European Environment Agency

Europe's biodiversity - biogeographical regions and seas

Biogeographical regions in Europe

The Arctic Ocean

- **home of the walrus**

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Summary

- The Arctic Ocean covers a large area with harsh climatic conditions.
- There are strong seasonal and geographical variations in light, temperature and ice cover.
- The European part of the Arctic Ocean covers only about 8 % of the total area of the Arctic Ocean, but due to its great depth it represents about 25 % of the total volume.
- The system of ocean currents induces an east–west temperature gradient with warmer conditions in the eastern part of the European Arctic Ocean, strongly influenced by the warm Gulf Stream. This keeps the Norwegian Sea and a large part of the Barents Sea ice-free and favourable for the growth of a wide range of open-sea (pelagic) and bottom-living (benthic) species. This biological production sustains huge stocks of pelagic fish in these areas.
- The extreme conditions in the area create unique marine ecosystems, and some species live on the border of their tolerance.
- Generally, the environmental quality of these waters is high, but there are several reasons for concern, and an urgent need for more knowledge about the biological systems in this vulnerable area.
- The main threats to biological diversity in the Arctic are
    - Extensive fishery is probably the greatest threat to biodiversity today. A better understanding of the effects of these fisheries is needed, especially of the effects of bycatch and effects on benthic habitats.
    - Effects of climatic changes are not yet unequivocally identified, but global warming can influence hydrographical conditions in the region. The recent possibility of ship passage along the Siberian coast may be an indication of such effects.
    - Accumulation of micro-contaminants in biota is of great concern, particularly since little is known about the relation between levels of contaminants and biological effects. Discharges from industry in the Russian area of Murmansk are considerable and make up a substantial part of total industrial outputs to the Arctic. Long-distance transport of contaminants from other areas is an increasing cause for concern. Data are needed on trends in inputs of contaminants and the geographical and temporal variation of their concentrations.
    - Current and potential projects indicate that shipping probably will increase. The extreme climatic conditions heighten the risk of accidents and complicate rescue and clean-up work, thus increasing the risks of environmental damage. Oil films are frequently detected on the surface in areas of intense shipping. Other possible impacts of shipping are introduction of non-indigenous species and biological effects of antifoulants.
    - There is a great potential for oil exploration in the Barents Sea and it is therefore likely that oil will pose a serious threat to marine life in the future.

1. What are the characteristics of the European Arctic Ocean?

1.1 General characteristics of the European area of the Arctic Ocean

The sea area treated in this chapter is referred to as the Arctic Ocean, and it is identical with OSPAR region I (boundaries are indicated in Map 1). Roughly, it is the sea area between Scandinavia, Greenland, Novaya Zemlya and the North Pole, including the European part of the Arctic Ocean, the Barents Sea, the Norwegian Sea, the Greenland Sea and the Icelandic Sea.

Table 1: Statistics for the European part of the Arctic Ocean

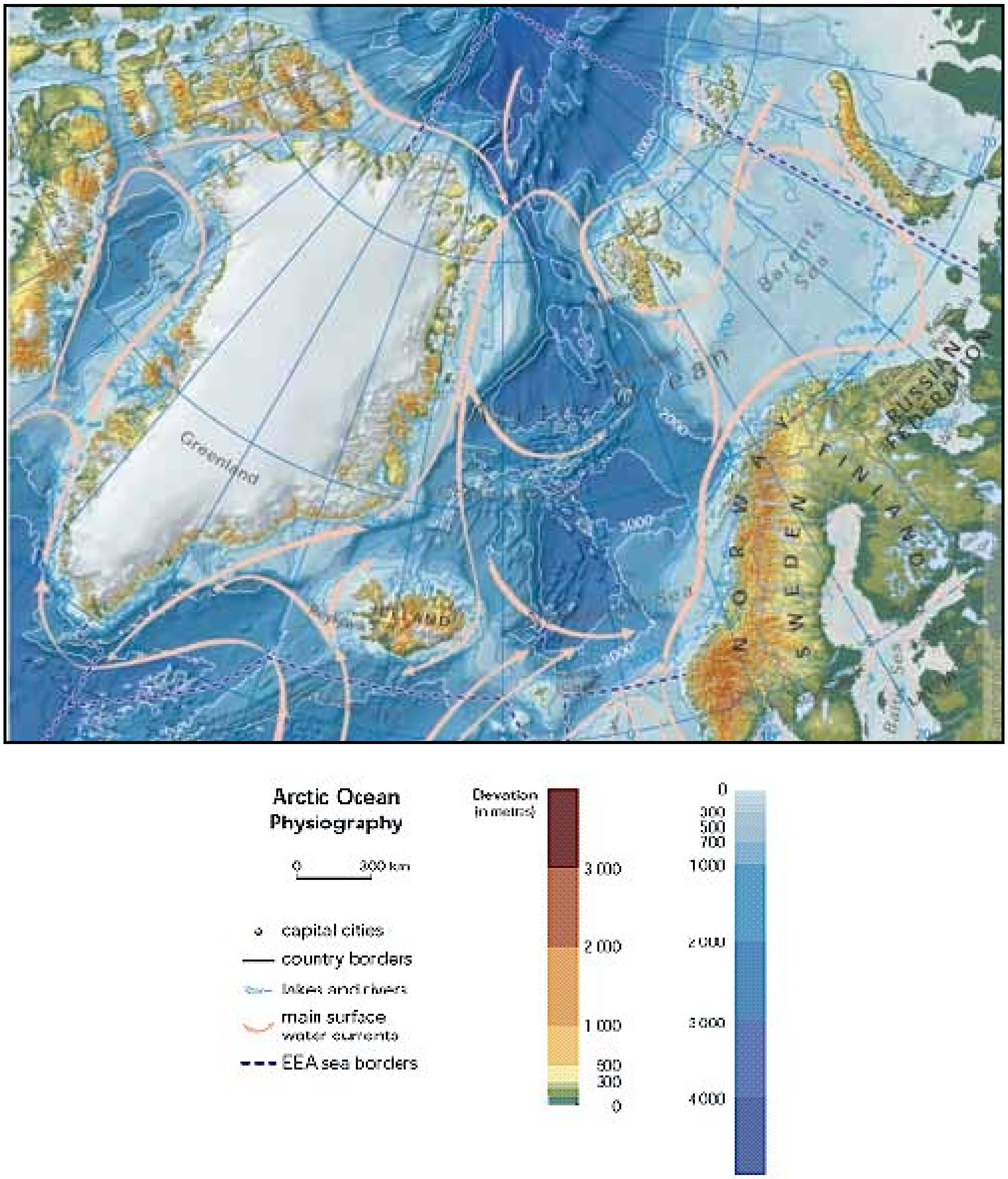
Surface area km^2	Catchment area km^2	Max. depth	Surface temperature	Salinity
5 500 000	550 000	> 5 000 m	– 1.8–14°C	30–35.4

Source: OSPAR 2000

Warm, high-salinity surface water from the Atlantic enters the European Arctic Ocean, where it is cooled and sinks to great depth. The cold water penetrates southwards at great depths and contributes to the oxygenation of the world's deep oceans. This is a simplified description of the formation of deep and intermediate waters in the European Arctic Ocean, one of the most important features of the global oceanic circulation. Variability of temperature in cold Arctic waters is small but important. The Arctic Ocean alternates between warm and cold states. The length of these states may vary, but fluctuations with periods of 3–5 years are most frequent and the variations appear to be generated by cyclic events rather than to represent progressive changes. The huge Russian rivers Pechora and Northern Dvina have great impact on the Barents Sea with their annual input of ca. 246 km^3 of freshwater (AMAP web site).

The Greenland-Scotland Ridge forms a barrier between the deep-water masses north and south of it (Map 1). A shelf extending northward from Iceland forms the floor of the Iceland Sea. The mid-ocean ridge forms the boundary between the deep basins in the Greenland and Norwegian Seas. These basins have relatively open connections to the Arctic Ocean. The shallow Barents and White Seas are the widest ocean shelf areas in the world. The Barents Sea is linked to the Nordic Seas through the gap between Norway and Svalbard, and is also open northwards to the wider Arctic Ocean.

Map 1: Arctic Ocean physiography (depth distribution and main currents in the European part)



Note: The sea area between Greenland and Norway is often called the Nordic Seas.
Source: EEA

The area includes many fjords with rivers flowing into them. In Norway, the coast is uneven with a number of bays, coves, inlets, islands and islets. The Norwegian fjords are relatively long, narrow and deep, normally with a sill that greatly affects circulation and contributes to making fjords sensitive to a build-up of contaminants from the land. The coast east of the Kanin Peninsula in the Russian Federation is low and temporarily flooded. North-western shores of the White Sea are rocky while south-eastern shores are flat and low. The coast of Iceland consists mainly of rock or sand, with fjords that are often more open and funnel-like than the Norwegian ones. The Faeroe Islands have mainly vertical cliffs rising directly from the sea, a result of intensive erosion by waves. The eastern coast of Greenland is mostly similar to the Norwegian coast. Icebergs, mainly from huge calving glaciers in the Greenland fjords, follow the coastal current along the Greenland coast and into the Atlantic Ocean. Much of the central Arctic drift ice forms in winter in the marginal seas. The main exit for Arctic Ocean ice is through the Fram Strait between Greenland and Svalbard.

1.2 Main influences

The main influences on the biodiversity of the Arctic Ocean are:

- fisheries
- offshore oil and gas industry

- contaminants and radioactive discharges
- climate change
- introduced species
- shipping.

1.3 Main political instruments

- The Arctic Council was established in 1996 and has eight member countries. The Council provides a mechanism for addressing the common concerns and challenges faced by the governments and the people of the Arctic. The Programme for the Conservation of Arctic Flora and Fauna (CAFF) and the Arctic Monitoring and Assessment Programme (AMAP), both established in 1991, are two programmes under the Council. CAFF addresses the special needs of Arctic species and their habitats in the rapidly developing region. AMAP is concerned with monitoring the levels and assessing the effects of anthropogenic pollutants in all compartments of the environment.
- The Convention for the Protection of the Marine Environment of the Northeast Atlantic (OSPAR) covers the part of the Arctic Ocean between 42oW and 51oE up to the North Pole (OSPAR region I).
- The North Atlantic Marine Mammal Commission (NAMMCO), set up in 1992, is an international body for co-operation in the conservation, management and study of marine mammals in the North Atlantic, including the Arctic part.
- The 1979 Bern Convention on the conservation of European wildlife and natural habitats has been signed by Norway and Iceland.

1.4 Biodiversity status

The cold, the extreme variation in light conditions and the extensive ice cover in the area create unique marine ecosystems. The strong gradients in environmental parameters result in marked differences in the geographical distribution of different types of living organisms. Some of these live on the border of their tolerance. Melting and freezing of ice form rich habitats close to the sunlit sea surface. The wide continental shelves provide large shallow areas, such as the Barents Sea, where freshwater from north-flowing rivers creates estuarine conditions. Arctic marine food webs can be very complex, but with only a few key species connecting the different levels (OSPAR 2000). Bottom-dwelling communities can be very rich along the ice-free coasts, where kelp forests and seaweed become nursing grounds for many fish species (AMAP 1998).

1.4.1 Plankton and benthos

- **Plankton**

The primary producers of the European Arctic Ocean are 200–300 species of microscopic plants called phytoplankton; half of these are diatoms (Zenkevitch 1963). When the phytoplankton bloom is in phase with the grazing from plankton animals (the zooplankton), most of the bloom is grazed. When out of phase, most of it is lost and not utilised in the pelagic food web because it sinks to the bottom. The spring phytoplankton bloom starts when stratification of the water masses is established and the light level is sufficient.

The zooplankton is characterised by a few dominant species. Crustaceans form the most important group, among which the copepods of the genus *Calanus* play a key role in the sub-Arctic and Arctic ecosystems. The 3–4 mm long *Calanus finmarchicus* is the most important contributor to the biomass and has a unique ecological position as the main food for herring, capelin, Arctic cod and other plankton-feeders. Krill is another group of crustaceans playing a significant role in the pelagic ecosystem as food for both fish and sea mammals.

Some organisms, such as ice algae, live in crevices in the snow and ice and can quickly take advantage of the light in spring. Among the ice-living forms are colony-building diatoms and blue-green algae that utilise the scant light that penetrates the ice. In addition to the prominent algal component, sea-ice biota also include other life forms such as bacteria, colourless flagellates, foraminifers, ciliates, nematodes, copepods, amphipods, krill and fish (Horner 1990, Horner *et al*. 1992).

• Benthos

Sediments in shallow seas and along coasts teem with life. There are, as an example, ca. 2 500 benthic species in the Barents Sea. Crustaceans, sponges and molluscs take advantage of dead plankton and other organic material falling to the sea floor from the productive surface waters. Some fish, eider ducks, bearded seals and walrus feed mostly on this benthic fauna. The benthic food chain is shorter than the one at the ice edge (AMAP 1998). The shallow communities are divided in two main biogeographic regions: the Arctic region and the east Atlantic temperate sub-region, both containing several biogeographic provinces and sub-provinces (see sea introduction chapter). The deep-sea fauna belongs biogeographically to the Atlantic region, but is separated into two sub-regions by the Greenland-Scotland Ridge: warm-water benthic species in the Atlantic sub-region and cold-water species in the Arctic sub-region.

Coral communities associated with the *Lophelia* coral are now recognised as important benthic features in the deeper waters of the Nordic Seas (Fosså and Mortensen 1998). *L. pertusa* has been recorded from the north-east Atlantic more frequently than anywhere else in the world. *L. pertusa* reefs have been identified as an ecosystem of particular importance which is diverse and very sensitive, but which has poor recoverability and is declining in extent, declining in quality, threatened and in need of action (see Map 2 in north-east Atlantic Ocean chapter). The deep-living *Lophelia* reefs can grow to 35 m high, be hundreds of metres wide, and reach 13 km length off Norway. Some reefs in Norway are found to be 8 000 years old. Studies of *Lophelia* reefs in the north-east Atlantic revealed a total of 744 associated species, but the number is probably far higher.

The macroalgae are dominated by large brown algae (Table 2). The diversity of macroalgae and the maximum depth to which they grow is generally lower at high latitudes than in temperate regions (Lüning 1990).

Table 2: Characteristic macroalgae of the eastern and western part of the European Arctic Ocean

European Arctic Ocean	Characteristic algae	Comments	Reference
Western part	Wrack (*Fucus disticus),* knotted wrack (*Ascophyllum nodosum,* bladder-wrack (*F. vesiculosus*), kelps (*Laminaria saccharina* and *L. digitata)*	The Arctic species *L. solidungula* is found on the coasts of Greenland and Svalbard	Lüning 1990
Eastern part	Flat-wrack (*F. spiralis)*, saw-wrack (*F. serratus)*, bladder-wrack (*F. vesiculosus*), wrack (*F. disticus),* channel wrack (*Pelvetia canaliculata)*, knotted wrack (*Ascophyllum nodosum)* kelps (*L. saccharina*, *L. digitata* and *L. hyperborea*)	Wrack dominate in the sheltered parts. A mixture of brown and small red and green algae occur in the more wave-exposed littoral areas. The wrack disappears from Kola Peninsula and eastwards.	Lüning 1990 Schoschina 1997

1.4.2 Large fauna

• Fish

The continental shelves along the Nordic countries are the spawning area of many fish species. The larvae spread from the spawning grounds into the open ocean. Some of the species perform long annual migrations between the feeding and the wintering areas. A selection of the fish species in the European part of the Arctic Ocean is briefly described in Table 3.

Table 3: Information on selected fish species in the Arctic Ocean

Species	**Description**
The north-east Arctic cod	Potentially the largest cod stock in the world, but biomass has fluctuated considerably during the past 50 years. During winter this cod is found in the southern Barents Sea. The migration to the spawning areas along the coast of Norway starts in December-January.
Blue whiting	Pelagic gadoid (cod fish) widespread in the Nordic Seas. Main food is plankton and small fish. Important as food for bigger fishes like cod, haddock and ling.
Herring	Pelagic plankton-eater with the copepod *Calanus finmarchicus* as one of its main prey organisms. The Norwegian spring-spawning herring constitute the largest single fish stock unit in the North Atlantic. However, abundance, spawning sites, feeding areas and migration routes have been subject to dramatic changes through history.
Capelin	Small pelagic salmonid fish that are found in the Barents Sea and around Iceland. Capelin lay their eggs on sand and gravel bottom along the coasts at shallow depths.
Polar cod (Arctic cod)	True Arctic gadoid with a maximum length of about 25 cm. Its distribution is associated with cold water and ice. The largest stock is found in the Barents Sea. The polar cod is a plankton eater and plays an important role in the Arctic food web.
The redfish	Four closely related species, of which two are commercially exploited – *Sebastes marinus* and *S. mentella*. The redfish has internal fertilisation, and the eggs hatch before they are released from the female. Redfish grow slowly and can become very old.

- **Squids**

The European flying squid (*Todarodes sagittatus*) occurs irregularly near the Norwegian coast where it feeds on migrating herring. It has been commercially exploited since 1993 and catches have fluctuated between 0 and 352 tonnes/year (ICES in prep). Another abundant species, the Boreal-Atlantic gonate squid (*Gonatus fabricii*), lives in the deep North Atlantic after spending the first year in the surface layers. It is an important prey for the bottlenose and sperm whales, and is also consumed by cod, herring and salmon. Squids are used as bait as well as food for humans. Generally, understanding of squid stock dynamics remains poor.

- **Seabirds**

The European Arctic Ocean is one of the most important seabird regions in the world. The breeding population of seabirds in this area exceeds 25 million individuals having major impact on the region’s ecosystem. Species may be grouped into surface feeders and pursuit diving sub-surface feeders. The prey species of Arctic seabirds is dominated by a limited number of key species, which makes the birds vulnerable to variations in the abundance of prey species. Many seabirds are specialised top predators and their sensibility to changes in the lower trophic levels makes them suitable as indicators of changes in the marine environment. The numerous and widespread guillemots are examples of such species.

- **Mammals**

There are two main groups of whales, both represented in the Arctic Ocean: Baleen whales are primarily plankton feeders, while toothed whales prey on fish, squid and seals (Table 4). Many baleen whales perform long and regular breeding migrations to warm and temperate waters during the winter, and migrate to cold water at higher latitudes to feed on the rich zooplankton supplies during the summer season.

Photo: White whale or beluga

Note: The white whale, or beluga, is the most common of the Arctic whales. It was commercially harvested in Svalbard up to 1960, and in the period 1945–1960 approximately 3 300 white whales were caught. Today these whales are totally protected.

Source: ©Ian Gjertz/ARC

Table 4: Population status of some species of whales occurring in the Arctic Ocean; abundance estimates are uncertain

Baleen whales	
Bowhead whale	Endangered Arctic species; stock heavily reduced during whaling up to the beginning of this century. Lives in Arctic waters throughout life. Present total number of animals around 8 000.
Blue whale	The population dropped severely during intense whaling early in the last century. The stock is increasing since protection in 1966. It has been observed regularly in the area in recent years and the global stock is growing (ca. 12 000 animals).
Humpback whale	Heavy exploitation in the past. Around 1 000 animals in the European Arctic Ocean in 1988.
Fin whale	Subject to hunting, especially north of Norway, but the N.E. Atlantic stock is still reasonably high. 22 800 animals in 1997.
Minke whale	Most important species in modern Norwegian whaling. Annual catches varied between 218 and 388 individuals between 1993 and 1996. The N.E. Atlantic population was estimated to be 112 000 animals in 1997.
Toothed whales	
Sperm whale	Found primarily in warmer waters. Whales encountered in the northern Atlantic are usually males. They dive down to 3 000 m, with dive-times up to 180 minutes. Globally protected in 1988. The number of individuals in the area is calculated at about 20 000.
Bottlenose whale	Like the sperm whale it can make deep dives to catch squid and fish. Has been protected since 1975. North Atlantic population about 40 000 animals in 1995.
Long-finned pilot	Known to occur in large schools. Newfoundland and Faeroe Islands have been

whale	traditional hunting areas; catch statistics since 1584. About 215 000 animals in N.E. Atlantic.
Beluga	Lives in Arctic waters throughout life. May occasionally be observed in large numbers on feeding migrations to the northern coast of Norway, eating capelin, salmon, squid and benthic animals. About 40–55 000 animals worldwide.
Narwhale	Lives in Arctic waters throughout life. The male has a long spiralling tusk which is not normally possessed by the female. 25–45 000 animals worldwide.

Source: Isaksen et al. 1998b with references, OSPAR 2000

In addition to the walrus, seal species found in the northern Atlantic north of 62°N are harbour seal, grey seal, harp seal, hooded seal, ringed seal and bearded seal. All seals are carnivorous, feeding on fish, krill, amphipods or bottom animals.

During the spring most seals collect in large aggregations to breed and mate, and they usually also gather during the moulting period. Harp seals, in particular, are very concentrated during breeding and moulting periods and have traditionally been extensively hunted. The pups, 'white coats', have been particularly important economically.

Photo: Walrus

Note: The walrus is a giant among seals in the Arctic Ocean. It has a disjunct circumpolar distribution and has been heavily exploited for its ivory tusks, blubber and thick skin. It has long considered endangered in the European part of the Arctic Ocean, but is now protected under the Bern Convention, Appendix II.

Source: ©Ian Gjertz/ARC

Polar bears are found in ice-covered areas and they have a circumpolar distribution. The Svalbard-Barents Sea population suffered from over-harvesting until 1973, but is now believed to have fully recovered. This population is unique in that it is the only one not currently hunted. The main food of polar bears is seals, which they catch on the ice. The distribution of bears is therefore highly dependent on the distribution of the ice and the seals. The polar bear is protected by Norwegian law and also under the Bern Convention, Appendix II.

1.5 Fisheries and other living marine resources

The largest and economically most important fish populations in the Arctic Ocean are cod, herring, capelin and blue whiting. The largest fisheries for the deep-water shrimp (*Pandalus borealis*) are in Icelandic waters. Squids are being fished for use as bait as well as for consumption by humans.

Table 5: Statistics on the economically most important fish populations in the European part of the Arctic Ocean

	Fishable stock tonnes 1997	Spawning stock tonnes 1997	Landings tonnes 1997
North-east Arctic cod	1 800 000	-	750 000
Icelandic cod	990 000	450 000	200 000
Faeroese Plateau cod	-	95 000	34 000
Herring*	-	12 000 000	1 400 000
Capelin	3 600 000	-	1 250 000**
Blue whiting	-	2 000 000	1 100 000***

*Norwegian spring spawning; ** autumn/winter 1996-97; ***1998

Source: OSPAR 2000

Hunting for ringed and harp seal, together with whaling for fin and minke whale, is part of the hunting tradition and of great importance to the population of Greenland, but the International Whaling Commission (IWC) has agreed on catch limits of stocks subject to aboriginal subsistence whaling. Hunting for small cetaceans like the narwhale and the beluga is regulated bilaterally with Canada. In the Faeroe Islands, non-commercial whaling for long-finned pilot whales has been carried out for more than a thousand years although recent regulations have banned some traditional practices and equipment. In the Barents Sea limited hunting for bearded seal is permitted to the native people. The Norwegian minke whale quota for 1999 was 753 animals. Norway has entered a formal reservation against the 1982 IWC moratorium on commercial whaling.

Seabirds have traditionally been caught in the Faeroe Islands, and also in Iceland and the Barents Sea, but the catch is now partly regulated.

In some areas various types of gastropods and mussels, like Iceland scallop (*Chlamys islandica*) and ocean quahog (*Artica islandica*), are harvested for human food and bait in long-line fisheries. Kelp and other brown seaweed are harvested for alginate production along the coast of Iceland and the west coast of Norway.

Fish farming in the Arctic area is limited, but production is expected to increase significantly. Norway is the biggest producer with 220 000 tonnes in 1997. Farming of shellfish includes only limited amounts of blue mussels, scallops and oysters.

2. What is happening to biodiversity in the Arctic Sea?

2.1 Climatic changes

Many species in the northern regions live and spawn at the limits of their distribution. Even moderate changes in temperature will have a pronounced effect on the distribution, growth, and success of spawning to a number of organisms. The results of scientific research and indigenous knowledge have increasingly documented climatic changes that are more pronounced in the Arctic region than in other regions of the world or are critical to our understanding of global-scale climatic processes (ACIA 2000):

- Record low levels of ozone were measured in 2000 in the Arctic with increasing evidence that these levels are likely to continue for the next 20 years (Shindell et al. 1999). Ongoing studies indicate that the current ultraviolet (UV) levels can have a significant effect on fish larvae survival rates.
- Observations from indigenous cultures of the Arctic of thawing of previously frozen ground, and variations in the geographic ranges of animals like beaver and moose, indicate that the physical environment, as well as the flora and fauna, has been changing (ACIA 2000).
- Recent indications of weakening in the deep-water formation system are a major concern. Climate models predict exceptionally large warming of the areas close to the North Pole with increased ice melting and freshwater supply as result (IPCC 1995). This may decrease the density of the surface layers, and thus reduce deep-water formation in the northern areas with reduced oxygenation of deep-water areas as a consequence.
- Evident patterns in the changes of populations of seabirds (guillemots) appear to be related to climate change; populations have declined in areas of warming while they have increased in areas of cooling. For this reason, CAFF recently decided to use guillemot as one of the biological indicators of climatic changes in the Arctic area.

So far, there is no consensus of scientific opinion on whether these changes are due to anthropogenic influences or to natural variation.

2.2 Fisheries

Most fish stocks in remote areas of the open sea are nowadays being exploited, and fish catches doubled several times during the last century. The collapse in commercial fish stocks is due to the combined effect of poor recruitment, increased natural mortality, reduced growth and over-exploitation. The problems increase when the exploited species are food for other commercial species.

Case study – Cod fishery

The traditional cod fishery is aimed at the spawners migrating to the Lofoten area in northern Norway during late winter. The fishery in the Barents Sea for young cod was intensified with trawlers after the Second World War, and by the 1950s negative effects on the spawning stock were observed in the Lofoten fishery. In spite of this, the fishing effort was not reduced, and in the following 30-year period the stock fell by more than 75 %. The decline was accelerated by low recruitment and by low temperatures impeding growth in 1976–80. The next few years were warm and gave hope for new growth and increased catches, but in 1986 capelin and herring, the main prey of cod, almost disappeared from the Barents Sea. Cod growth decreased drastically, and the mean weights of several age groups dropped to about half the normal level (OSPAR 2000).

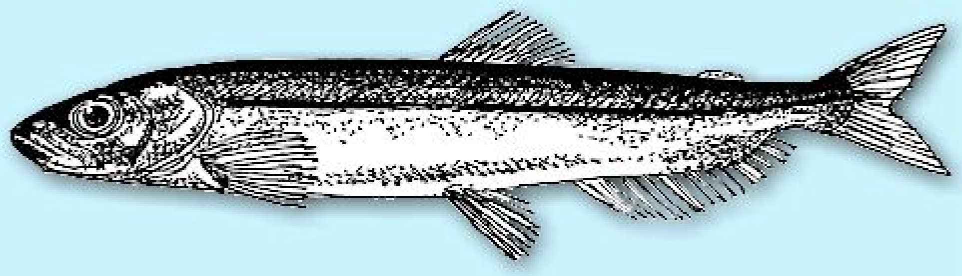
The three most important fish populations in the Barents Sea are herring, cod and capelin and these three species are biologically strongly linked: young herring feeds on capelin larvae, while young cod eats the mature capelin. Thus, years with good recruitment of herring and cod have resulted in poor capelin recruitment and subsequently a low capelin stock, which severely shrinks the young cod's diet. After the collapse of the Norwegian spring spawning herring stock in 1969, capelin recruitment was high and the interest in capelin fishery increased. Fishery was large until the mid 1980s when the stock collapsed. The consequences of this collapse are described in the case study below.

Case study – Collapse of Capelin stock

Capelin (*Mallotus villosus*) has a lifespan of only 3–4 years, and few individuals survive the first spawning, so the stock is more subject to rapid changes than the herring. The capelin stock collapsed between 1984 and 1986, mainly as a result of recruitment failure. Later investigations have shown that juvenile herring of the rich 1983 spawning fed on capelin larvae, and this was the main reason for the collapse (Gjøsæter 1998). The collapse of the capelin stock had dramatic effects on other components of the Barents Sea ecosystem, for example:

- a shift in the diet of cod from capelin to zooplankton, leading to a decrease in the growth rate and weight of cod;
- an increase in migration of harp seals to the Norwegian coast during 1986–88, probably in search of other prey;
- an 85 % reduction of the common guillemot bird population on Bear Island in 1986 – in 1995 the number was still less than 50 % of the population before the collapse (Mehlum and Bakken 1995).
-

Illustration: Capelin (*Mallotus villosus*)



Source: Petter Wang

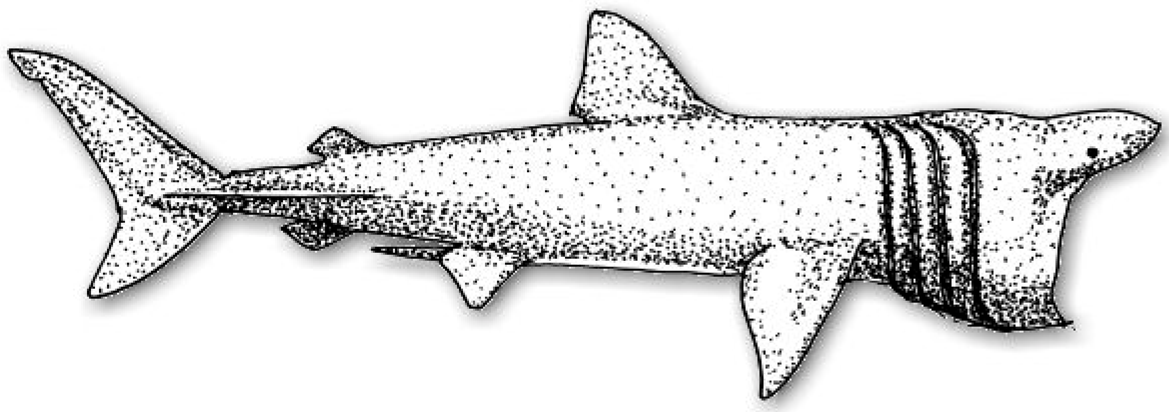
Photo: Common guillemot (*Uria aalge*)

Note: Several populations of the common guillemot collapsed in 1986 as a result of the previous collapse of the capelin stock. These populations are now recovering.

Source: Vidar Bakken

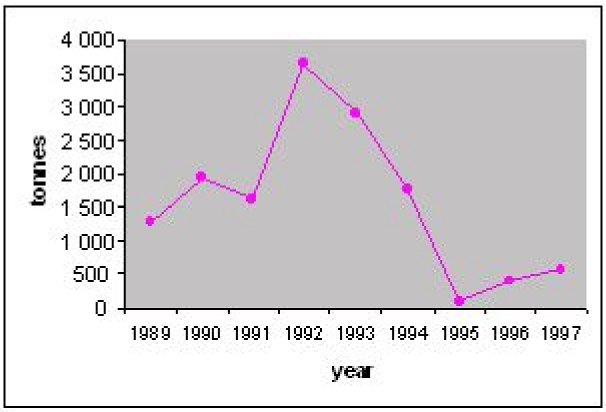
The second largest shark, the basking shark, is threatened by overfishing because of low to very low productivity. Documented fisheries in several regions have usually been characterised by rapidly declining local populations as a result of short-term fisheries exploitation, followed by very slow or no recorded population recovery (Froese and Pauly 2001). In the Arctic Ocean, Norway and Iceland have a small harpoon fishery for this species. Fishbase has listed it as a vulnerable species (Froese and Pauly 2001), and it is now protected in some territorial areas but not in the Arctic Ocean. The FAO (Food and Agricultural Organization of the United Nations) is leading a plan to establish international shark fishery management strategies for a number of species, including the basking shark.

Illustration: Basking shark



Source: Petter Wang

Figure 1: Norwegian catches of basking shark



Source: Froese and Pauly 2001

Other major impacts of fishery activities on biodiversity are as follows.

- **Bycatch**

Bycatch is thought to be the primary mortality factor for several seabird species in the Barents Sea region (Follestad and Runde 1995). The common guillemot population on the Norwegian coast has shown a marked decline in population, which can be accounted for by mortality in fishing nets. In some areas breeding colonies have decreased by more than 95 % since they were first counted in the 1960s. This may, to a large extent, be explained by drowning in cod and salmon nets (see Anker-Nilssen *et al.* 2000). Little is known about the bycatch of seabirds in the Barents Sea region, but the problem is probably most relevant for populations breeding at the Norwegian coast.

• **Discards**

Offal and discards from fishing provide food for scavengers. It is difficult to obtain exact figures on the extent of discards and therefore difficult to assess the effects on the biological communities. The dramatic population increase of the fulmar is, however, at least partly due to the rapid increase in food available from discards (Ollason and Dunnet 1988).

• **Effects on benthos**

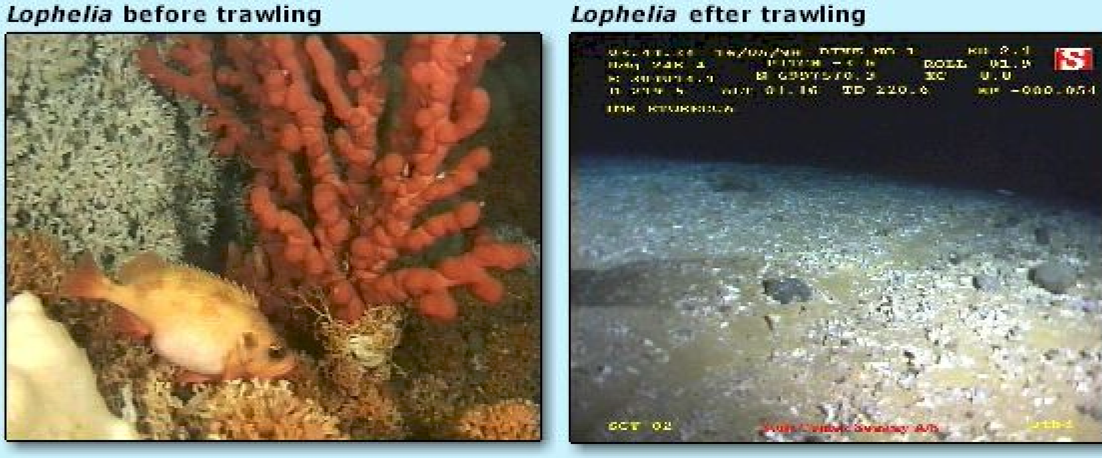
The extent of damage from trawling within the Arctic Ocean is not well known. Effects of disturbance on vulnerable species and habitats, e.g. deep-water coral reefs, have been identified; further assessment of these effects along the Norwegian coast will be carried out. The extensive sponge communities in the Barents Sea are affected by trawling, but the wider consequences of this are still unknown (OSPAR 2000).

Case study – fishery effects on deep-water coral reefs

A particular type of hard-bottom habitat is the deep-water coral reef communities. These communities are, in the European part of the Arctic Ocean, mainly found at the offshore shelf edge outside mid Norway and around the Faeroe Islands. The basis for the reef formation is the coral *Lophelia pertusa*, but a few other coral species are also present. The reefs, which may be several kilometres long and more than 30 m high, host a large variety of associated fauna (Fosså and Mortensen 1998). ROV (remote operated vehicle) investigations in recent years have shown considerable damage to some of the offshore reefs due to trawling activities. In addition to negative effects on the reef fauna itself, associated fish like ling, bream and redfish might also be affected. The reef seems to be important to redfish reproduction. The *Lophelia* reefs have recently been protected from fishing activities by the Norwegian authorities.

Photo: *Lophelia* reef before and after trawling

Lophelia **before trawling** — ***Lophelia*** **after trawling**



Note:
Left: Lophelia reef before trawling. Sebastes marinus and S. *viviparus* are the two most common fish species on Lophelia reefs. They may lie resting directly on the corals or school above the reefs.
Right: *Lophelia* reef after trawling. Video photograph from the Norwegian continental break at 220 m depth (16 May 1998), showing a barren landscape with spread, crushed remains of *Lophelia* corals. This is an area that is subject to considerable bottom trawling. A track can be seen stretching from bottom left to top right of the photograph, indicating the path of a trawl.

Source: Institute of Marine Research, Bergen, Norway

• **Whaling**

Whaling from the 17th century up to the 19th century led to the depletion of several whale species in the Arctic region. The recovery of the over-exploited species has been very slow for some species, such as the bowhead and the blue whale. Elements of the ecosystems have probably been permanently altered by intense whaling.

Case study – Bowhead whaling

Bowhead whaling in Svalbard started in 1611, when the Spitsbergen stock is estimated to have numbered 25 000 whales. Whaling ceased in 1911 at which time this stock was considered extirpated. During the 1990s occasional observations of bowhead whales near Svalbard suggest that a small remnant stock may exist. The observed animals may, however, be stray whales from other stocks. Bowhead whales are considered an endangered species on the Nordic Red List and are protected under the Bern Convention, Appendix II.

Photo: Only skeletal remains of the large bowhead whales are commonly found on Svalbard today

Source: ©Ian Gjertz/ARC

There is today very limited commercial whaling. Aboriginal subsistence whaling is permitted from Greenland for fin and minke whales. A major area of discussion has been the killing of whales for scientific purposes; Iceland carried out a four-year research programme between 1986-89, killing 292 fin and 70 sei whales. Norway carried out a seven-year research programme starting in 1988 to study and monitor minke whales in the north-east Atlantic; 289 whales were killed.

- **Fish farming**

In some local areas emissions from fish farms represent the largest anthropogenic input of organic matter, but no wider effects of this have been reported. One of the most serious current problems of fish farming is the spread of salmon lice from farmed to wild fish. Generally, lice infection on salmon seems to have increased, but how much of this is contributed by the spread of lice from farmed to wild salmon has not been identified. The most effective strategy for controlling lice infections in salmon farms appears to be the use of several species of the small fish wrasse (*Labridae*) together with chemicals. Wild salmon stocks are currently falling while salmon farming is growing rapidly. Escaped farmed salmon could pose a threat to the genetic diversity of the Atlantic salmon.

Photo: Goldsinny wrasse (*Ctenolabrus rupestris*)

Note: The small Goldsinny wrasse (*Ctenolabrus rupestris*) is used to remove salmon lice from farmed fish: 1 wrasse per 50 salmon is recommended.

Source: NIVA

2.3 Offshore activities

Pollution from offshore oil and gas activity is primarily related to accidental oil spills and operational discharges of oil and chemicals. In the Arctic, environmental conditions increase the general risk and the consequences of accidents. The south-western part of the Barents Sea was formally opened for exploratory drilling for oil in 1989, but to date there is no oil or gas production north of the Arctic Circle (66° 33´ N). Drift ice, and in particular the marginal ice edge, is important for Arctic marine life. An oil spill entering such an area can cause significant harm to animal populations. The potential effects on seabirds and marine mammals of petroleum activity in the Barents Sea have been evaluated (e.g. Isaksen et al. 1998a) and birds like auks and ducks, and marine mammals such as the polar bear, are especially vulnerable to such activity. It is, due to the great potential for oil exploration, likely that oil will pose a much more serious threat to marine life in the Barents Sea in the future (Anker-Nilssen *et al.* 2000).

2.4 Shipping

Shipping in the Arctic poses a greater risk of accident than shipping further south, because of the extreme climatic conditions of ice, darkness and fog; these also complicate clean-up work and thus increase the risks of environmental damage. Ships are themselves point sources for long-time/low-level emissions to air as well as discharges to sea. Oil films are frequently detected on the surface in areas of intense shipping. Other possible impacts of shipping include the introduction of non-indigenous species, noise and physical disturbance, and the biological effects of antifoulants. Constructions of harbours and industrial installations will destroy habitats in the coastal zone. The environmental impact of increased shipping in the Arctic has recently been thoroughly evaluated in relation to the opening of the Northern Sea Route from Europe to Japan along the Siberian coast (e.g. Brude *et al.* 1998).

2.5 Contaminants

Many organisms in the Arctic Ocean are under stress as a result of environmental characteristics such as low temperatures and extreme seasonal variations in light. Such conditions also make them especially vulnerable to environmental contaminants. For example, since the ability to gather and store energy is a prime requirement for survival during the dark and cold winter, fat plays a more important role in animal metabolism in the Arctic than in temperate regions, and this, in turn, increases the importance of biomagnification of fat-soluble contaminants. Bioaccumulation of contaminants is also accentuated in many Arctic animals by long lifespans.

So far, there is no evidence that contaminants are causing effects on population levels in the Arctic (Knutzen 1999). Recent investigations within the area are, however, indicating that contaminants can have effects on biological communities. There is evidence of:

- polychlorinated biphenyls (PCBs) causing biological effects in glaucous gulls from Bjørnøya (OSPAR 2000) –a negative relationship was found between PCB levels in gulls in 1997 and the probability of the birds returning to Bjørnøya in 1998;
- PCBs affecting the immune systems of polar bears (Bernhoft et al. 2000);
- PCBs leading to pseudohermaphrodite polar bears at Svalbard (Wiig et al. 1998);
- tributyltin (TBT) causing imposex in females of dog whelks and common whelks (OSPAR 2000);
- cadmium levels in seabirds and marine mammals from north-west Greenland possibly being high enough to cause kidney damage (OSPAR 2000).

2.6 Radioactive discharges

The Sellafield reprocessing plant on the north-west coast of England, the Tsjernobyl accident in 1986 and trial blasting of nuclear weapons are the most important sources of the anthropogenic radionuclides found in the Arctic marine environment (Strand *et al.* 1997). The mobility of radionuclides accumulated in sediment is, however, low and levels of radionuclides in fish, seals and whales collected in Greenland waters and in the Barents Sea since the early 1960s are very low (AMAP 1998) and pose a minor threat to marine biodiversity.

Significant threats to the environment from radionuclides in the Arctic are today mainly associated with the potential for accidents in the civilian and military nuclear sectors.

2.7 Introduced species

The most significant ecological effects of non-indigenous species are competition with indigenous and/or commercially important species for food, space or light, and pathogenic effects. Introduction of harmful planktonic algae is considered a major global problem, but problems in the Arctic are not serious compared with the more southern areas. Only a limited number of non-indigenous organisms have been reported in the European Arctic Ocean (Table 6).

Table 6: Non-indigenous marine species in the Arctic Ocean

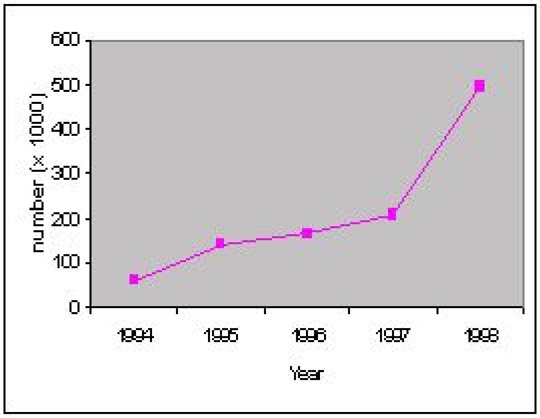
Species	Common name	Class	Origin
Bonnemaisonia hamifera	Red algae species	Rhodophyta	Japan
Codium fragile	Green sea fingers	Chlorophyta	Indo-Pacific
Colpomenia peregrina	Oyster thief	Phaeophyta	Pacific
Fucus evanescens	'Rockweed'	Phaeophyta	N. Atlantic/Pacific
Petricolaria pholadiformis	Bivalve	Mollusca	N. America
Crassostrea gigas	Pacific oyster	Mollusca	Japan
Teredo navalis	Common shipworm	Mollusca	W. Pacific
Mya arenaria	Sand gaper	Mollusca	N. America
Teredo navalis	Ship worm	Mollusca	W. Pacific
Tapes philippinarum	Manila clam	Mollusca	S.E. Asia
Balanus improvisus	Bay barnacle	Crustacea	America
Paralithodes camtschatica	King crab	Crustacea	W. Pacific

Molgula manhattensis	Sea squirt	Tunicata	America

Source: Hopkins 2001, JNCC 2001, OSPAR 2000

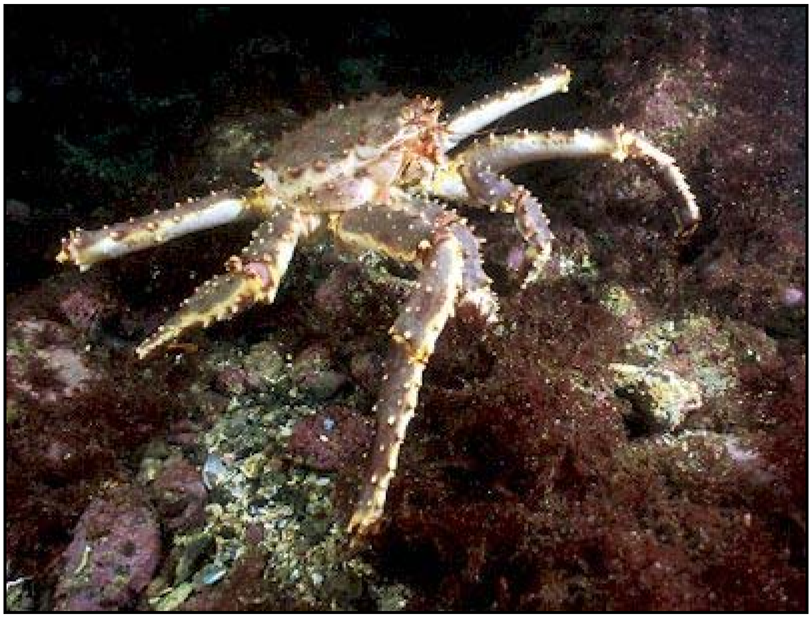
There are few quantitative estimates of ecological or economic impacts from these species. The bay barnacle, introduced as fouling on ships, may change the habitat and compete for space with indigenous species. About 12 500 king crabs, a commercially important shellfish in the northern Pacific, were introduced to the Barents Sea in the 1960s. This big crab (>10 kg) has now migrated westwards to the coasts of northern Norway where the population is increasing. Studies have been made of the yearly output in northern Norway (Olsvik 1996), but not of the effects on or interactions with native species which have no economic significance. There is concern that the crab may have a negative ecological impact on the native species (see Hopkins 2001).

Figure 2: King crab (*Paralithodes camtschatica*) in Norway, stock abundance estimates



Source: Toresen 1999

Photo: King crab



Source: Stein Johnsen/www.uvfoto.no

2.8 Red List species

Polar bear, walrus, harbour seal, otter, 11 species of whales and 14 seabird species are the marine Arctic animals on the Norwegian Red List. Five of the whale species are internationally (IUCN–The World Conservation Union) listed as endangered or critically endangered (the Svalbard stock of bowhead whales moved from endangered to critically endangered on the 2000 List). The only fish species listed as critically endangered by IUCN in the European Arctic is the common sturgeon. No fish species are listed as endangered. Blue skate, Atlantic halibut and acadian redfish are, however, considered endangered in European Arctic waters by Fishbase (Froese and Pauly 2001). Generally, the status of non-commercial fish stocks is not well known. In addition, loggerhead and leatherback turtles are listed as endangered and critically endangered, respectively, by IUCN. No marine invertebrates are found on the IUCN Red List for this area. Lack of knowledge about this huge group of animals makes evaluation of the status of most marine invertebrates very difficult.

3. What policies are at work in the Arctic Sea?

3.1 Nature protection

3.1.1 Protected areas

Nature protection is mostly land based, and the Arctic countries have identified gaps in their protected area systems and have proposals for additional protected areas. Among the most poorly covered are marine areas, coasts and fjords. However, even with all the proposals implemented there would still be major gaps in coverage of critical habitats and representative ecosystems (CAFF 2000a). Habitat conservation is a declared priority in CAFF's Work Plan.

National legal instruments for marine conservation in the Arctic have been summarised by CAFF (2000b).

- Iceland has comprehensive legislation and regulations for the marine environment, with a focus on fisheries. The inner part of Breidafjordur became in 1995 the first Icelandic marine conservation area protected by a special law.
- In Norway a total of 17 river mouth deltas are protected areas and three Norwegian biogeographical marine sub-provinces have been identified for protection. Norway has been given sovereignty to regulate activities in the Svalbard area within the framework of the Svalbard Treaty. National parks and nature protection areas now constitute 56 % of the total area of Svalbard (OSPAR 2000).
- Greenland has traditionally been regulating fisheries quota and marine mammal hunting, but is currently reviewing its entire nature conservation regime, including protected areas.
- In Russia, responsibility for the marine environment is shared between the territorial states and the federal government. The country is establishing a legislative base to enhance Arctic marine conservation and there is sufficient information to identify the need for protected areas, but so far marine protected areas are absent.

3.1.2 Red List species

International nature protection conventions and programmes extend protection to several marine species in the Arctic Sea on the basis of international and national Red Lists. Gaps in species protection have been identified by CAFF. As an example, 16 marine mammals in Russia are considered endangered, but the ranges of these mammals are basically unprotected (CAFF 2000a). Most Red-Listed species in the Arctic are protected under the Bern Convention (Appendix II or III), which is ratified by Iceland, Greenland (Denmark) and Norway, but not Russia.

3.2 Protection of marine resources by restrictions on fishing and hunting

Commercial hunting and fishing is generally strictly regulated in the European Arctic marine areas. There is a common understanding that an optimal and sustainable development of the marine resources must include regulations. The size of quotas is mainly based on previous scientific stock estimates and international agreements. ICES (International Council for the Exploration of the Sea) and IWC (International Whaling Commission) are in this context important providers of scientific information and advice on living resources and their harvesting.

Nature protection:
Lophelia coral reefs outside central Norway have recently been protected by law from the destructive effects of fishing activities. Kelp forest communities are protected by regulating the frequency of kelp trawling; exploited kelp areas are divided into sectors where trawling is allowed only every fifth year.

Species protection:
The great baleen whales in the Arctic are protected from hunting, but still have numbers substantially below

'natural' levels due to past hunting (OSPAR 2000). Small cetaceans are not under IWC authority, but hunting of species like narwhal and beluga is regulated bilaterally with Canada. International trade in polar bears is regulated under CITES where the polar bear is listed as an Appendix II species. The Norwegian population in Svalbard was estimated at 2 000–2 500 in 1973 and had doubled to 4 000 to 5 000 by 1983 (Larsen 1984). No hunting of polar bears has been permitted in Svalbard since 1973. Catching of seabirds was extensive in former days, but is now reduced and regulated by law.

3.3 Research projects and monitoring programmes

Since 1997, AMAP has had a ministerial mandate to continue to carry out 'monitoring, data collection, exchange of data on impacts, assessment of the effects of contaminants and their pathways, increased ultraviolet-B (UV-B) radiation due to stratospheric ozone depletion, and climate change on Arctic ecosystems'. CAFF developed a 'Strategic plan for the conservation of Arctic biological diversity' in 1998, and the plan identifies monitoring as one of the key objectives. Early in 2000 CAFF/AMAP arranged a workshop to advance the work on biodiversity and monitoring of climate change in the circumpolar Arctic region.

The International Arctic Science Committee (www.iasc.no/) is a non-governmental organisation, which advises the Arctic Council and promotes several programmes of direct relevance to biodiversity. The Arctic Ocean Sciences Board (www.aosb.org) is another non-governmental body that supports multinational and multidisciplinary natural science and engineering programmes, e.g. the International Arctic Polynya Programme.

Case study – Polynyas

Polynyas are productive areas of open water surrounded by sea ice. Polynyas can vary in size from less than a few square kilometres to immense areas of over 50 000 km^2. Some polynyas occur at the same time and place each year. Animals can adapt their life strategies to this regularity, and such recurring polynyas are of special ecological significance. In winter they provide overwintering ground for marine mammals such as walruses, narwhals and belugas that do not migrate south. In spring, the thin or absent ice cover allows the penetration of light into the surface layer as soon as the winter night ends, which triggers the early blooming of microalgae, the basis of the marine food chain. Hence, recurring polynyas are suspected to be focal points for the intense production of the planktonic herbivores that ensure the transfer of solar energy fixed by planktonic microalgae to Arctic cod, seals, whales, polar bear and man (the International North Water Polynya Study web 2001).

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