pipelines should not traverse spawning grounds or wintering holes.

5.3. The key areas for preserving bioresources in the region

A number of areas in the Barents Sea play a particularly unique role in the natural environment and represent key regions for supporting biological diversity and preserving biological resources. These areas are also characterised by the greatest vulnerability to oil pollution since they are vital to numerous plant and animal populations. The most important areas for preserving bioresources and supporting biodiversity in the region are as follows:[14]

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[11] *"The basis for investment in the first phase of the Shtockman field infrastructure development project involving the production of liquefied gas and its transport by sea". Vol. II - Technical solutions for producing liquefied gas. Book 8. Evaluation of the effect on the environment. Section 8.1 Offshore structures. The "Giprospetsgaz" public company, St. Petersburg, 2005*

[12] "*Basic tasks in preserving bioresources when carrying out oil and gas activities on the Continental shelf of the Russian Federation", Mishin V.L., Timov O.V., Plotitsina N.F. - materials from the international conference entitled "Oil and gas on the Arctic shelf", Murmansk, 2004*

[13] *A. Sutyagin, project entitled "Monitoring the Baltic pipeline system"*

[14] "*The Barents Sea Ecoregion. A biodiversity assessment", edited by: Tore Larsen, Dag Nagoda and Jon Roar Andersen, WWF*

- The Polar Front area - the most important feeding ground for fish, sea birds and mammals.
- Stationary polynias and ice barrier areas - the wintering place for sea ducks, walruses, Greenland seals, and possibly white whales.
- The high Arctic islands and adjoining bodies of water.
- The body of water to the west of Novaya Zemlya.
- The Murmansk coastal shelf - the spawning migration routes of fish of the Salmonidae family pass by when entering the rivers on the Kola Island. This is the feeding and breeding ground for growing whales. Rare species of seal are also found here. The greatest diversity of species is concentrated in the coastal waters of Murman - the expanses of water adjacent to the coasts of the Kola Peninsula and Novaya Zemlya which are most intensively utilised by sea birds and mammals.
- The coastal strip of Murman and Tersk coast along the White Sea.
- Pechora Sea: the Pechora basin, Pechora Bay and Cheshskaya Bay.

The Bellona foundation strongly advocates defining vulnerable areas of this region before the development escalates. More detailed information regarding vulnerable areas of the Barents Sea can be found in the OTTAR article by Cecilie H. von Quillfeldt entitled "Vulnerable areas" (translation from Norwegian) – Appendix (V-i) and Special ecological features of the Barents Sea (appendix V-ii)

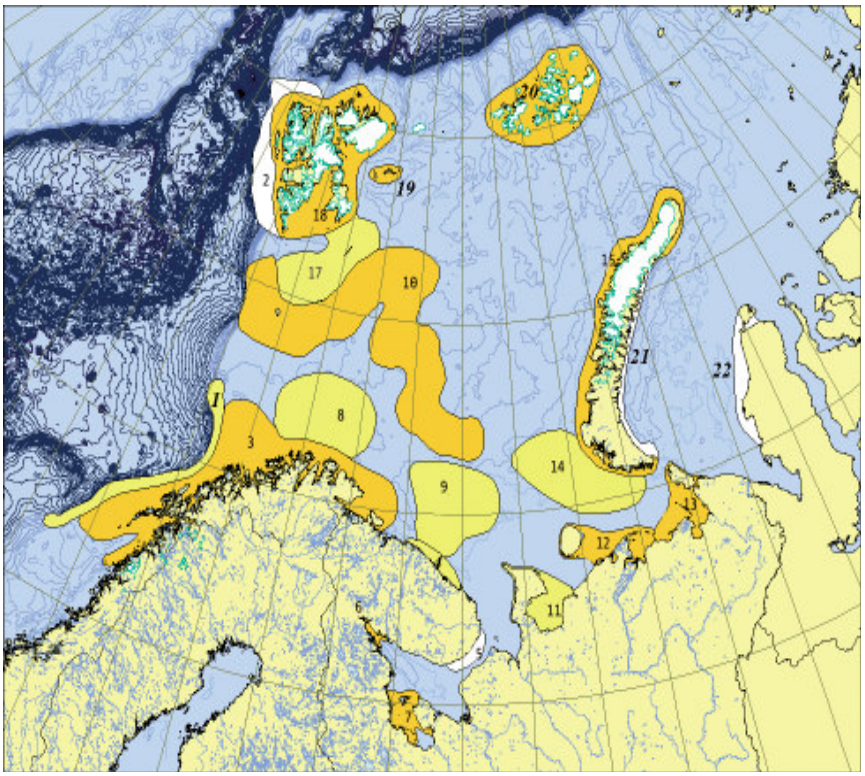


Fig. 6 Priority regions for preserving biodiversity in the Barents Sea eco-region[15]

Dark yellow - of extreme priority
Yellow - high priority
White - priority

Names of the territories:
1. The south-west area of the shelf
2. The north-west area of the shelf
3. The Norwegian coast and Tromsø bank
4. The coast of Murman
5. Narrow entrance to the White Sea
6. Gulf of Kandalaksha
7. Gulf of Onezh'ye
8. Nord Kapa bank
9. Banks along the coast of Murman
10. Polar Front
11. Kanin Nos and Cheshskaya Bay
12. The western part of the Pechora Sea
13. The eastern part of the Pechora Sea
14. North-east Barents Sea
15. The (sea)coast of Novaya Zemlya
16. Ice barrier (not indicated on the map)
17. Spitsbergen bank
18. The coast of Spitsbergen
19. King Charles Land
20. Franz-Joseph Land
21. The eastern coast of Novaya Zemlya
22. The eastern coast of the Kara Sea

[15] *"The Barents Sea Ecoregion. A biodiversity assessment", edited by: Tore Larsen, Dag Nagoda and Jon Roar Andersen, WWF*

Conclusions

1. The special ecological features of the Barents Sea determine its high level of biological productivity and variety of species but, at the same time, its ecosystem is very vulnerable to the effects of pollutants, and the regeneration of elements destroyed by pollution requires a long time.
2. Oil pollution on the sea surface reduces the reproductive capability of living organisms. Even in small concentrations, petroleum hydrocarbons passing along the food chain accumulate in organisms and lead to disruption of their life cycle processes, or even death.
3. Oil spills are particularly pernicious for sea birds. When their plumage comes into contact with oil, it loses its heat-insulating properties and renders birds unable to fly. Birds perish as a result of supercooling and nervous stress.
4. The greatest damage caused by oil spills is experienced by coastal ecosystems, near to which are located breeding areas and spawning grounds for fish, as well as resting places for migratory birds. The deterioration in coastal marine ecosystems and the contamination of seafood with toxic compounds has a negative impact on people's health.
5. The region examined consists of ecologically significant and vulnerable areas (fishing areas, specially protected nature reservations, wetlands, breeding grounds, stopover points, spawning areas and migration routes) and is extremely important in terms of bioresources. Therefore, all activity connected with exploration, extraction and transportation should be strictly regulated and controlled. .
6. The development of oil and gas fields on the Arctic shelf, including the surveying, extraction and transport of petroleum products represents a multiphase, large-scale process which is accompanied by a complete set of various negative influences on the environment. These influences are for example physical, chemical and biological disruptions in the open water, on the sea floor and in the atmosphere. In this regard, practically all the chains in the marine and coastal ecosystems are under serious threat

Appendix V-i. Special ecological features of the Barents Sea.

Author: Cecilie H. von Quillfeldt has a doctorate in marine biology from the University of Tromsø. She has worked in different regions of the Arctic since 1985 and is now an environmental consultant for the Norwegian Polar Institute. Since 2002, she has been one of the institute's leaders.

The Barents Sea is a comparatively shallow part of the Pacific Ocean with an average depth of 230 m. The contours of the bottom are characterised by the presence of a great number of sand banks which separate the deep water currents and the basins. The contours of the bottom also have a significant impact on the separation and movement of water bodies. In the west, the Continental slope extends 2000-3000 meters deep alongside the Norwegian Sea which, compared with the Barents Sea, is a deeper ocean section. The part of the sea to the north of Spitsbergen is also very deep.

Sea currents and water bodies

There are many types of sea currents: light surface currents, ground currents with high densities and currents in open water. The direction of the currents and the properties of the water bodies which the currents bring with them are very important to the ecology of the region.

Surface currents which move in a northerly direction convey warm Atlantic waters to the Barents Sea and the west coast of Svalbard (see fig. 1). Currents from the north and east convey cold Arctic waters in a southerly direction to the Barents Sea. However, the majority of the currents which flow from the Arctic Ocean originate in the Fram Strait region between Svalbard and Greenland.

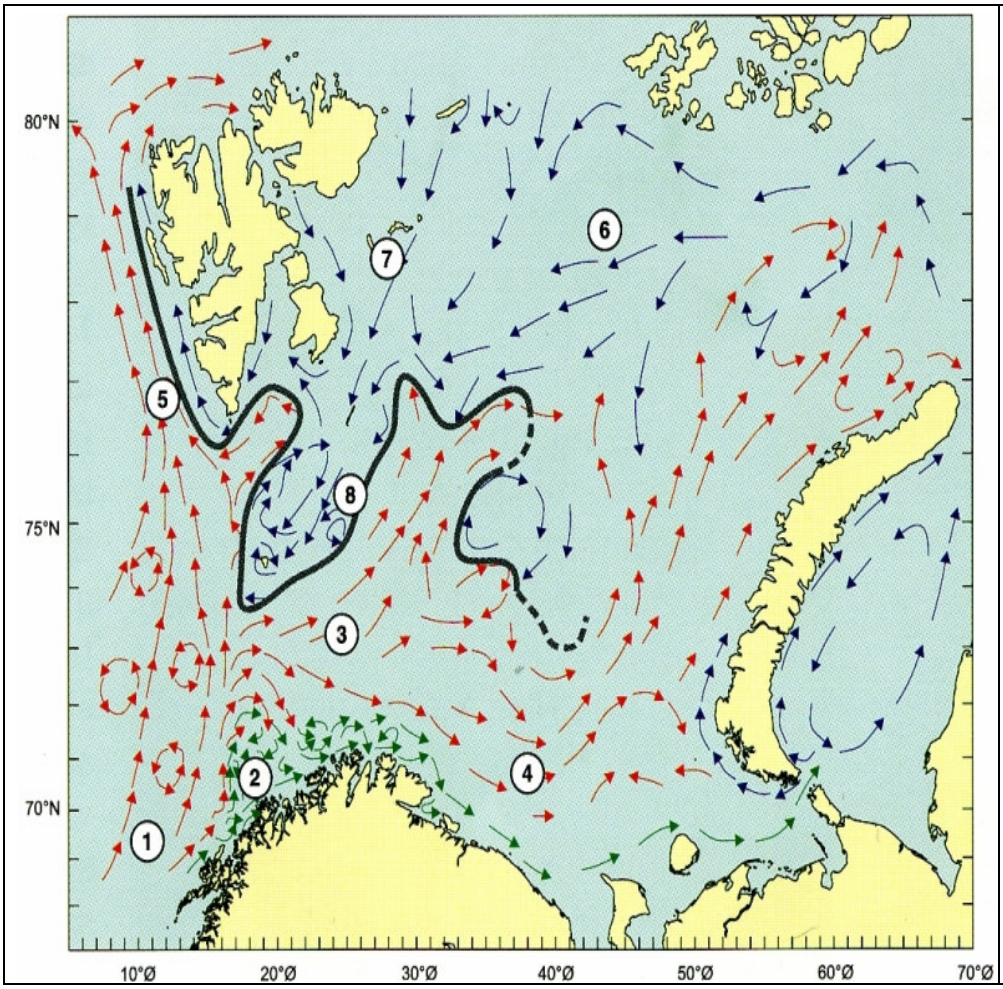


Fig. 1 Surface currents in the Barents Sea.

Red arrows: Atlantic waters.
Dark blue arrows: Arctic waters.
Green arrows: Coastal waters.
Black line: Average position of the Polar Front

1. Atlantic current,
2. Norwegian current,
3. Nørkapp current,
4. Murmansk current,
5. West Spitsbergen current,
6. Persey current,
7. East Spitsbergen current,
8. Bear Island current.

Source: Saxhaug (1994).

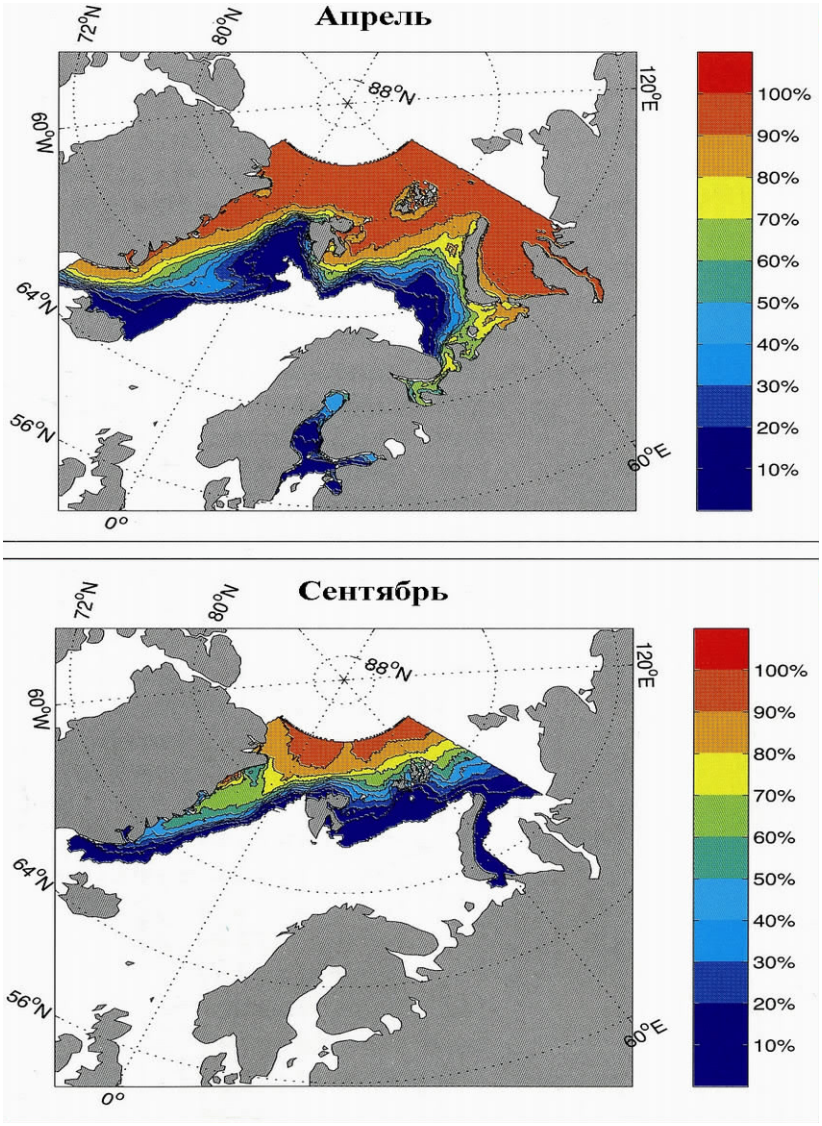
The transition area between the Arctic and Atlantic waters is referred to as the Polar Front. Its position is relatively stationary, especially in the west, and largely dependent on the contours of the bottom. The dispersion of many marine species depends on the temperature but, for several species the Polar Front represents the external boundary of their habitat.

A current with a somewhat different water composition than the Atlantic waters also moves in a northerly direction, following the Norwegian coastline before it continues its journey along the Russian coast. In addition to the three basic types of water masses, there are also water types which form locally and seasonally. In the northern part of the Barents Sea, for example, sea ice which thaws every year, produces a light surface layer in the upper 20-30 meters of the water column with a lower salt content than occurs in either Atlantic or Arctic waters.

Sea ice

Up to 75% of the surface of the Barents Sea is covered with ice. However, there can be marked seasonal variations (see fig. 2). The surface area which is covered with ice is at its peak between March and May, and at its lowest in September. However, from one year to the next there may be significant variations. In the transition area between ice-covered and ice-free sea there is a 20-50 km wide zone (the ice edge) which retains scattered ice. In the Barents Sea, drift ice which is no more than 1 year old predominates. The majority are of local origin. North of Svalbard there is more multi-year ice. Ice acts as a geographical boundary for species whose life cycles are entirely, or partially dependent, on ice.

Fig. 2 Probability of ice in April and September in the Barents Sea. Source: Kvingedal (2005)



The age of the ice determines its characteristics. Among other things, it determines its light transmission capability and the amount of light received by algae on the underwater side of the ice, and in the open water. These ecosystems contain microscopic algae which are entirely dependent on sufficient light for their growth. In addition to the age and thickness of the ice, the amount of snow on the ice surface is significant for the its transparency. Various species of algae have adapted to different light conditions, such that the algaes specific composition will vary depending on the age of the ice. This has implications for the organisms that consume it, that is, the next link in the food chain. In drift ice, algae and organisms dependent on it are established every year, while in older ice algae and organisms can develop over the course of several years. In the latter case, the ecosystem is more specialised and will contain species which cannot be found anywhere else in the ice.

In shallow water, glaciers and pack ice can scrape against the bottom and influence the existence of species. In areas where dry land and ice come into contact, ice scraping results in fewer species of macro algae (seaweed and laminaria) and organisms in the tidal zone. Species which are one year old, and species which are capable of moving up and down depending on variations in ice conditions, predominate here. In tidal zone areas without glaciers there are well developed ecosystems of algae and organisms present.

Production

Primary production, i.e. production which is the result of the ability of algae and seaweed to utilise light and inorganic compounds to produce organic material, constitutes the first level in the food chain. The principal consumers (for instance, crayfish) make use of this production and become food themselves for other organisms (see fig. 3). Due to the high production of plankton and fish, the Barents Sea has one of the largest bird colonies in the world. This is also one of the world's most important fishing regions.

Many circumstances contribute to productivity in the Barents Sea. High primary production requires sufficient light, nutrients and relatively stable conditions. The latter arise either when water bodies heat up (the southern part of the Barents Sea), or when ice thaws (the ice-covered part of the Barents Sea). A stable surface layer impedes the mixing of water bodies to push the algae so deep underwater that there is too little light for primary production. In autumn, changes in temperature and increased winds lead to the destruction of this stable layer of water and this mixing occurs from the water surface to the sea bottom if the water is not too deep. Nutrients which are utilised on the surface are replaced by new layers from the bottom, and everything is ready for new development when there are favourable conditions the following year. This situation will occur over large parts of the region precisely because the Barents Sea is a shallow sea.

Certain areas appear to be especially productive compared with others. One such region is the Polar Front. The merging of Atlantic and Arctic waters results in an especially strong vertical mixing and a good supply of nutrients, and therefore a higher primary production. The Arctic ice edge is another productive area. Here, the melting ice produces a stable surface layer, and at the same time, the concentration of salt in the water masses is at its highest level. Therefore, algae development begins 6-8 weeks earlier than it does in areas which have not been covered by ice. Certain wind directions will produce surface currents away from the ice edge. In this manner, nutrient-rich water from the depths is moved to the surface promoting further development. In practice, the ice edge and the production belonging to it moves from Bear Island in the south, to Svalbard in the north in the course of a year. Microscopic algae within the ice, but especially algae ecosystems on the underside of the ice surface, contribute to an increase in total production in this region.

Polynias are large open areas of water surrounded by ice which, for different reasons (current, variation in tide, wind) appear in the same spot at the same time each year. Due to favourable physical conditions (light, stability), such areas usually have a high biological production. In glacial fronts, there may at certain times be an increased access to prey because water which passes beneath the glacier churns water from the seabed to the surface. Frequently, cold winds blowing along the glacier result in replacement of surface waters by nutrient-rich water. The edge of the Continental shelf is also an area with increased productivity. In the Barents Sea there are certain banks, such as the Spitsbergen sand bank, where the water is so shallow that the layers mix to the bottom the entire year without there being too poor lighting conditions for primary production. All these areas with heightened biological productivity are attractive foraging grounds for several levels in the food chain. Such areas can have high concentrations of plankton, fish, birds and marine mammals.

The conveyance of animal plankton (secondary production) from the Norwegian Sea is another important contributor to the total productivity in the Barents Sea. Transport varies depending on the time of year and the intensity of the incoming water current from the Atlantic. Young crayfish are definitely the most important species in this plankton group and can comprise up to 80% of the total biomass volume of animal plankton.

Unstable environment

Significant changes in physical factors may take place during the course of the year and from one year to the next. These factors include: the amount and temperature of the Atlantic waters in the Barents Sea, ice conditions, wind, clouds, light and salinity. These factors affect production in the area as well as relations between species which depend on this yield. Organisms living in the Barents Sea have adapted to this unstable environment and the changes in the type and quantity of food in different ways. Many species build up fat reserves which may be utilised during lean periods. Several species only reside in the Barents Sea at certain times of the year or at certain stages of their life cycles, for example, herring and cod. Capelin can also make long forays to spawn and feed, but it tends to stay within the Barents Sea. Likewise, many seabirds

migrate south during the winter, and there are only a few species of whale (the White Whale, Greenland Whale and Narwhal) which spend all of their time in the Barents Sea and adjoining Arctic ocean regions. For example, the Minke Whale, Humpback Whale and Blue Whale only use the Barents Sea as a feeding ground, but calve in tempered oceans.

In the Arctic, there is a high probability of unsuccessful reproduction one year, and at the same time a high mortality rate among offspring. Adaptation to this is shown by the fact that many species grow relatively slowly, reach a high age, and give birth to relatively few young. Nevertheless, several species, for example, capelin, mature quickly, have a short life span and a high reproduction rate. Such a species adapts more easily to changes in the environment, which can result in relatively large swings in population size over time. Animals which rely on this species for its main nourishment must be able to endure this fluctuation. One possibility is for these animals to be capable of utilising many types of prey as food, to be generalists. Many animals in the Arctic possess this ability.

Short food chains and a high number of individuals

In general, Arctic food chains are relatively short with a few, robust species which have adapted to the unstable environment. The populations of each species are often large and can be located over large areas. In this way, rivalry between species is reduced. The further south you go, the lower the number of species encountered due to larger seasonal variations and changes in the environment. Animals which live at great depths, however, experience relatively stable physical conditions and the total diversity can be high here despite seasonal changes in food access. In the vicinity of Svalbard, over 1000 benthos (organisms that live on or at the bottom a water body) have been registered.

Close relationship between the sea and dry land

A close relationship exists between terrestrial and marine ecosystems. Energy is transferred from the sea to land when nesting sea birds fetch their food from the sea. As a result of this, plants located near colonies of breeding birds obtain an additional source of nutrition and their growth is stimulated. Reindeer and geese on Svalbard benefit from this. In addition, mountain foxes, which steal fledglings and eggs, often have lairs in these areas. Several marine mammals also establish sanctuaries on dry land for shorter or longer periods in connection with giving birth or moulting, while pregnant polar bears go into hibernation in the snow late autumn.

Appendix V-ii. Vulnerable areas

Cecilie H. von Quillfeldt

During work carried out within the framework of a plan for managing the Lofoten islands in the Barents Sea, a number of areas were earmarked as being particularly vulnerable. The physical, chemical and biological characteristics of the areas differ and the region rarely has the same degree of vulnerability throughout the year or in relation to the various influencing factors. As to what kinds of activity can be allowed in such regions, and how this work must be carried out, will be examined within the framework of a programme concerned with the future management of the Barents Sea.

When defining a vulnerable region, it is certainly worthwhile explaining in what respect it is vulnerable. Which species reside in this region and what role is played by their biological characteristics? In many cases, not all species in the separately viewed region exhibit the same degree of vulnerability in relation to the same influencing factors.

Productive areas

As has been mentioned in the chapter on special ecological features, several regions have a higher initial production than others do. In this connection, regions with a higher initial production will be more attractive as areas where zooplankton can feed which, in turn, represents a source of food for other species. The effective transfer of energy between the various links in the food chain is of great significance in terms of the ecosystem as a whole functioning properly. A negative effect in such regions will have serious consequences compared with less attractive areas for foraging.

Annual variability and changeability over the course of a year

Frequently, an area is vulnerable at a particular time of the year. Therefore, the time of the year is of great significance as regards the influence exerted on a region. Hence, for instance, an oil spill occurring at a time when phytoplankton is blossoming, when large concentrations of zooplankton which feed on this phytoplankton are forming, and when spawn and fish larvae are being distributed, will have more serious consequences than if an oil spill occurred in the middle of winter (lower production). During this period, one is less likely to encounter large flocks of sea birds. The exception to this may be several wintering ground areas which are important for sea birds.

When selecting habitats which are important for separate species, consideration must also be given to the fact that these regions may be liable to change over the course of the year. Capelin can be cited by way of example. The area where capelin spawn, the wintering grounds and areas for foraging largely depend on environmental conditions. This is linked to the fact that the capelin is a short-lived species. Herring, which has a longer life cycle, has more habitual migration routes. It is also known that cod spawn in the more easterly regions of Finnmark during years when the sea temperature is higher.

A large number of species in one region

Important habitats for marine mammals are situated along the sea coast where very large flocks of birds may accumulate at certain times of the year. Despite the fact that the main birds in the colony are well known, many species also form large flocks in separate areas during foraging, or when their plumage or wintering grounds are changing. None of these areas have yet been sufficiently studied or recorded on maps. What is known, however, is the fact that the Tana Basin on the Varanger Peninsula is very important when birds are changing plumage, while in the area between Hornsund and Sorkapp on the Spitsbergen archipelago, large flocks of eiders can also gather. On the continental part, however, as far as coastal species are concerned, an important role is played by the Lofoten islands - Vesterålen, Tromsø-Valsfjord and Varanger Fjord. Moreover, Varanger Fjord is of special interest

since 5-10% of the World's population of Steller's Eiders winter in this very region. Steller's Eider is the rarest diving duck in the world and it is therefore important that Norway should take care of this region.

At separate times, walruses and other seals can form large colonies on the coast or on ice floes, in particular, during the period when mothers are carrying pups, and during moulting or rest. In the area of the Spitsbergen archipelago, many walrus breeding grounds have been revealed, although it is not yet sufficiently clear how important these breeding grounds are. During the summer period, Edgeøya is an important region while in the winter, the Thousand and Hope Islands region acquires significance.

As far as the areas where whales forage are concerned, as a result of catches or oil spillages, their food base may suffer, although whales can leave this region in the event of being faced with unfavourable feeding conditions.

Tyus-Fjord - Ufut-Fjord is an important area for killer whales which follow herrings as they migrate. Since the majority of Norwegian cod which spawn during the spring winter in this very region, it is also extremely important in terms of fishing during the autumn/winter period. At the same time, there are signs that the migration paths adopted by herrings can change position in the open sea region.

The number of individual species in the separate region is of decisive importance as regards the consequences in the event of significant pollution as a result of oil products and the degree of vulnerability with active vessel movements, for example, in connection with tourist activities. The danger of a negative impact being inflicted on all stocks arises if the matter involves small stocks distributed over a single, small area.

Behaviour

A species' behaviour and its capacity to move from one region to another are also important as regards its vulnerability. The longer the amount of time a sea bird spends on the water searching for food or changing its plumage, the more vulnerable it is to oil spills. Being caught in a net unintentionally also constitutes a problem for several species. Birds such as the Polar Guillemot and the Common Eider are species which spend a lot of time on the water, with the Eider usually staying closer to the shore than the Puffin. The distance these birds are forced to fly in search of food and, accordingly, the foraging area, also depend on the species being examined.

Feeding

Food allowance is another important factor. In spite of the fact that the Polar Guillemot and Brünnich's Guillemot are similar in appearance and behaviour, the Polar Guillemot basically eats one type of food (capelin), while the diet of Brünnich's Guillemot is more diverse. Thus, in the event of a change to the food supply brought about, for instance, by climatic changes, the species with the more varied diet will be less vulnerable than that species with a more specialised diet.

Age

The vulnerability of many species varies with age. They are at their most vulnerable during the initial stages of the organism's life cycle during which different physiological functions develop, for instance, the immune and nerve systems, the system where enzymes are formed. In determining the regions which are of great significance for the individual species, it is necessary to know where these species dwell at the start of their life cycles. This can be traced with the greatest precision in the case of fish. Spawn and larvae are largely carried by the current and concentrated in time and space. They are practically unable to move away from the oil spill whereas an adult fish can move away

independently. Marine mammals provide another example. Females carry milk which is especially rich in fats and which allows their young to develop quickly in the Arctic environment. Consequently, large concentrations of toxic substances in the milk will be transferred to the young during feeding. Many marine mammals possess limited ability to break up toxic substances of this nature and drive them from their bodies.

Differences between groups of animals

Different groups of organisms can have varying degrees of vulnerability to the same influencing factors. The plumage of sea birds contains a layer of air which is important for keeping them warm. Should a bird become stained in oil products, this thermal insulation layer can be destroyed and the bird may die. As the history of marine bird development has demonstrated, they become vulnerable if the adult birds start to perish. The reason for this lies in the fact that sea birds have long life spans, mature sexually at a fairly late stage and have a low coefficient of reproduction (laying few eggs). Consequently, large oil spills can have a long-lasting effect on the populations of these birds. Despite the fact that seals have fur which can also be contaminated with oil products, this does not pose the same risk as it does to sea birds since seals have a fatty layer which serves to keep them warm. As regards the White Bear, the situation is somewhat different. Fur is also a heat insulator and improves the bear's buoyancy. Both of these qualities are reduced when oil products get into the fur and, in addition, the danger arises of oil getting inside the animal when the bear tries to lick his fur clean.

Sea floor

The situation on the sea floor is very different from what is happening in the open water. A large number of sessile species live on the sea floor which are unable to move away from the area afflicted by pollution. Therefore, groups which dwell on the sea floor are especially vulnerable to local pollution sources and physical interference in benthic communities, both when fishing and when constructing technical structures.

Key species

A key species is a species which has a special significance as regards the ecosystem. If a considerable influence is exerted on such a species, then this may affect the entire ecosystem. Knowledge regarding which species are considered "key" and where they accumulate in the greatest numbers helps keep control of the environment, in particular when monitoring the state of the environment. Cod and herring are key species in the southern part of the Barents Sea while shrimp, capelin and Polar cod are the equivalent for the northern region. Of Polar cod and capelin, Polar cod is the most significant for sea regions which are covered in ice.

Border areas

Determining the external boundaries of a particular species' distribution is necessary if this species is particularly vulnerable in these areas.

Typical and/or rare indigenous varieties

Certain exotic species may dwell in several areas or flocks of several species may appear simultaneously (especially high biodiversity), for example, coral reefs which are also breeding grounds for a number of species of fish. The Ryustraum current, which is located to the south of Tromsø, is another example. In this area, strong tidal currents restrict the number of species which can attach themselves to the bottom, while those species encountered form quite dense accumulations.

Reserves which have a national or international significance

A number of species in the Barents Sea are entered in the Red Data Book of the Russian Federation, i.e. species which, for one reason or another, are threatened with extinction or a significant reduction in their numbers. The International Red Data Book is published at fixed intervals, the most recent issue being 1999. The aim of such a book is to ensure the preservation of a species on Earth and support the countryside so that it is in a sound and productive state. The idea centres on the fact that this data can be used by any party whose activities may affect species which are threatened with extinction. Such a principle only works if the locations of the most important areas for such species which are included in the Red Data Book are known.

Several species are defined as "critical", i.e. species which are only encountered (endemic animal species) in Norway or in the north, or not less than 25% of the European population is to be found in Norway, or these species are included in the European or International Red Data Books. Hence, 10 species of sea bird and 13 species of marine mammal in the area around the Lofoten islands in the Barents Sea are regarded as critical.

Determining vulnerable areas

When drawing up the management plan for the Barents Sea, certain areas are regarded as being more vulnerable than others. In terms of earmarking vulnerable areas, it is necessary to find out which areas are important irrespective of what type of activity is carried out in these areas. An area may be important for several reasons, but a region which already has a high level of biological productivity and/or high degree of biodiversity at the start of the process is defined as being of particular significance. Another criterion may be contained in the fact that the given area is important for a species which is threatened with extinction, has a unique specific composition or, for one reason or another, is proposed as a protected marine region and so on. The criteria of such a species play the most important role in determining local, and usually small, regions.

It was then revealed to what extent these areas are vulnerable to one or other influencing factors. As a result, 16 areas, or types of area, were obtained, among which 7 were defined as being particularly vulnerable. Four regions are examined below which have a high level of biological productivity and/or high degree of biodiversity. In other words, they are important for several groups of species. In these regions, a negative influence irrespective of the time of year could have a significant impact which may affect the ecosystem as a whole. In general, the entire coast of North Norway and the Spitsbergen archipelago will be vulnerable at certain times, although the reasons for this and the duration may change.

A high level of biological productivity and/or high degree of biodiversity

Lofoten islands - Røst bank - Vesterålen Islands

This area has special significance as spawning, breeding and wintering grounds. In connection with this, large schools of various species of fish, flocks of bird and herds of marine mammals form in this area at different times of the year. Many of these species are regarded as key in relation to the ecosystem and are protected at a national and/or international level. The largest known colony of cold-loving *Lophelia peretusa* corals is located to the south-west of the Røst bank.

Active fishing is carried out in this area. Overfishing may affect the food base of many species of sea bird on their breeding grounds in this area. The accidental catching of sea birds and porpoises in nets, or the destruction of benthic communities as a result of trawling using a trawl line on the sea bed, are potential problems for such areas. Large oil spills when it is being extracted, or following accidents on

oil tankers, may have significant consequences locally for sea birds and, during March and April, for spawn and fish larvae.

Tromsø Bank

A large part of the main species of fish caught this year is concentrated in this area over the summer period. In connection with this, a specific size of oil spill may harm the majority of a whole generation of fish. Many sponges also reside in this area, and probably corals as well, which render the region vulnerable to fishing throughout the year.

Polar Front

The Polar Front is characterised by increased biological productivity, making it an important region for foraging. In addition, it represents a boundary in terms of the distribution of a number of species.

Since the Polar Front is important for sea birds while nesting in the region comprising the Hope Islands, Stur-Fjord and the Bear islands, the catching of young fish on beds, especially to the west and north of the Bear Islands, may affect the food base of sea birds in this region. Depending on the volume, type of waste and the time of the year, petroleum products which appear in this region may have a negative impact on sea birds searching for food in this area, and possibly also on species wintering in this region. Possible climatic changes may also affect the distribution of species and the onset of spring blossoming.

Ice barrier

During the winter period, the ice barrier coincides with the Polar Front, but during the summer and autumn, the ice barrier moves north, passing to the north of the Spitsbergen archipelago. The area is characterised by a short-lived, yet intense initial production. Since the yield is realised in a comparatively narrow belt 20-50 km wide, at fixed periods, the concentration of feeding species may be high. For this reason, the area is vulnerable to oil spills. In addition, oil and other toxic substances can freeze in ice and be released when it thaws. Many of the species in this area are “valuable” at a national and international level.

Since the production is concentrated in time and space, animals which live in open water cannot eat everything available and, as a result, a part falls to the bottom where it plays a fairly important role in feeding benthic organisms. Furthermore, many marine mammals use the sea ice for resting and giving birth to young. The ice barrier also represents a boundary in terms of the distribution of a number of species. The time when the ice forms and then thaws influences the period, localisation and intensity of the yield in open water. If there is less ice, it will disappear completely, which will affect species whose life cycles are linked to the ice, or will also affect the yield and biodiversity conditions in the given region.

Conclusion

In the text outlined above, mention is made of the fact that an area may be vulnerable for different reasons. Therefore, not all vulnerable regions can be managed in the same way and the management of every region must be appraised separately. Possible management measures may include a ban on certain forms of activity over the entire region, or parts thereof, or a possible ban on all forms of activity. The latter measure may be topical for small areas. Specific requirements concerning the time of the year and the nature of the technology and the instruments may also be laid down, along with the extent (number of vessels, quotas, etc.) to which this type of activity may continue. In addition,

monitoring must be conducted in the region, while any gaps in one's knowledge which have been revealed must be filled so that no undesirable or irreparable damage results.

Sea hare	Grey seal	Sea birds which go on long flights in search of food	Sea birds which keep to coastal areas
North Norway: Stø, Anda, Gilsøy, Ongstadvika, Hadseløy, Nurmela - Andøy, Bergsøy, Tranøy and the commune of Torsken, Serøy and Risøy, Sandøy, Måsvær, Grimsholman, Tana and Kongsfjord **Spitsbergen:** Cape of Prince Carl	**North Norway:** Auvær - Flatvær, Kamøy island, Refsholmen, Yesverstappan, Large Tamøy, Koyøy and Kongsfjord	**North Norway:** Røst, Verøy, Fuglenyuken/Mosnuken, Bleksøy, Sorfugløy, Nurfugløy, Loppa, Jelmsøy, Yesverstappan, Sverholt, Umang, Syltefjorden and Hornøy/Rainsøy. **Spitsbergen:** Kovalskyfella/Stellingsfell, Hornsund, Midterhuken, Ingeborg-fjel, Fuglehuken, the Bear and Hope Islands	**North Norway:** Røst, the remaining part of the outer land of the Lofoten and Vesterålen Islands, Kama region - Bundøy, Revsbotn, Rolvsøy, Ingøy, the northern part of Kongsfjord **Spitsbergen:** The ice-floe region of Western Spitsbergen, north-west Spitsbergen and the western parts of Barentsøy Island, Edgeøya and Tusenøy Island.

Several important breeding grounds for the sea hare and grey seal, as well as important nesting areas for sea birds which spend a long time in the sea. Such birds either go on long flights in search of food or feed close to the shore by way of preference. Species which usually stay close to the shore nest in other areas, relying on good feeding conditions in the immediate vicinity of the nesting site.

Literature

Aglen A., Yossiter H., Holst I.K., Klungsur I. and Wilson O. 2005, Valuable regions for cod, haddock, herring and capelin in the area around the Lofoten Islands in the Barents Sea. Note from the Institute of Marine Research in Bergen to the WWF, p. 16.

Anon. 2005. Appraisal of natural habitats. Vulnerable areas. A conflict of interests. Working group report to a group of experts on the development of a management plan for the Barents Sea.

E. Wilson and Cecilie H. von Quillfeldt (ed.) 2003. Determining especially important areas in the waters around Lofoten islands in the Barents Sea. Report to the inter-departmental committee for management planning for the Barents Sea.

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Appendix V-iii. List of normative and legal acts.

Federal Law No. 52 dated 24.04.1995 “regarding the animal kingdom”

Federal Law No. 187 dated 30.11.1995 “regarding the Continental shelf of the Russian Federation”

Federal Law No. 166 dated 20.12.2004 “regarding fishing and the preservation of aquatic biological resources”

Federal Law No. 16 dated 17.02.1995 “regarding ratification of the Convention on biodiversity”

Resolution No. 997 of the Government of the Russian Federation dated 13.08.1996 “regarding approval of the requirements for preventing the death of fauna and flora when carrying out production processes and also when utilising transport routes, pipelines and communication and power transmission lines”

Resolution No. 1289 of the Government of the Russian Federation dated 26.12.1995 “regarding the species of fauna which may be hunted”

Resolution No. 13 of the Government of the Russian Federation dated 06.01.1997 “regarding approval of the rules for catching animal kingdom species which are entered in the Red Data Book of the Russian Federation”

Order No. 169 of the State Committee of the Russian Federation on fishing dated 10.09.1996 “regarding approval of a list of species of living organisms which are part of the Continental shelf of the Russian Federation”

Order No. 3 of the Ministry of Agriculture of the Russian Federation dated 04.01.2001 “regarding approval of provisions concerning the procedure for issuing one-off licences to use species of fauna which may be hunted”

Order No. 491 of the Ministry of Agriculture of the Russian Federation and Order No. 654 of the Ministry of Natural Resources of the Russian Federation dated 29.09.2004 “regarding approval of the rules concerning fishing and other methods whereby Kamchatka crab in the Barents Sea is utilised”