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The State of the European Arctic Environment

Editors:
John Richard Hansen, Rasmus Hansson & Stefan Norris

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Contents

Preface

This report provides a general assessment of the pressures, state and trends of the European Arctic environment. This remote, harsh and vulnerable environment consists of large productive marine areas containing some of the World's largest fish stocks, ranging from Icelandic waters in the west to the Kara Sea north of the Russian Federation in the east. Its landmasses, being the home also to indigenous peoples, include islands and the northern part of continental Europe as far as the Ural mountains. Although this huge and sparsely inhabited landmass in Northern Europe is severely affected by local human impacts, it also contains the largest areas of pristine nature in Europe, providing in its tundra regions the only breeding and molting area in the World for several species of migrating birds.

There are plenty of threats to the Arctic environment: over-fishing, improper storage and dumping of nuclear wastes, long-range pollution, increased tourism, and petroleum exploitation, for example. Although the majority of these threats are global, their impact is generally more acutely felt in the Arctic where the duration of damage is much longer than elsewhere. Action at the national, regional and international level to protect the values of this unique environment, its ecosystems, biodiversity, wilderness areas and cultural heritage, should therefore be reinforced in order to ensure sustainable development in this part of Europe.

The report has been prepared by the Norwegian Polar Institute as part of the Norwegian support of the European Environment Agency.

Opinions and views expressed in the report are the sole responsibility of the Norwegian Polar Institute and they are not necessarily those of the European Commission or the European Environment Agency.

Domingo Jiménez-Beltrán
Executive Director

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This report has been prepared and edited by John Richard Hansen, Rasmus Hansson and Stefan Norris at the Norwegian Polar Institute (NP).

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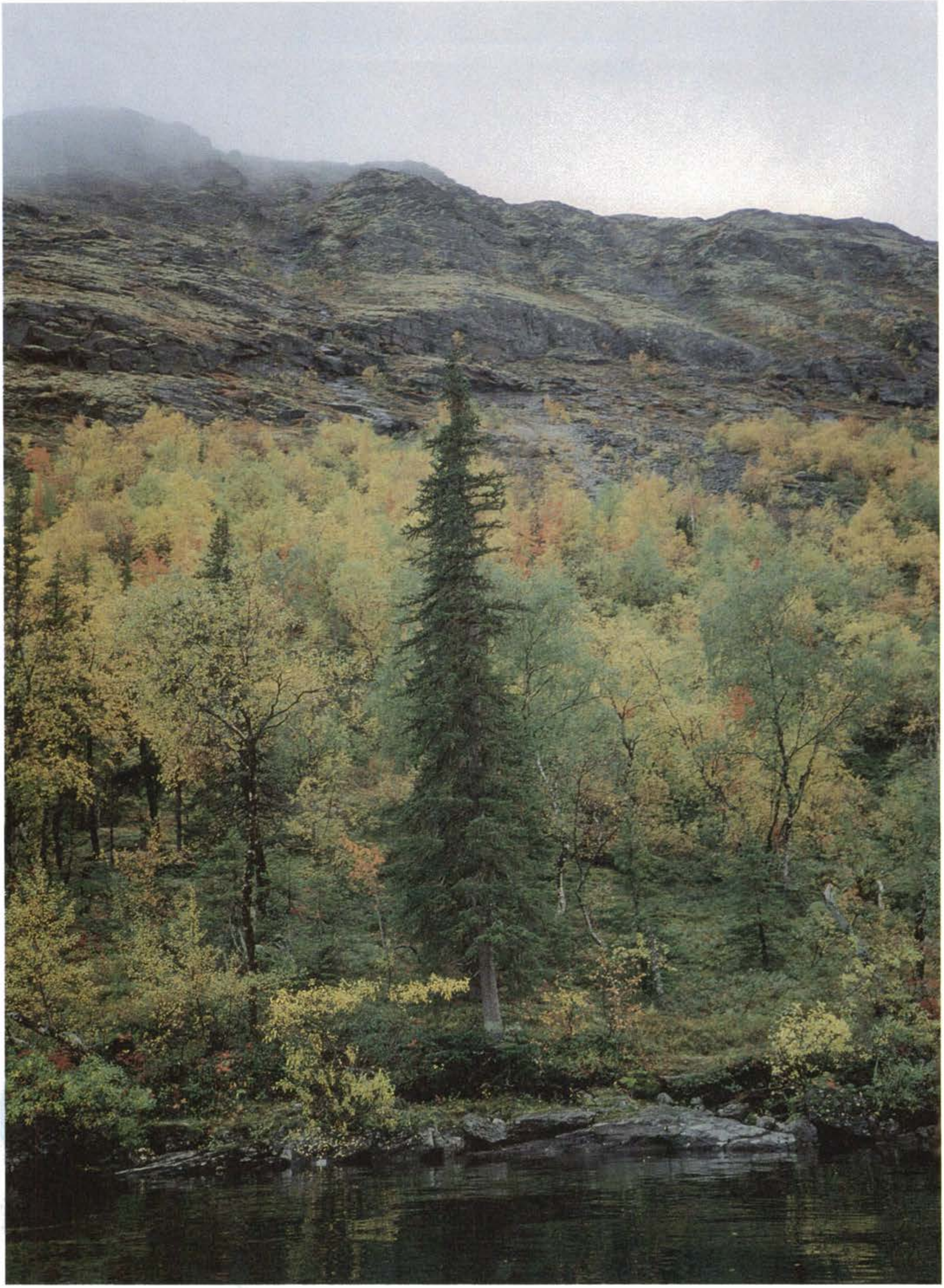


Executive summary

The European Arctic: Remote, but still threatened

Mixed forest in the Kola Peninsula. (photo: Torfinn Kjærnet)

Despite its vast area, small human population, and limited industrial and economic development, the European Arctic is affected by several aspects of human activity. This large area of sparsely populated land and sea has been seen as a region for unlimited resource harvesting, into which large amounts of contaminants, such as nuclear wastes, can be deposited. The Kola Peninsula and surrounding areas are particularly affected by heavy industrial pollution, large scale physical encroachments and military installations and activities. Large amounts of improperly stored radioactive material in this area are serious threats to all of the European Arctic. Intensive, partly unregulated fisheries in the Barents and Norwegian Seas, have over-exploited key species. Even in remote, high arctic areas, high levels of long-range transported contaminants are found in mammals and birds.

Oil exploration, and other activities based on obsolete technologies, cause heavy pollution in some areas. The expected large scale oil and gas development in the region will increase the potential for major environmental impacts seriously.

Europe's last wilderness – a unique asset

While the European Arctic is substantially influenced by humans in some areas, it is at the same time an area with environmental assets which are unique in Europe. Its large wilderness areas are virtually pristine and intact, and the habitats, vegetation and populations of fish, birds and mammals are far less affected by man than elsewhere in Europe. The marine ecosystems are highly productive and of great economic, social and cultural importance, not only to the region itself, but also to many other European nations. Geophysical processes in the region are of major importance in the regulation of the global climate. The region offers unique opportunities for monitoring changes in the global environment, and for studying other natural processes of global significance. It can confidently be predicted that in a world where areas unaffected by man are rapidly decreasing in size and number, the European Arctic wilderness and its ecosystems will - if properly managed - become an increasingly valuable asset.

The state of the European Arctic environment can be summarised as follows:

The High Arctic islands

(Svalbard, Franz Joseph Land, the northern part of Novaja Zemlja and the surrounding areas of the Barents and Kara Seas)

- Are "sinks" for long-range transboundary air and marine pollution.
- Contain large, undisturbed wilderness areas.
- Have marine and terrestrial ecosystems that are largely regulated by natural processes.
- Have large populations of naturally occurring species.
- Have low human population densities, and limited human activities and impacts.
- Are highly valuable as scientific and environmental reference areas.
- Are important in climatic processes, and as indicators of other globally important environmental changes.

The north-eastern seas and tundra

(Eastern Barents, Pechora and Kara Seas, adjacent coastal and tundra areas and large river estuaries)

- Are important pathways (rivers, sea ice, ocean currents) for pollutants (radionuclides, hydrocarbons, persistent organic pollutants (POPs), heavy metals etc.) to the European Arctic.
- Contain large amounts of radionuclides dumped in the Kara and Barents Sea.
- Have high persistent organic pollutants levels in top predators in the Svalbard area.
- Have depleted capelin stocks (a key species) in the Barents Sea.
- Have areas with oil contamination of soil and watercourses.
- Have substantial areas where the wilderness has been degraded (oil/industry infrastructure encroachments).
- Are home to indigenous peoples.
- Have large marine, coastal and tundra wilderness areas.
- Have highly productive (the Barents Sea) and healthy marine ecosystems and unique drift ice ecosystems.
- Contain large populations of naturally occurring species, including seabirds, seals, and characteristic Arctic species (e.g. polar bear, walrus).
- Are of high value as scientific and environmental reference areas.

The north-western seas

(Icelandic waters, the Greenland Sea and northern Norwegian Sea)

- Contain expanding populated, cultivated and industrialised areas in Iceland.
- Contain unique geological landscape features in Iceland.
- Is completely deforested (historically; overgrazing).
- Have over-exploited cod stocks, while herring stocks are recovering.
- Still contain large marine areas that are highly productive, with healthy and economically important marine ecosystems.
- Have large populations of naturally occurring species, including seals and seabirds.
- Are home to viable populations of large baleen whales.
- Are of high value as scientific and environmental reference areas.
- Have low levels of contamination.
- Are a region of globally important climatic processes (atmosphere – sea ice – ocean).

The Fennoscandian region

(Northern Scandinavia and Finland, Kola Peninsula/ Murmansk area, and the White Sea).

- Is severely affected by pollution in the central Kola area (watercourses, estuaries, soil, vegetation, human health) as well as in other Kola rivers and the Pechora and Dvina.
- Has potential for large-scale environmental disasters from improperly stored radioactive waste, petroleum development, new infrastructure and over-exploitation of biological resources.
- Has comparatively large human populations, as well as industrial and other activities.
- Is home to indigenous peoples.
- Contains large areas of relatively undisturbed nature: Tundra, taiga, parts of large river ecosystems and estuaries.
- Has large populations of naturally occurring marine and terrestrial species.

Threats and challenges

Threats

The main current threats to the European Arctic environment are:

- Habitat fragmentation, degradation or destruction.
- Over-harvesting of biological resources.
- The potential for radioactive contamination.
- Persistent organic pollutants.
- Oil pollution.
- Tourism in vulnerable areas.
- Introduction of alien species and diseases.
- Cumulative impacts.
- Long-range pollution transport.
- Climatic change.
- Ozone depletion, UV-radiation.

Challenges

Three characteristics of human activities both threaten (challenge) the integrity of the European Arctic environment and provide opportunities for reconciling such activities with environmental needs:

- The need for development: Economy and industry in the north-west of the Russian Federation.
- The tragedy of the commons: Sustainability of national and international fisheries.
- "The last frontier" attitude: Obsolete and ageing practices and technologies are more accepted in remote and 'wild' areas.

Objectives and recommendations

Long-term goals

The following long term goals are proposed for the European Arctic environment:

- *To protect and maintain the biological diversity and wildlife habitats of the area in their relatively pristine condition.*
- *To protect and maintain the biological productivity of the European Arctic ecosystems as a basis for sustainable development.*
- *To secure the long term environmental basis for local and indigenous peoples in the area.*

Objectives and actions

Based on the current threats, future development trends and long term goals, the following objectives and actions are recommended:

Objective I
Integrate environmental concerns into the economic and industrial activities in the area, in particular in north-western Russia.

Both Russian and other European Arctic national legislation include environmental regulations and standards for most types of activities. It still remains a challenge to ensure that these are enforced and complied with, particularly in Russia.

Actions needed:

1 Development of internationally environmental management regimes, standards, impact assessments, reporting procedures and mitigating measures.
2 Development and international exchange of expertise on arctic environmental management and science.
3 Establishment of economic incentives for environmentally safe operations and equipment, including insurance and taxes.
4 Improvement of scientific data and knowledge on the European Arctic environment and impact factors. It is important to realise that ecosystem research in the Arctic in most cases is not comparable to ecosystem research in more temperate areas.
5 Improvement of information on European Arctic environmental issues to the public and to decision makers.

Objective II

Ensure sustainable management of European Arctic marine living resources and ecosystems.

If properly coordinated, the existing management tools and scientific knowledge of the European Arctic countries could probably provide a sufficient basis for sustainable management of the marine resources in the area. Currently, however, these tools are insufficiently coordinated and partly disputed.

Actions needed:

1 Establish internationally agreed upon management regulations, quotas, and inspection mechanisms in international and disputed waters.
2 Improve multi-species and ecosystem management models.
3 Enforce efficient countermeasures against over-harvesting, by-catches, and incorrect catch reporting.
4 Reduce or remove economic incentives for unsustainable practices.

Objective III

Protect European Arctic wilderness areas and important habitats.

Large parts of the European Arctic can still be characterised as wilderness. While the northern parts of the area have many established and planned protection regulations, wilderness areas are being challenged in the north-west of the Russian Federation and Fennoscandia, and partly in Iceland.

Actions needed:

1 Support the development and implementation of the Circumpolar Protected Areas Network (CPAN) strategy of the AEPS/Rovaniemi process.
2 Develop national and regional coordinated plans for environmental management and infrastructure development in non-protected areas in order to minimise habitat fragmentation.
3 Implement the provisions of the Biodiversity Convention at the national and regional levels in the European Arctic, including development of national strategies for conservation of biodiversity.

Objective IV

Reduce long-range transportation of pollution to the Arctic.

Some agreements restricting the production and use of certain environmentally hazardous substances are to a large degree in force (i.e. ozone depleting substances), while others (organochlorides, heavy metals, CO_2), are being negotiated. Economic and political interests, as well as insufficient scientific data, slow the progress of this work.

Actions needed:

1 Research in order to identify sources, transport routes, mechanisms for, and biological effects of long range pollutants.

2 Contribute to reducing economic incentives for the production and use of harmful substances that may be transported to the Arctic.
3 Support the development of protocols under UN/ECE Convention on long-range Transboundary Air Pollution in order to contribute to the reduction of pollution transport to the European Arctic.
4 Consultation with non-ECE nations whose emissions and discharges of pollutants contribute to pollution of the European Arctic.
5 Contribute to improvement of testing and knowledge of the effect of new substances potentially harmful to the European Arctic environment.

Objective V
Ensure safe storage of radioactive wastes in the region and operation of nuclear facilities.

Radioactivity levels in the European Arctic environment are currently relatively low. Marine dumping sites and most land storage facilities and installations are recorded.

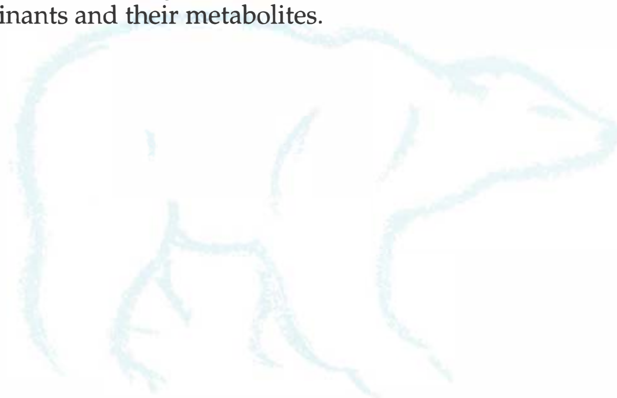
Actions needed:
1 Contribute financially and technologically to the improvement of currently insufficient storage facilities in the European Arctic to long term safety standards.
2 Contribute financially and technologically to maintenance, upgrading or decommissioning of unsafe nuclear facilities.
3 Support research in order to identify potential transport routes and mechanisms for radioactive pollutants

Objective VI
Utilise the relatively intact ecosystems and low impact levels in the area as a reference for regional and global environmental monitoring, and for research to provide new knowledge on fundamental ecological processes.

Several international long term monitoring programmes are operating or being established in the European Arctic. European and other nations are currently increasing their co-operative research effort in the area.

Actions needed:
1 Further develop long trend global and regional environmental monitoring programmes in the European Arctic, primarily based on existing and planned programmes:
   (a) Climatic change (radiation, stratospheric ozone, ocean, sea ice, glacier, paleogeology and vegetation changes studies);
   (b) The state of High Arctic ecosystems (marine and terrestrial);
   (c) Biodiversity mapping and monitoring (species, populations, distribution).

2 Basic studies of ecosystem functions and individual adaptations:
   (a) Marine ecosystem functions in ice-free and ice-covered waters and in estuary and coastal waters;
   (b) Vegetation and soil (permafrost) response to climatic change;
   (c) Individual and synergistic effects of contaminants and their metabolites.



Polar bears in Svalbard (photo: Ian Gjertz).

1 Introduction

This report gives a brief overview of the environmental situation in the European Arctic. It presents the main environmental challenges for the region, and recommendations for policies and management. Several European nations have been and are still active in exploration, resource exploitation, and research in the region. This international activity is likely to increase. As such, the European Arctic is a part of Europe's common environmental and cultural heritage.

The aim of this report is to increase the European awareness of the fact that the region is of great value to all of Europe, and that it is also facing serious environmental threats. Therefore there is a strong need for a common European effort to manage the Arctic environment in a sustainable manner for the future.

The report does not attempt to give a fully comprehensive picture of the region, its ecosystems, or its plant and animal species. It is produced over a brief time period, based on the information available. The references are restricted to the most basic literature. The background text is primarily intended to facilitate an understanding of the important and characteristic features of the European Arctic environment, and the impacts of human activity upon it.

Several international processes are underway producing detailed and well documented status reports for various aspects of the Arctic, such as:

- the AMAP Assessment under the Rovaniemi process; a large scale arctic environmental assessment produced in co-operation between the eight arctic countries.
- the report on the State of the Barents Sea Environment, by the Russian-Norwegian

Figure 1.0 **The European Arctic**. (See p. 16 for definition.)

Marine Environment Group.
- the Nordic Council of Ministers' report on the Nordic Arctic Environment.

The above reports are to be published in late 1996 or 1997.

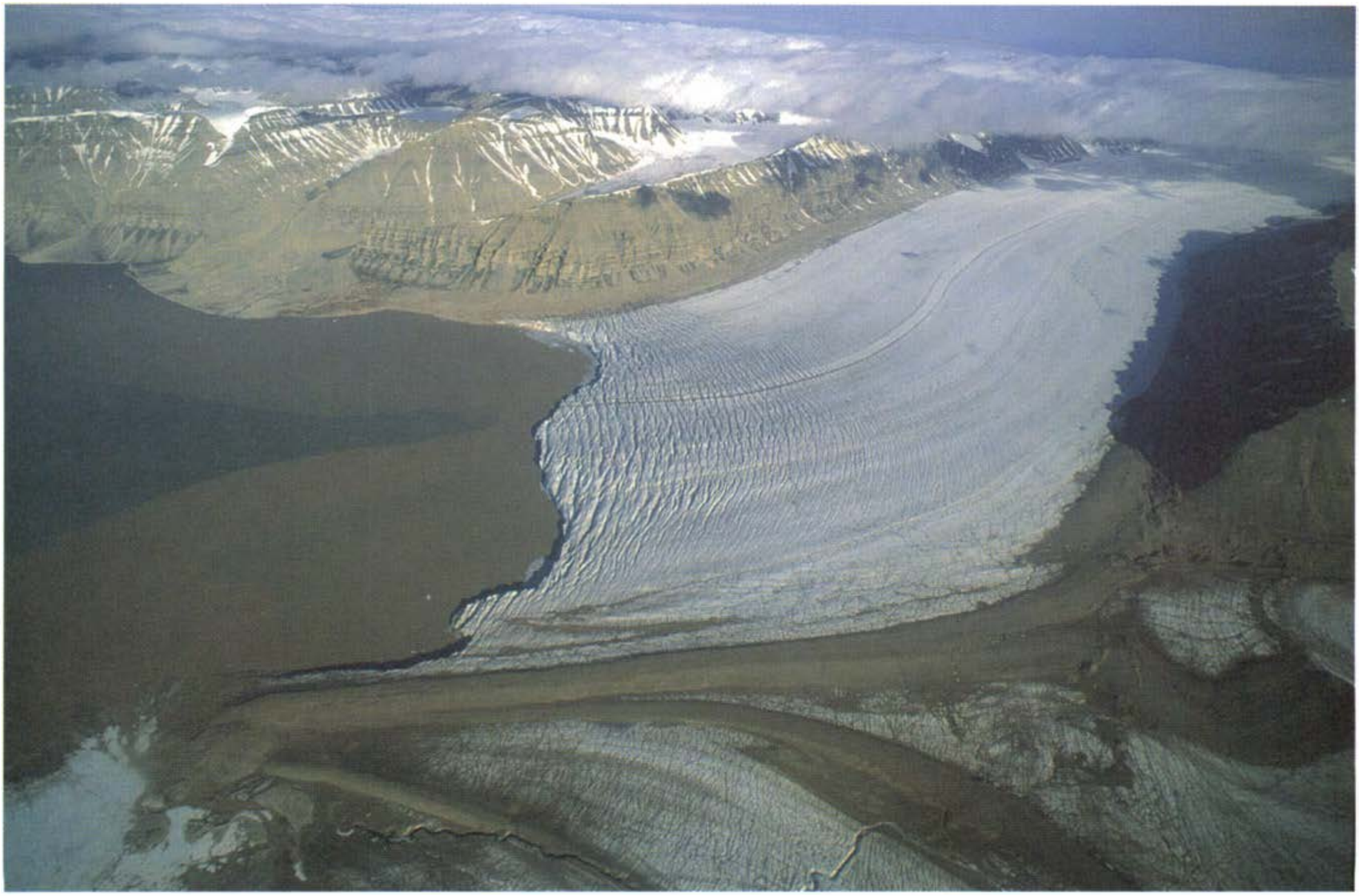
There is no single geographical definition of the extent of the Arctic, and even less so of the European Arctic. There is also no political agreement on the definition of the concept. The definition used in this report is therefore deliberately imprecise, as the geographical distribution of the various phenomena, species, impacts, characteristics, etc. of importance to the region do not always coincide (Figure 1.0).

For the purpose of this report, the European Environment Agency has identified the European Arctic as follows:

- Iceland, Svalbard archipelago, Franz Joseph Land, and Novaja Zemlja,
- Scandinavia and Finland north of the Arctic Circle,
- Murmansk oblast and northern Arkangelsk oblast, northern Karelia, and Nenets east to Yamal,
- the seas of these land areas as well as the international waters between them.

The report has been prepared for the European Environment Agency by the Norwegian Polar Institute with suport from GRID Arendal and several other institutions (see Acknowledgement).

2 Geophysical characteristics



Shaping the landscape: Arctic glaciers transport large amounts of sediments to the sea. (photo: Torfinn Kjærnet)

The main geophysical characteristics of the Arctic are low temperatures with pronounced seasonal variations in climate, including a large variation in the solar radiation between the long night of winter and the long day of summer, and the extended periods of ice and snow cover. On land the temperatures vary greatly through the seasons, and permafrost strongly influences soil formation, vegetation structure, and hydrological processes. Glaciers are predominant only on the High Arctic islands.

Arctic sea temperatures are more stable than land temperatures throughout the year. Sea ice development strongly influences the marine ecosystem dynamics. The Barents and Kara Seas are among the largest shallow continental shelf seas in the world. Due to influxes of warm air and water from the south, these areas are generally the mildest and most humid parts of the Arctic. These ocean and air currents, along with the Transpolar Current flowing out from the Arctic Basin into the waters of the European Arctic, also make the area a "sink" for long-range contaminants and pollutants.

The geophysical characteristics of the arctic seas also contribute to large-scale deep water formation east of Iceland and Greenland. The function of these seas as a CO_2 *sink, along with their large areas with high albedo caused by ice and snow, are important features affecting the global climate system and the regulation of the greenhouse effect.*

Regional climate

In addition to the low temperatures and the strong seasonal variations of light and precipitation, the factors most strongly influencing the climate of the European Arctic are:

- the warm North Atlantic Current , which penetrates into the Barents Sea from the south-west, affecting the climate in all but the easternmost parts of the region,
- the low-pressure weather patterns frequently sweeping in from the south-west, transporting warm humid air into the Arctic.

The influx of warm water from the south-west accounts for the southern part of the Barents Sea remaining virtually ice free throughout the year.

The climate from northern Iceland, via northern Norway and into the Barents Sea up to 79°N on the west coast of Svalbard is of a 'marine sub-arctic' or 'tundra' type, (Strahler 1969). It is characterised by persisting cloudy skies and strong winds, high precipitation, and frequent east-moving cyclonic storms. In the southern parts of Iceland and northern Norway temperatures are around 10°C during the warmest month, and seldom below –7°C during the coldest month.

A more 'continental sub-Arctic' climate is found in the inland parts of the European Arctic from Scandinavia to Siberia. This climate is colder and drier, with cool, short summers. Less than four months of the year have average temperatures higher than 10°C (Table 2.1).

Table 2.1. **The weather**: Average air temperatures and precipitation in the European Arctic, 1961-92.(Source: Norwegian Meteorological Institute)

Location	Average Temperature °C January	Average Temperature °C July	Precip. (mm)
Arkangelsk	-16.4	15.0	530
Murmansk	-11.5	11.8	446
Petrozavodsk	-13.9	15.0	595
Luleå	-11.5	15.5	506
Vardø	-5.1	9.2	563
Longyearbyen	-14.6	6.5	210
Bodø	-2.2	12.5	1020
Jan Mayen	-5.7	4.2	687
Reykjavík	-0.5	10.6	799

Topography

The land areas

Several glaciations during the past 400,000 years have shaped the landscape of most of the European Arctic. Between the mountains of northern Scandinavia and the northern

Patterned ground: A typical feature of permafrost areas. (photo: Torfinn Kjærnet)

Figure 2.1 **Topography, bathymetry and major ocean currents of the European Arctic**. (Source: GRID-Arendal).

branch of the Ural mountains in the east, the land has a comparatively low relief. The arctic archipelagos Novaja Zemlja, Franz Joseph Land, and Svalbard are characterised by glacial features and large ice caps. Iceland differs from the rest of the region by the mostly volcanic origin of its landscape. Lowlands border the White Sea to the south and west, and coastal plains border the Kara Sea and the south-east of the Barents Sea (Figure 2.1). Continuous permafrost in the European Arctic is found on the High Arctic islands and in the Russian Federation east of the White Sea. Some areas of discontinuous permafrost occur in the northernmost areas of Norway, Finland and the Kola Peninsula (Figure 2.2). On permafrost, summer thawing of the ground (the "active layer") is only between 15

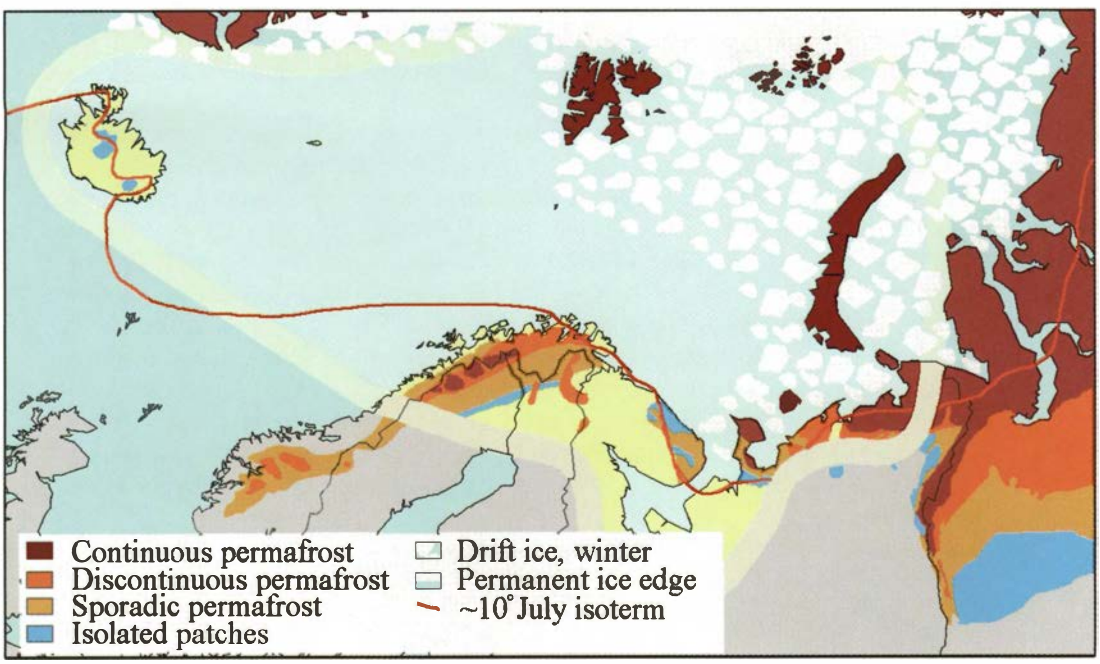
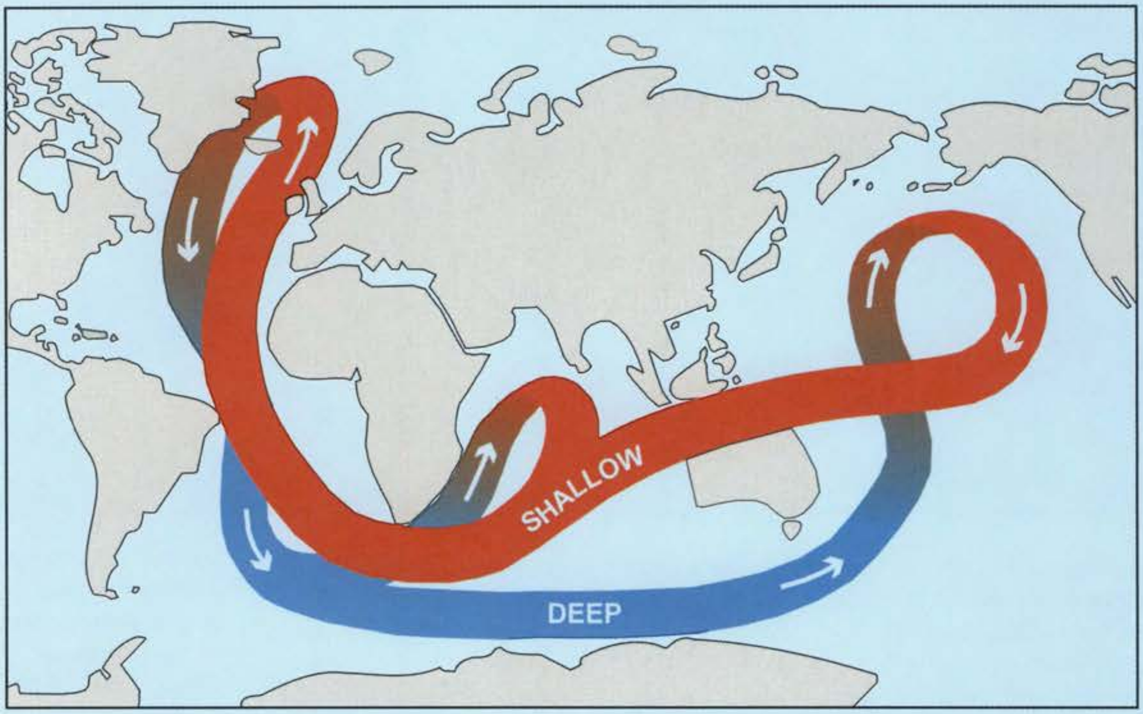


Figure 2.2 **Basic properties of the Arctic environment:** The distribution of permafrost, winter and summer sea-ice and the 10°C July air isotherm in the European Arctic. (Source: GRID-Arendal).

BOX 1 – EUROPEAN ARCTIC SEAS AND THE GLOBAL CLIMATE

The sun heats the Earth nonuniformly, delivering most of the heat to tropical areas. Both the atmosphere and the oceans redistribute the heat. The oceans' role is often referred to as the termohaline circulation: Warm water in the upper layers flows towards the poles from lower latitudes. In the north the water becomes cold and more saline, and it sinks to the ocean floor as it becomes denser and heavier. This cold, deep water returns towards the equator where it gradually upwells as it is heated and then flows towards the poles again. The formation of deep, cold water is a fundamental component of global oceanic circulation, and of global and regional climate regulation processes.



Global ocean circulation: Cold Arctic water absorbs atmospheric CO_2, sinks and flows southward. This is a major driving force for the warm, northward surface currents that create a relatively mild climate in Northern Europe. (Source: Eystein Jansen)

The European Arctic region is one of the world's most important areas for deep, cold water formation. The main areas for this process are the Iceland Sea, the Greenland Sea, and along the Norwegian Atlantic Current as it moves into arctic waters (Mauritzen & Owens 1994).

An added effect of the formation of deep, cold water, is that it absorbs enormous amounts of the greenhouse gas CO_2. Once absorbed and transported to the bottom layers with the cold water, the CO_2 can remain removed from the atmosphere for 500 years. Without this mechanism, substantially more CO_2 would enter the atmosphere, contributing to the greenhouse effect and to global warming.

Current models predict that global warming will cause the temperature in the Arctic to rise approximately twice the global average. If such a warming causes reduced snow and ice cover in the Arctic, the high albedo of the region would be reduced and more solar energy would be absorbed. Deep water formation might be reduced, the large-scale termohaline circulation in the ocean might be affected, and the ocean CO_2 storage capacity might be reduced. All these factors could contribute to increased global warming and thus to a possible feedback effect in these areas, where the effect of a warming increases the regions susceptibility to further warming. Current models cannot determine what the long-term effects of such positive feedback effects would be.

Global warming is expected to have more dramatic effects on terrestrial systems than on marine systems, since the former often have sharper boundaries between zones and slower movement of populations. Permafrost characterises much of the European Arctic land areas. Melting or reduction of permafrost could have dramatic effects on soil, vegetation, and erosion, and it would completely alter the terrestrial landscape of the Arctic. Many theories indicate that global warming could lead to rising sea levels. This would seriously affect many low-lying parts of the European Arctic, particularly the smaller islands.

cm and 5 m, depending on the vegetation cover, with the shallowest depth within peat areas. This leaves a poorly drained, marshy landscape with limited plant growth. Forests do not grow in areas with continuous permafrost. Under the active layer the ground can be frozen to a depth up to 500–600 metres.

The oceans

The European Arctic ocean floors are also heavily influenced by glacial activity and by sediments. The sediment layer on the western slope of the Barents shelf is at places more than 4,000 m thick. The Barents Sea is among the largest shallow shelf seas in the world. The Kara Sea is on average shallower than the Barents Sea. The deepest parts of the European Arctic seas are along the continental margins separating the Barents Sea from the Norwegian Sea to the west and the Arctic Ocean to the north. The northern parts of the Norwegian Sea basin are very deep (>3,000 m), and the basin of the Arctic Ocean is more than 4,000 m deep. The semi-enclosed White Sea has a maximum depth of 350 m.

Oceanography

The Barents Sea is the central sea of the European Arctic region. Surrounding the Barents Sea, and also included within the region, are the western Kara Sea, the eastern Greenland Sea, and the north-eastern part of the Norwegian Sea.

The water masses

The waters of the Barents and Norwegian seas can be subdivided into Atlantic, Arctic, coastal, and deep ocean waters. The atlantic waters are influenced by the North Atlantic Drift, while the arctic waters are influenced by the Transpolar Current which transports cold water and ice from the east past the North Pole through the Fram Strait between Greenland and Svalbard, and by cold water flowing in from between Novaja Zemlja and Franz Joseph Land.

The Kara Sea and the adjoining White and Pechora Seas are less influenced by the North Atlantic Drift than are the Atlantic waters of the Barents Sea. They thus receive less warm sea water and nutrients. These seas are also covered by ice eight to twelve months per year. These factors contribute to limiting the biological production of these seas. Their water structure is primarily influenced by the Barents Sea, the Arctic Ocean, and runoff from the Ob and Yenisey rivers. This river runoff contains substantial amounts of particulate matter and pollutants. The Russian rivers contribute nearly 90per cent of the freshwater entering the Arctic Ocean.

The discharge of river ice into these northern seas is considerable. The annual river ice transport to the Arctic Ocean is estimated to be 2,340 km³ (Melnikov 1991), which is nearly in the same order of magnitude as the annual transport of sea ice to the Fram Strait (about 2,600 km³).

The annual mean water temperatures of the Barents sea fluctuate with an amplitude of 1–3°C and a periodicity of three to ten years. These variations strongly affect the biological productivity of the system. Atlantic waters have an average temperature of between 3.5° and 6°C and a salinity of 35 per thousand. Arctic waters have an average temperature of 0°C and a salinity of between 28 and 33 per thousand.

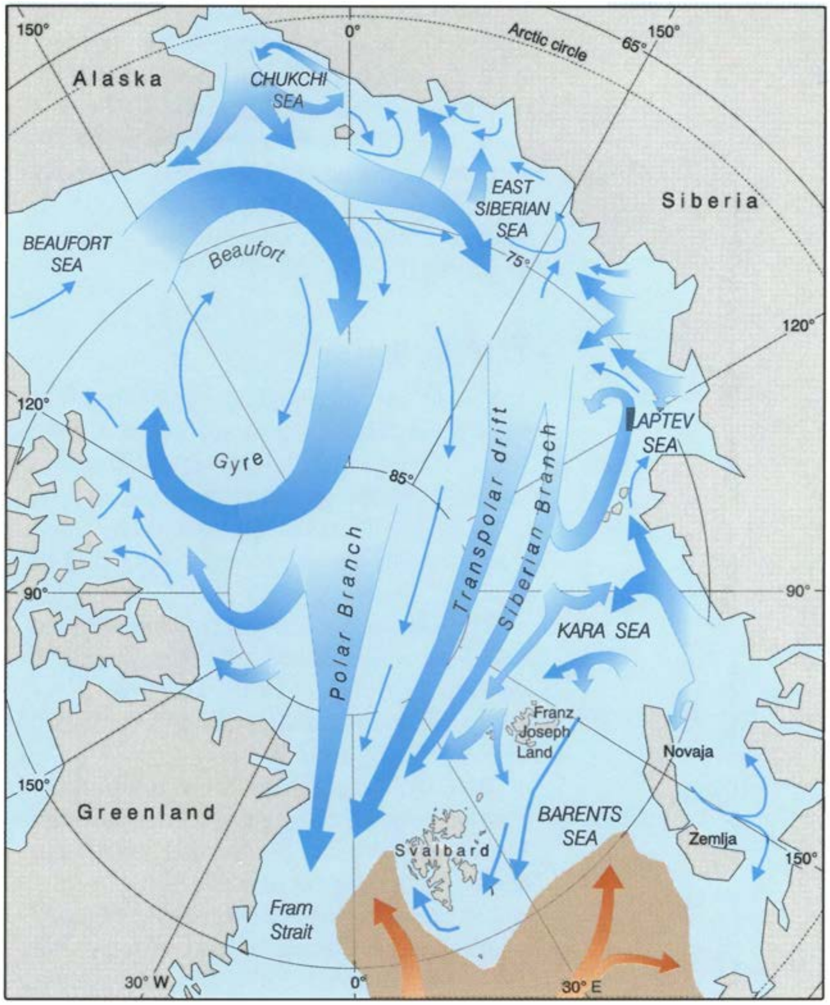


Figure 2.3 **Polar Basin ice drift and ocean currents**: Ice and sea water generally move from the eastern Arctic toward the western European Arctic, almost the only "outlet" of this ocean. (Source: Norwegian Polar Institute)

The boundary between the south-flowing arctic water and the north-flowing warmer atlantic water in the Barents Sea is called the *Polar front*. Vertical mixing along the Polar front brings up nutrients from the bottom, and creates a zone of high biological production. The position and shape of the Polar front is controlled by currents and the topography of the ocean floor.

The sea ice

A three to four metre thick permanent ice sheet covers about eight million km^2 of the Arctic Ocean north of Svalbard and Franz Joseph Land. Surrounding this area, an additional 15 million km^2 are covered by seasonal pack ice for four to eight months of the year.

The Transpolar Current transports about 2,600 km^3 of sea ice annually from the Eurasian Arctic out through the Fram Strait between Svalbard and Greenland (Kvambekk & Vinje 1993) (Figure 2.3).

Both the Kara Sea and the White Sea are covered with ice during the winter months. The western coast of Svalbard is usually partly ice-free during the winter. During spring and summer the ice retreats north to Franz Joseph Land and north of Svalbard, and the rest of the European Arctic oceans remain ice-free all year.

This seasonal retreat of the sea ice is vital to biological production in these seas. The melting ice forms a stable, nutrient-rich surface water layer with optimal conditions for phytoplankton blooming, and correspondingly high secondary production. This area attracts fish, seabirds, and marine mammals. This is known as the "ice-edge effect".

Hydrology

The European Arctic is in general among the oldest land areas on earth. Apart from Iceland, where the oldest rock formations are only 16 million years old, most of the region originates from 400 to 600 million years ago. Since then the land has continuously been formed through continental drift, various ice ages, and other natural changes.

Due to topography and climate, the land areas of the European Arctic are rich in freshwater resources, both originating in the Arctic and flowing in from lower latitudes. In general, countries with long coast lines relative to their land area, such as Norway, Sweden and Iceland, have a large number of relatively short rivers with small river catchments. Five rivers in the European Arctic have catchment areas larger than 50,000 km^2 (in total 31 in Europe), and four of these lie in the Russian Federation (Kristensen & Hansen 1994). Of these the Severnaya Dvina and Pechora rivers rank as number five and six in Europe respectively. These rivers, however, are small compared to the Volga – the largest river in central Europe – with a catchment area four times that of Severnaya Dvina.

The rivers in the eastern part of the Arctic are in general larger than those found in the west. Mean annual inflow of fresh water into the Norwegian and Barents Seas, including the White Sea, is 735 km^3, whereas the inflow to the Kara Sea is estimated to 1347 km^3. In spite of the fact that the basins of Ob and Yenisey are situated to the east of the Ural mountains, their annual run-off of approximately 530 and 603 km^3 respectively, should be taken into account due to significant environmental impact on the marine ecosystem of the European Arctic.

Northern Norway has the highest surface run-off in the Arctic. The run-off from terrestrial areas of the European Arctic contributes more than 40 per cent to the total freshwater inflow to the Arctic Ocean.

Many European lakes were formed or reshaped 10–15,000 years ago, during the last glacial period. During this time, the ice sheet covered northern Europe, but in central and southern Europe it was only found in mountain areas. In general, the areas that were affected by the glacier sheet, today have many natural lakes. Thus, Norway, Sweden, Finland and the Karelo-Kola part of the Russian Federation have numerous lakes of various sizes. Twenty-one of the 24 lakes in Europe with surface areas larger than 400 km^2 are found in this area, and of all the lakes in Europe with surface area larger than 0.01 km^2, between 65 per cent and 90 per cent are found in the Arctic.

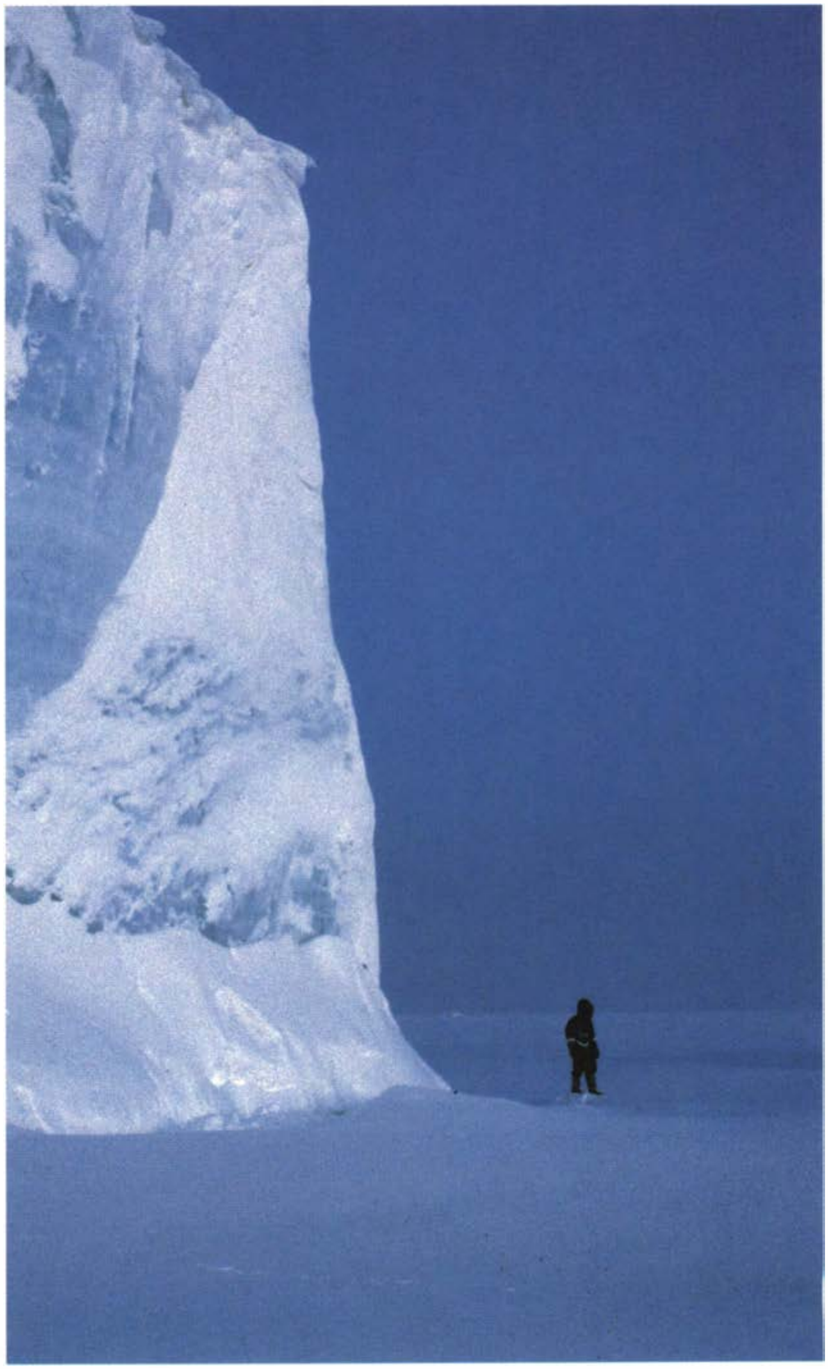
Many lakes were also created in Iceland during the last glacial period, but none of these have surface areas larger than 100 km^2. The biggest lakes and rivers are located in the eastern part of the area, in the Russian Federation. This is mainly due to the amount and topography of the loose materials deposited here during the past glacial periods, in addition to the permafrost which prevents the water from penetrating into the ground.

Regions with low gradients generally have larger drainage areas than steeper regions have. In contrast to the western part of the European Arctic, which is dominated by high and steep mountains, the north-west Russian Federation is made up of enormous flat steppe-like plains of tundra and taiga.

A prominent difference between the freshwater resources in the Arctic and those in more southern areas is that much of the water is bound above and below the ground as glaciers and permafrost. Illustrating the extent of ice cover in the High Arctic, 80 per cent of Franz Joseph Land, 60 per cent of Svalbard, and 11 per cent of Iceland are covered by glaciers.

The largest glaciers on Svalbard and Iceland cover an area of approximately 8,500 km^2 each. Thus, each of them covers an area as big as all the glaciers in Scandinavia and the Alps together. The largest glaciers of the European Arctic are around 500 metres thick.

Much of the permafrost in the region penetrates several hundred metres down into the ground. In other parts of the regions e.g. some places on Iceland and in the Scandinavian mountains, the permafrost only reaches a few metres deep. The glaciers bind huge masses of water and cover the ground, but they also supply their downstream areas with a steady flow of meltwater during spring and summer. The permafrost prevents water from penetrating into the ground. A few metres of the ground surface is thus through spring and summer constantly saturated with water, producing wetlands and peat. During this time of the year, the river flow and water levels of the lakes in the region shift dramatically.



Climate archive: Layers from hundreds of years of winter snowfall are compressed in Arctic glaciers. (photo: Ian Gjertz)

Cold but rich: The European Arctic is home to some of the largest seabird populations in the world. (photo: Georg Bangjord)

3 Biota of the European Arctic

The European Arctic is dominated by the marine environment in its central and northern parts. Terrestrial ecosystems are limited to Arctic islands and to the continental land masses at the southern limits of the region. In general, strong seasonality, with its associated intensification in environmental harshness, distinguishes the polar environment from intermediate and lower latitude environments. The evolution of Arctic organisms has therefore led to specific adaptations to seasonal stress. Most Arctic ecosystems subject to strong environmental variability have relatively few species, but within them there can be large populations of one or more of these species. The more stable environments, such as the marine benthic environment, may contain levels of species diversity similar to that of more southern latitudes.

Most of the European Arctic – including the high Arctic islands – is biologically richer and more productive than other Arctic areas at similar latitudes. This is primarily due to a large, continuous influx of warm, nutrient-rich water-masses from the south, with accompanying warm winds, as well as a steady supply of nutrient-rich water masses from the Arctic Sea to the north. The marine ecosystem of the European Arctic is also characterised by large natural variations in biological production and in standing biomass. At times these natural fluctuations have catastrophic consequences for populations. The main factors influencing these fluctuations are shifts in the direction and temperature of the water flowing into the system from the south.

Where cold Arctic water-masses meet the warmer water from the Atlantic ocean, there is a zone of strong thermal gradients and mixing, referred to as the polar front. The polar front shifts position depending on the volume, temperature and direction of the component water-masses. The area around the polar front in the Barents Sea is among the most productive marine areas in the world. This production supports many species of marine invertebrates, fish, mammals and sea birds. It also supports a large international fishing industry.

Most of the productivity in this area of otherwise low production is concentrated along the marginal ice-zone during spring and summer. The melting of sea ice creates a stable upper water layer with lower salinity. These stable water masses, combined with sufficient irradiation and nutrients, allow an enhanced production along the borders of the retreating pack ice. The northern Barents and Kara Seas are less productive because they are covered by ice most of the year, and only receive a limited influx of warm, nutrient-rich water. However, there is a net influx of nutrients to the European Arctic seas in the deeper water layers.

The terrestrial ecosystems of the European Arctic are less rich in species, and far less productive than the marine ecosystems. The land ecosystems are, however, far more stable, and are thus not adapted to large-scale fluctuations in climate or nutrients. The land areas are dominated by boreal forests in the south and by tundra on permafrost in the north. Winter survival is often the limiting factor for Arctic land species. Only a few animal species have developed life-strategies which enable them to spend all year in the Arctic terrestrial environment. Other animals in the European Arctic only take advantage of the bountiful Arctic summer biomass production – both on land and in the seas – by migrating north in the spring and south in the autumn. Migratory species thus constitute a large proportion of the summer fauna – especially on land – in the European Arctic.

General characteristics

This chapter describes the main biological components of the ecosystems in the European Arctic – in their natural state. A presentation of the actual status of these ecosystems – following centuries of human influence – is given in the following chapters.

With the exception of the high Arctic islands and Iceland, most of the Arctic areas of today's Europe have been inhabited by humans since the end of the last ice-age. The human population densities have, however, always been relatively low. During most of this time the human influence has been limited to local fishing, hunting and gathering, simple agriculture, and pastoralism.

The impacts of these activities were widespread, but not extensively damaging. There was little urbanisation in the region until the latter part of the 20th century. Except for some scattered towns and industrial areas in the Norwegian and Russian Arctic and in Iceland, the European Arctic is still largely a non-urbanised region. The high Arctic areas have not been permanently inhabited or extensively used by humans, except for a few limited settlements late in this century.

Compared with the rest of Europe, most of the European Arctic has only to a limited extent been influenced by man. The uninhabited areas in the north and east are the last remaining large wilderness areas in Europe. Most of the plants and animals in these areas exist in a relatively natural state.

Adaptations

The main factors controlling life processes in the European Arctic are low temperatures and extreme annual variation in sunlight, with up to three months of darkness during winter, an equivalent amount of continuous sunlight during summer, and an extreme rate of change in day length during autumn and spring. The highly variable environmental conditions between seasons and years, cause major fluctuations in access to food and shelter and limits the possibilities for reproduction (Cameron et al. 1993, Stokkan 1992).

Organisms living in the Arctic are therefore adapted to extreme cold, long periods of food shortage, and years of failed reproduction. They must also both grow quickly and accumulate fat efficiently during the brief summer. This fat is stored energy for use during periods of low food abundance during winter and early spring. Most species living in the Arctic have developed strategies of energy storage (Lindgard et al. 1992, Crete & Huot 1993).

The Arctic ecosystems are often regarded as relatively simple because of their low species diversity. There is, however, little competition between the few species that have adapted to this environment, and their population sizes are often correspondingly large. To survive in the harsh and variable environmental conditions, many Arctic species are generalists, i.e. they are able to utilise several food sources and survival strategies. In terrestrial organisms the adaptations resemble those of mountain species further south.

Marine organisms are mostly subjected to extreme environmental fluctuations in the upper part of the water column, particularly near the surface and in the littoral zone where sea ice scours the shores. Deep water and benthic organisms experience little annual fluctuations in light and temperature, but they are subjected to seasonal fluxes in food supply. The biological diversity is generally lowest in variable and high stress environments, whereas it is greater in environments experiencing less climatic fluctuations, such as the deeper marine habitats.

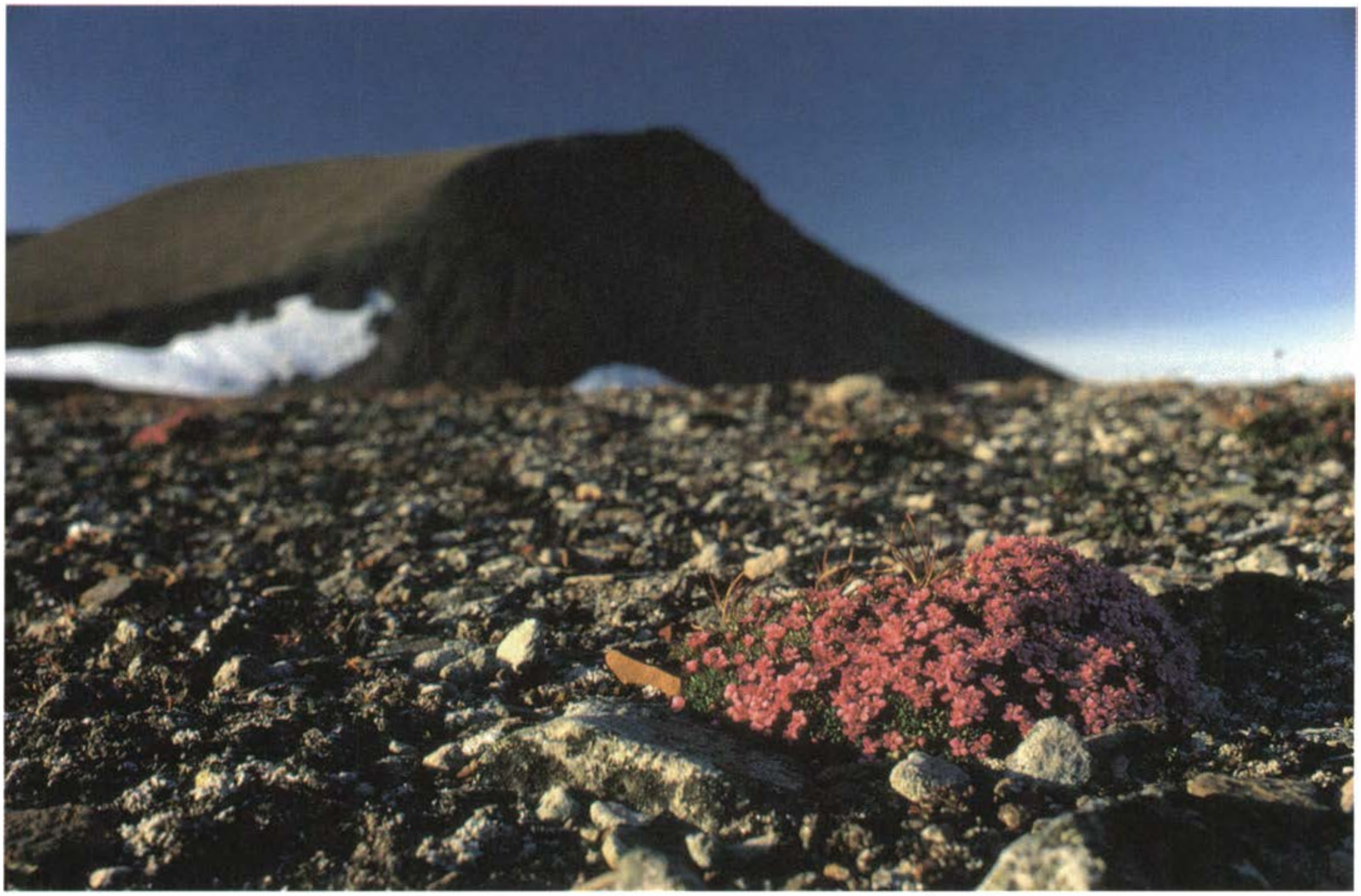
Although the species diversity in most Arctic ecosystems is low, the genetic diversity in many of these species is often high. This is most apparent in terrestrial and limnic (freshwater) environments. Genetic diversity strengthens the species' ability to adapt to variable environmental conditions.

Plants

Arctic plants must photosynthesise, grow, reproduce, and build energy reserves at temperatures close to the lower limit of biochemical processes. The growing season in the Arctic is shorter than further south, and the plants must tolerate continuous sunlight during this period.

All Arctic plants must endure months of sub-zero temperature during winter. The freezing of available water leads to desiccation, and the cold also requires adaptations to the freezing of water in the plant cells. The build-up of snow and ice during winter, and the damaging effects of wind, necessitate special structural adaptations.

As one moves north, the plants are



A harsh environment: Purple Mountain Saxifrage (*Saxifraga oppositifolia*) is the world's northernmost occurring flowering plant (photo: NP)

exposed to ever shorter and colder growing seasons. In the far north the plants must photosynthesise at about 0°C. There are also less and less insects to assist in pollination as one moves north from more temperate areas, and the soils are generally poorer and have lower nutrient levels.

To persevere under these conditions the plants have generally developed a range of characteristic adaptations or survival strategies:

Many Arctic plants have reduced exposed leaf areas. They have needles or small, narrow leaves, or they shed their leaves during winter. Such adaptations increase survival in cold climates, and when there is a lack of available moisture during winter.

Most plants in the High Arctic have developed low, creeping structures. This increases survival when cold, drying, and damaging winds are prevalent. Many Arctic plants also have bowl-shaped flowers and hairy stems and leaves, and many smaller plants grow in tussocks. Such structures capture and contain heat from the sun. Many of the trees of the boreal zone are formed such that they shed snow as it falls, thus avoiding breakage.

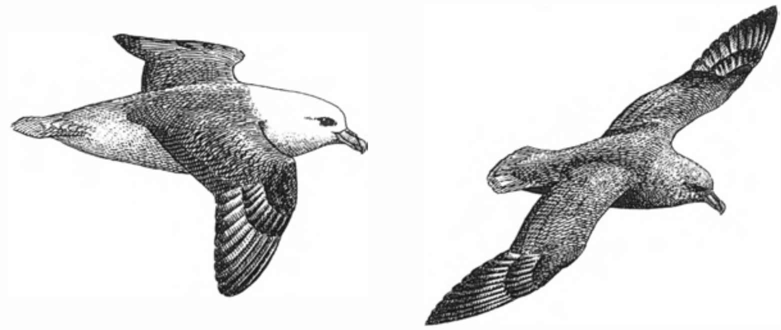
Many high Arctic plants reproduce asexually or vegetatively, which is an advantage in areas with few or no pollinating insects and where the climate makes sexual reproduction difficult.

In general, land plants of the European Arctic have low growth rates, low production capacities, inefficient sexual reproduction, and simple distribution mechanisms. Growth and production decreases as one moves further north. In regions further south, where there is more competition between species, these characteristics would place a species at a disadvantage. In the Arctic where there is little competition, there might be little advantage in being more productive or efficient, particularly since such features are energetically costly.

On land, much of the biomass is bound in standing vegetation, dead organic matter, or frozen soil. By contrast, organic matter in the marine ecosystems is in constant circulation.

Plankton, ice-algae and kelp

In the seas of the European Arctic, most of the primary production is performed by phytoplankton in the open water masses, and to a lesser extent by algae directly associated with ice. Phytoplankton is the basis for the Arctic



Fulmar *(Fulmarus glacialis)* (drawing: Viggo Ree)

marine food chains. It is also the biological part of the ecosystem which is most strongly linked to physical processes.

The most important plankton bloom in the European Arctic is during the spring, and it is often concentrated in the marginal ice-zone. The bloom is caused by the combination of a stable top layer of nutrient rich water with low salinity from the melting ice, and continuous sunlight. The dynamic situation with convection is also important. At times there is a deep chlorophyll maximum at 30–40 m, which probably indicates the light-limit for active photosynthesis in the area.

This "ice edge effect" is vital to the northern Barents Sea ecosystem because it occurs earlier than the general, larger spring bloom in open waters. It creates an early food basis for zooplankton, fish, seabirds, and mammals, which concentrate at the ice edge during this period (Sakshaug et al. 1992).

Ice-algae are directly associated with ice. They appear either as a thin brown mat on the underside of the ice, or as several metres long strands (*Mellosira arctica*). These algae are important as food for the ice-fauna. The melting of ice causes seeding of algae and plankton spores to the water column, a feature which may actually initiate early spring blooms.

Kelp is important only in shallow areas below where ice-scouring 'cleans' the shoreline. Kelp forests represent a very productive ecosystem. They use available nutrients to grow during the winter and spring, and may to some extent control the subsequent algal bloom in shallow waters. The high kelp forest biomass modifies a smooth substrate to an heterogeneous habitat which can sustain higher biodiversity of benthic flora and fauna.

Relatively dramatic structural changes in Arctic kelp communities have been identified. These are most often a result of grazing by sea urchins. Such changes in the benthic ecosystem may also be climatically induced, but long-term monitoring is needed to elucidate this.

Mammals and birds

Though animals are more mobile than plants, they face many of the same challenges regarding survival strategies in the Arctic. Animals living permanently in the Arctic, or that visit the area for parts of the year, all have special adaptations which enable them to survive in and take advantage of the Arctic environment.

Both marine and terrestrial mammals generally have relatively large body-volume to surface ratios (large, round bodies), and they can store considerable amounts of energy as body fat. Arctic birds and mammals are generally also quite mobile, even though the Svalbard reindeer are extremely sedative.

Many of these animals are also long-lived, and they reproduce often, but have few young each time. This adaptation increases the chances of successful reproduction when it is likely that reproduction in a given year will fail, and when mortality is high among the young, such as is generally the case in the Arctic.

Fishes and invertebrates

In the freshwater systems of the European Arctic there are few fish species, and there is a low diversity of invertebrates. On Svalbard, the Arctic char (*Salvelinus alpinus*) is the only fish species present, although the continental part of the Arctic contains additional species.

The diversity of freshwater fish at the population level is high, with anadromous, resident, and landlocked populations being common, in addition to many genetically isolated populations. All of them need suitable wintering sites in lakes or springs since most of the riverine habitats disappear because of freezing.

Most marine Arctic fish are benthic species, and the diversity is generally low. There are only a few pelagic fish species in the European Arctic, such as the polar cod (*Boreogadus saida*) and the capelin (*Mallotus villosus*). These pelagic species may however be very abundant and function as keystone species in the marine food chains, i.e. most of the energy flow is channelled through them from lower to higher trophic levels.

Pelagic fish have antifreeze components (glycoproteins) in their blood to prevent them from freezing solid when they come in contact with ice at sub-zero temperatures (saltwater freezes at -1.9°C, whereas a fish without antifreeze will freeze solid at about -0.5 °C if in contact with ice). Benthic fish remain relatively inactive at the bottom in a super-cooled state during cold periods, away from contact with ice since they commonly do not have antifreeze.

Invertebrates are relatively uncommon in the terrestrial environment. They are represented by only a few groups, e.g. collembolas, but they are quite abundant in the marine environment. The invertebrate fauna can be divided into pelagic, sympagic (ice-associated) and benthic faunas.

The pelagic invertebrates consist of several species of copepods, amphipods and krill, although only a few species are dominant in abundance (e.g. *Calanus glacialis*, *Themisto libellula*, and *Thysanoessa indermis*). Their life strategy is timed to the seasonal plankton bloom. The seasonal production of phytoplankton biomass is transferred by key zooplankton species to fish within approximately six months.

The sympagic invertebrate fauna consists mainly of a few species of amphipods that are adapted to live in association with ice, and to utilise the food chains originating from ice-algae. There is also an abundance of meiofauna (ciliates and nematodes) that live inside the ice in pockets and channels of brine which are formed in the freezing process of sea ice.

The benthic invertebrate communities are the most diverse of all animal communities in the Arctic. They play a critical role in the recycling of nutrients through the marine ecosystem, and form an important element in the food-chains which support extensive fisheries. The ice-scouring zone along the coasts is a very harsh environment with low diversity, but below 3–5 m there is an abundance of hard and soft bottom communities of invertebrates. These organisms are more or less sheltered from strong environmental fluctuations, but they experience seasonal fluctuations in food supply depending on the coupling of production on the bottom and at the top of the water column. For organisms living under permanent ice cover this coupling is weak and they are dependent on food transported into the Arctic Ocean from the marginal seas further south.

Because of the relative stability, and the immobility and longevity of many benthic organisms, they can be viewed as static integrators of the effects of changing local conditions, such as disturbances from fishing activities and the extraction of hydrocarbons.

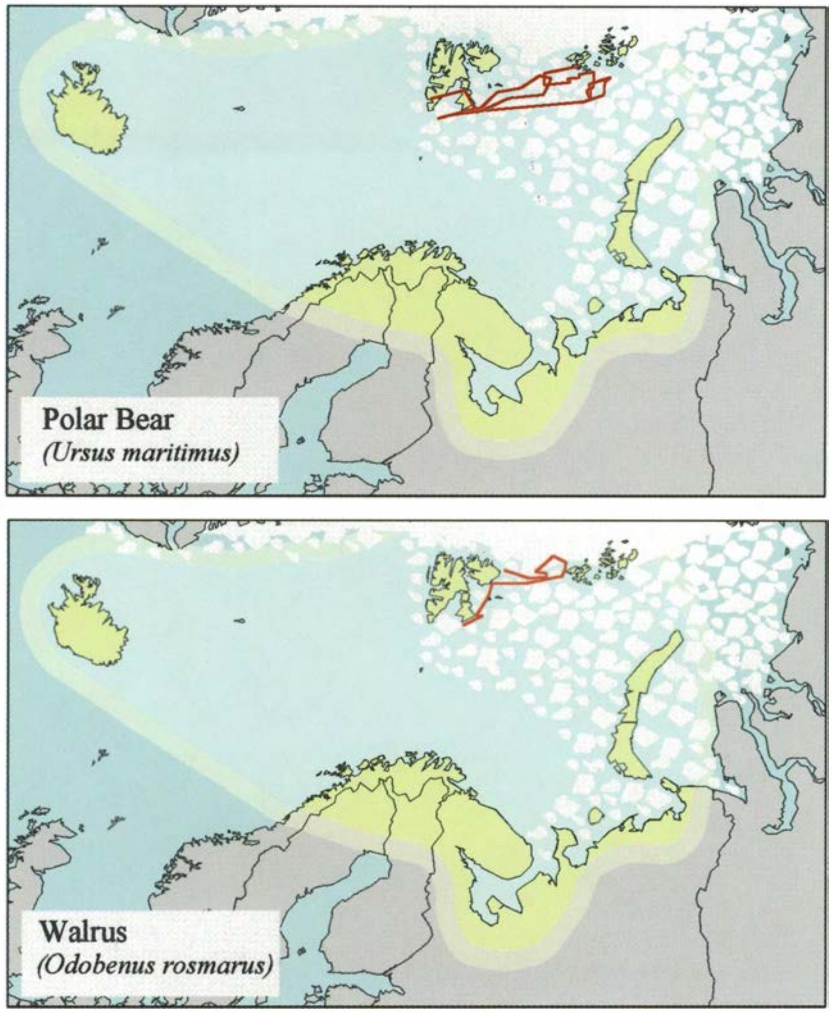


Figure 3.9 **Large home ranges**: Many resident Arctic species utilize extensive areas. Red lines show examples of short term movements of individuals of polar bear, walrus, bearded seal and fulmar, satellite-tracked by the Norwegian Polar Institute.

Survival strategies

There are three main life strategies for Arctic animals:

1) Remain active in the Arctic all year round

This group includes most larger terrestrial mammals and some birds. These animals are generally extremely well insulated with fur or feathers and body fat or blubber. They have a great capacity for collecting and storing energy, and for reducing energy needs and utili-

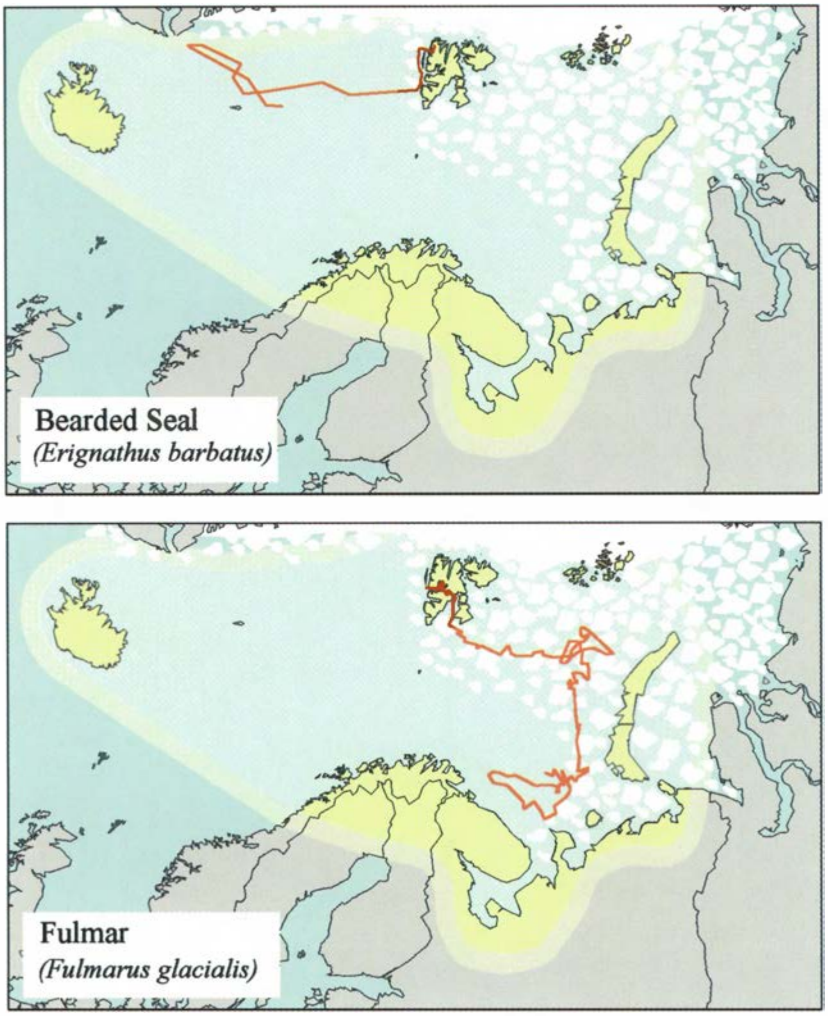


Figure 3.9.
Continued from p. 29.

sation in times of food shortage. They can usually move over great distances, but have low general levels of activity (Ryg et al. 1993, Scholander 1955). However, most marine mammals, except the ringed seal, are dependent on areas of permanently open water (polynyas) to be able to spend the winter in the High Arctic. The permanent residents also include most marine invertebrates and fish, although some of the very mobile fish species may undertake seasonal migrations.

2) Remain in the Arctic all year, but only active during the summer
This group includes terrestrial invertebrates, reptiles and amphibians, and some mammals (e.g. brown bear and bats). During the winter these animals hibernate, or they tolerate severe reductions in body temperature (Barnes 1989, Sømme 1993). This group also includes some of the marine invertebrates with relatively dormant wintering stages or general inactivity because of sub-zero water temperatures.

3) Stay in the Arctic only during the summer
This group includes most birds, highly migratory fish, and most sea mammals. These animals often carry out long, energy-demanding migrations between winter quarters and the Arctic summer areas. They take advantage of the surplus production of the Arctic spring and early summer, when they often have their young. Most marine mammals follow the ice-edge of the receding ice-pack and therefore remain in the Arctic region all year even though they undertake long seasonal migrations.

All three of these strategies benefit from the open and relatively undisturbed access to the high biological production of the Arctic summer.

Vulnerability

Organisms and ecosystems in the Arctic are not necessarily more vulnerable than those of other regions. The adaptations of Arctic organisms and ecosystems render them robust and resilient to natural disturbances and harsh climatic conditions. Their vulnerability lies primarily in that several of the very adaptations, which function successfully in their natural environment, at the same time leave them particularly sensitive to certain human impacts. The physical conditions of the Arctic environment (e.g. low temperatures) cause the effects of such impacts to be more long-lasting and complex than at lower latitudes.

Following are some examples of specific vulnerabilities of European Arctic organisms and ecosystems.

Slow revegetation

Slow biological processes due to low temperatures lead to slow revegetation of areas where vegetation has been damaged or removed. On tundra, larger impacts, such as tracks from heavy vehicles on thawed ground, can remain visible for decades. Coupled with the lack of adaptations to interspecific competition, slow revegetation may render Arctic plants vulnerable to major, long-term environmental shifts, such as climatic change, as well as to the introduction of new species (Råheim 1992, Crawford et. al. 1993).

Erosion

Because of slow revegetation rates, the constant freezing and thawing of exposed soil, and the effects of wind and running water, the

Arctic ground is very vulnerable to erosion. Due to the delicate balance between temperature and hydrology in permafrost ground, such areas are particularly sensitive to physical disturbances and changes in the insulative properties of the ground cover. On permafrost, running water may turn even moderate scars in the soil into irreversible erosion (Råheim 1992).

Disturbance of habitats and migration routes

Arctic species, especially mammals, need large, undisturbed territories and home ranges to meet demands for food, breeding and shelter. Fragmentation of such territories by roads, pipelines or other human activities may alter or block animal movement patterns and disrupt their optimal use of the area. Such disturbances can alter population structures of key Arctic species as well as the overall terrestrial ecosystem dynamics of the European Arctic.

Migratory species are highly dependent on suitable and available resting and feeding areas in their summer and winter territories, and along the migratory routes themselves. Such feeding and resting areas are often small. Large portions of total populations are gathered in these small areas for a limited time during migrations. Disturbances of such areas may seriously affect the entire population of a migratory species (Mortensen et al. 1983).

Energy-costly disturbances

As winter survival of Arctic animals is often dependent on their ability to store energy (fat) reserves, the summer and fall feeding activity is important. Disturbance during this period may reduce time spent feeding and thus also the energy stored. Disturbances often result in increased activity levels, for example flight to avoid dangers, and thus to increased energy consumption. They also cause animals to move from optimal forage areas to areas with sub-optimal conditions. In sum, these factors all reduce chances of winter survival.

During the winter, and particularly in the spring before the snow cover has melted, individuals of several terrestrial Arctic species are often in poor condition due to depleted energy reserves and lack of new food resources. Disturbance leading to increased activity and energy consumption may be harmful or fatal to weak individuals during this period.

Vehicle tracks in Northwest Russian tundra (photo: Georg Bangjord)

Adult mortality

The typical Arctic bird and mammal species, where individuals live long and reproduce many times but produce only a few young each time, can sustain several years with high offspring mortality. Among these species, the adult individuals, and in particular the females, constitute the "backbone" of the population. Such Arctic populations are vulnerable to high mortality among adults.

If food shortage, over-exploitation, pollution, or environmental contaminants lead to extensive adult mortality, the result can be long-lasting impairment of the population, with fewer adults remaining to contribute to reproduction. The smaller the population, the more vulnerable it is to increased adult mortality.

Vulnerable animal concentrations

In several Arctic species, significant portions of a population gather for shorter or longer periods in limited areas in connection with feeding, reproduction, migration, etc. Exam-

Specialisation: The common guillemot (*Uria aalge*) feeds its chicks almost exclusively on capelin (photo: Georg Bangjord)

ples of large aggregations are nesting colonial sea birds, concentrations of birds and mammals near the ice edge in the spring, seal populations during moulting and pupping, and pre-spawning and spawning schools of fish.

On such occasions a single disturbance, such as a discharge of pollutants, can result in extensive and long-lasting impacts to a large portion of a population.

Over-exploitation and loss of key species

Some of the key marine species of the Arctic, such as the polar cod and capelin, are found in high concentrations and large populations in the European Arctic. Such concentrations of natural resources are easily exploitable and may attract industrial and economic interests. A significant reduction in the population size of these key species, or disruptions to their migration patterns, can have serious consequences for species higher in the food chain, as well as for the entire ecosystem. One example of this was the many years of reproductive failure in seabird populations of puffins and guillemots caused by the crash in capelin stocks in the north Atlantic in the mid-1980s.

Benthic slow-growing species

Some benthic species, such as scallops and clams, may occur in high concentrations, but their annual production is low because of slow growth under Arctic conditions. Increasingly efficient harvesting technologies make many such species vulnerable to over-exploitation. A prime example of this is the fishery for Iceland scallop (*Chlamys islandica*) in the waters around Svalbard, which only lasted a few years at high intensity before the resource was depleted. Because of slow growth rates, it may take years for the population to rebound.

Accumulation of environmentally toxic substances

Many Arctic animals withstand food shortage by storing energy in the form of body-fat when food is available. This adaptation renders the animal vulnerable to fat-soluble contaminants, such as persistent organic pollutants (POPs). POPs mainly enter the Arctic food chain through primary producers in the marine environment, are then accumulated in the fatty tissue of animals preying on these organisms, and may finally reach toxic levels in predators at the top of the food chain (raptors, gulls, seals and polar bears). During lean periods, these higher animals use their stored fat as an energy source and the contaminants are released into the body (Muir et al. 1992). High levels of POPs can, among other things, affect reproduction and immune defence systems. POPs are accumulated with age, and adult animals are therefore most vulnerable (Tryphonas 1994, Helle et al. 1976).

Oil spills in the Arctic

Because of increasing oil drilling activities in the Arctic, and the opening of shipping routes such as the north-eastern sea route, there is an increased probability of oil spills happening in ice-covered waters. Such spills may remain in the area for a long time, and can also be transported by the flowing sea ice to other vulnerable areas. Oil can also be soaked up into the ice itself where it negatively affects the primary production, as well as the entire ice-associated food web.

In addition, there is the problem of the constant input of hydrocarbon compounds to the Arctic marine ecosystem by the large Arctic rivers, particularly in the Russian Federation. Little is known about the effects of large oil spills in the ice, or about the more chronic effects of pollutants carried into the Arctic environment by rivers. Some Arctic marine organisms seem to be adapted to dealing with both pollutants and crude oil as long as concentrations are relatively low. However, significant decreases in benthic diversity have been identified in the immediate vicinity of oil platforms.

Marine ecosystems

The marine ecosystems in the European Arctic are among the most productive in the world. This is due to :

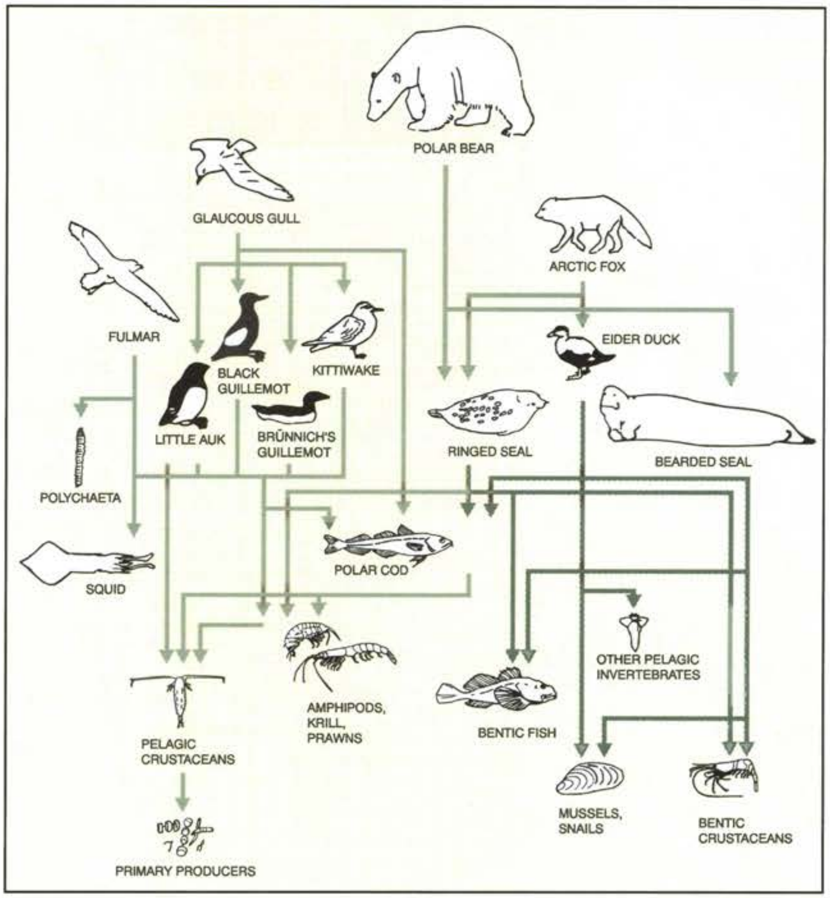
- massive influx of warm atlantic waters which blend due to strong winds and currents in the southern parts of the Barents Sea,
- massive influx of Arctic water, in particular north of Bjørnøya, which brings nutrient-rich water from ice covered areas,
- banks in the shallow seas which cause considerable vertical blending without lowering the light regime for high primary production.

Together with abundant solar energy (24 hours daylight during the summer), these nutrient-rich water masses support a large production of new biomass in the form of algae during spring and summer – the 'spring bloom'. This biomass is consumed by higher trophic levels, and eventually by top predators, including man who exploits the resources through large scale fisheries (Figures 3.1 and 3.2) .

The region's marine ecosystems are characterised by large stocks of a few key plankton, crustacean, and fish species, and large populations of seabirds and certain mammals.

High biological production in the southern part of the European Arctic oceans occurs in particular along the Norwegian coast to the Kola Peninsula, around Iceland, around Bjørnøya, and the Svalbard bank. However, the production is generally high all over the shallow Barents Sea well into the drift-ice zone, as well as in the north-east Norwegian Sea. The even shallower Kara Sea is somewhat less productive due to lack of warm water influx and ice cover 8–12 months per year.

The coasts of the southern parts of the region, and of the high Arctic islands, are strongly linked to the marine ecosystem. Nutrients from the marine ecosystem greatly improve the productivity and diversity of the terrestrial ecosystems in these areas. Organic



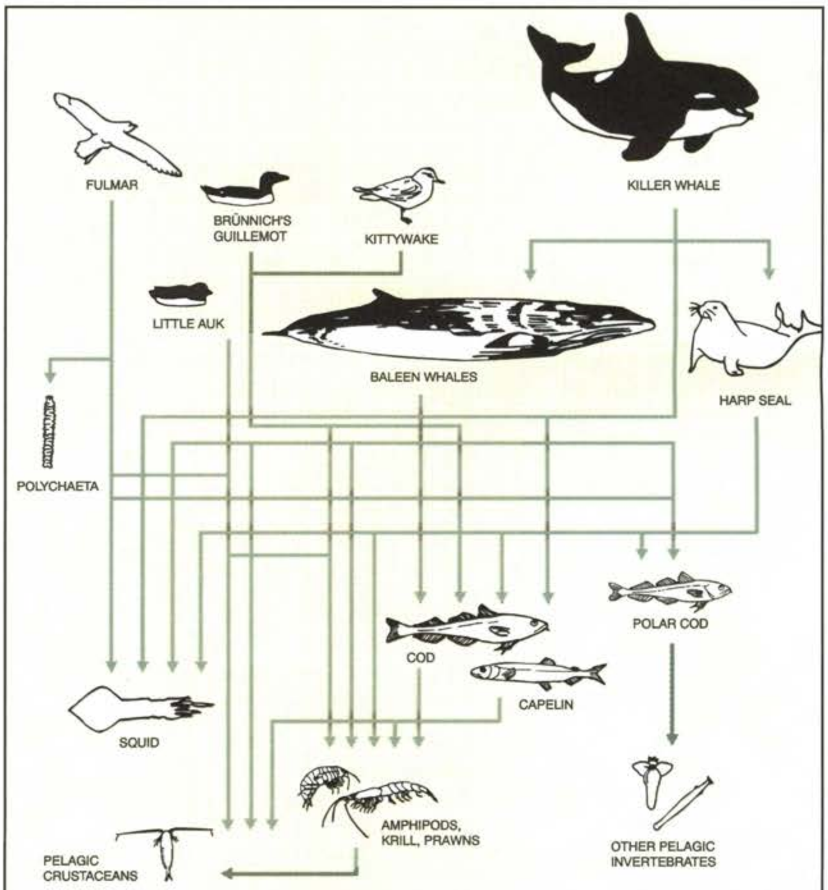


Figure 3.1& 2 **The food webs** in ice covered and ice-free waters in the Eurpean Arctic are characteristically short, with a low number of species, but large populations . (Source: Sakshaug et al 1992).

deposits (guano) from seabirds provide nutrients for the vegetation, and thus improved grazing for terrestrial herbivores (e.g. geese, other birds, reindeer), and for freshwater fish migrating to sea (salmon, trout, and Arctic char). Some mammals (e.g. fox and otter) also benefit from this marine-based increase in terrestrial production.

Unlike species-rich, tropical marine ecosystems with little new, harvestable production, and unlike stable terrestrial ecosystems such as the boreal forests, the marine ecosystems of the region are dynamically unstable. Variations in the influx of warm water, and secondary effects of this, cause irregular variations in primary production, and in the survival and production of key fish and other species. The consequence of such fluctuations may at times be dramatic, in particular for species at higher trophic levels. Such incidents are normal features of the European Arctic marine ecosystem. Additional human impacts through over-harvesting and mismanagement may, however, enhance negative trends and lead to severe or irreversible changes in the ecosystems.

Primary producers

Plant algae (phytoplankton) are the primary producers of the oceans. These organisms use solar energy and inorganic nutrients to create organic matter (biomass) through photosynthesis. These algae are the basis of the marine food chain, as they are food for zooplankton, and through them also for most other higher marine organisms.

The algae found in the largest concentrations are the diatoms, together with the flagellate *Phaeocystis*. These are the most important during the spring bloom.

The total annual primary production in the Barents Sea is estimated at approximately 110 tons of carbon (tC)/km^2/year. The production per unit area south of the polar front is higher (est. 165 tC/km^2/year) than north of it. This production is high compared with the temperate oceans further south (<50tC/km^2/year) and compared with the ice free parts of the southern oceans. It is probably higher than in the Kara Sea (no data), but slightly lower than in the Bering Sea and coastal areas of the north Atlantic. The production is however far lower than in tropical rain forests (up to 800 tC/km^2/year).

A unique quality of the marine ecosystem is that 50–60 per cent of this production can be harvested without depleting the resources, because it is based on new nutrients supplied by inflowing currents and local bottom sediments. However, the Barents Sea exhibits a marked gradient northwards in terms of new productivity. In the southern part of the Barents Sea, the annual new productivity may be as high as 90 g carbon per m^2, whereas north of the oceanic Polar Front it is <40 g carbon per m^2 (Sakshaug et al. 1994). In tropical rain forests, warm oceans, and most other ecosystems, nearly no new nutrients are supplied, and far less or none of the production can be harvested without reducing the total nutrient supply of the system (Sakshaug et al. 1992).

The distribution of phytoplankton species is determined by the position of the polar front, the freshwater influx from Siberian rivers, and the freezing and melting of sea ice. The species north of the polar front are mainly Arctic, and those south of the front mainly Atlantic, but there is substantial overlap in distribution.

Secondary producers

Most zooplankton species graze on phytoplankton and are themselves an important food source for many other species. Zooplankton are thus the link between primary producers and higher organisms in the pelagic (upper-water) marine food web.

The timing of zooplankton production in relation to the relatively short period of phytoplankton bloom is crucial to the transfer of energy from primary production to higher trophic levels. Variations in the "match" or "mismatch" of this relationship strongly influence the production of economically and otherwise important species.

The most important zooplankton species in the European Arctic are various crustaceans, including copepods and krill species, as well as jellyfish plankton and chaetognaths.

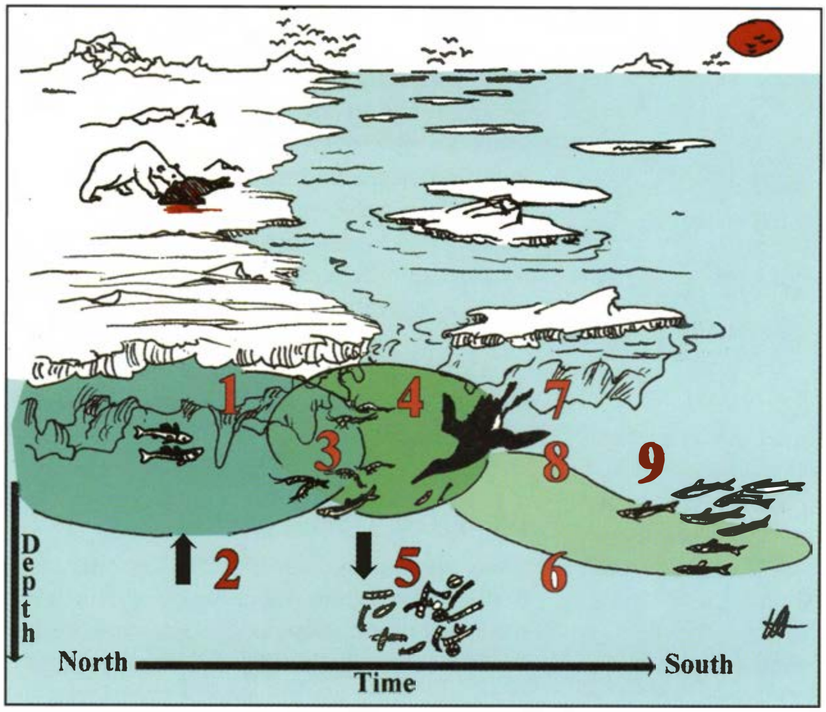
The three most common species of copepods constitute up to 90 per cent of the total zooplankton biomass in large parts of the European Arctic seas during parts of the year. Copepod species are the primary food for herring and capelin. Krill is the main food for cod fry and other young fish. They are also important as food for seabirds, seals, and whales. Further north the amphipod *Parathemisto* and the wing snail *Limacina* play important roles as food for adult fish species, seabirds and seals.

The sea ice ecosystem

During spring and early summer, a 20 to 40 km wide belt of high algae production (an 'algal bloom') follows the ice edge as it retreats northwards. The bloom is caused by the combination of a stable top layer of nutrient rich water with low salinity from the melting ice, and continuous sunlight. This "ice edge effect" is vital to the northern Barents Sea ecosystem because it occurs earlier than the general main, large spring bloom which takes place in open waters (Figure 3.3). It creates an early food base for zooplankton, fish, seabirds, and mammals, all of which concentrate at the ice edge during this period (Sakshaug et al. 1992).

The ice-covered parts of the seas are generally less productive than the ice edge or open water. But the areas are still important, i.a. as a source of nutrients and algae prior to the spring bloom. The Arctic sea ice sustains a community of primary producers (phytoplankton), higher invertebrates, and fish (primarily polar cod).

The biological production associated with ice plays, quantitatively speaking, a minor role in the total Arctic ecosystem. However, the ecological role of the ice flora and fauna becomes more important northwards towards the continuous multi-year ice. It plays a very important ecological role in areas north of Svalbard, Franz Joseph Land and Novaja Zemlja. Close to the marginal ice-shelf, the food intake of polar cod and little auk can contain up to 25 per cent ice fauna species, which also are important as food for seals and whales (see e.g. Lydersen et al. 1985).



As the ice edge retreats northwards, phytoplankton blooms along the ice edge due to stable and nutrient-rich water and abundant light (energy). Zooplankton develop "behind" this zone and capelin feed on the zooplankton.

1. Nutrient-rich water, before blossom
2. Over-wintering zooplankton, migrating to the surface
3. Zooplankton spawning
4. Nutrient-rich water, ice edge blossom
5. Sedimentation of phytoplankton
6. After blossom, layer of max chlorophyll A
7. Surface water deprived of nutrients
8. New generation of zooplankton developing
9. Capelin feeding migration

Figure 3.3 **The ice-edge effect** facilitates early and increased biological production as the sea ice retreat northward in spring. (Source: Sakshaug et al.1992).

Sea-floor and coastal ecosystems

There are an estimated 2,000 species of benthic (bottom-dwelling) animals in the Barents Sea and adjacent areas, constituting 80–90 per cent of the total number of marine animal species. Sponges, cnidarians, polychaets, crustaceans, molluscs, bryozoans, echinoderms, and ascidians are the most common groups along with bottom-dwelling fish. One reason for this richness is that the pelagic species are unable to entirely consume the nutrients from the spring algal bloom. The rest falls to the bottom as food for the benthic species.

South of the ice-covered areas, the tidal and sub-tidal zones down to 20–30 m also contain numerous benthic (bottom-dwelling) species of algae.

Kelp constitutes most of the biomass, (up to 10,000 ton wet weight/km^2), along both the Norwegian and Murmansk coasts, but the dominance of kelp is reduced eastwards (Lein et al. 1987). The kelp forest with all its associated seaweed species are important nursery grounds for many fish and crustaceans. The primary consumer of kelp in the kelp-forest is sea urchins *Strongylocentrotus droebakiensis*.

Common benthic algae species in the outer fjords of Svalbard and Franz Joseph Land are *Alaria* spp. and *Laminaria saccharina* (Hansen & Jenneborg 1996).

In the littoral (seashore) zone of the ice covered parts of the region the biodiversity is mainly low (Hansen & Haugen 1989). This is primarily due to the scraping of ice along the coasts. Many high Arctic fjords are also relatively poor in benthic organisms in their inner parts due to the deposition of silt from glacier runoff, whereas outer parts can have comparatively exceptionally high diversity (see e.g. Weslawski 1983).

Shrimp *(Pandalus borealis)*

The deep-water shrimp is commercially the most important deep-water organism in the region. It has an Arctic-boreal distribution. In the European Arctic it is found around Svalbard, in the Barents Sea, south along the Norwegian coast, and around Iceland and Jan Mayen. It is found above sand, clay, or flat rock beds on the ocean floor, and only in water temperatures between -1.7 and about 4°C.

The shrimp is an important food source for cod and certain other fish, seabirds, and marine mammals.

Marine fish

There are approximately 150 fish species in the Barents-, White- and Kara Seas. This is a relatively low number of species compared to the temperate seas, but among these species are some of the world's largest fish-stocks. The stocks of capelin, cod[1], and herring are the largest. These stocks are found primarily in the southern (boreal) parts of the European Arctic waters (Figure 3.4). The largest stocks of fish in the colder Arctic water further north are found among the species capelin and polar cod. Other important fish species are Greenland halibut, halibut, lumpsucker, north-east Arctic haddock, north-east Arctic saithe, redfish, and wolffish.

Economically, and also ecologically, the most important species in the European Arctic seas are capelin, cod, herring, haddock, saithe and shrimp. Polar cod is primarily an ecological important species.

Capelin *(Mallotus villosus)*

The capelin is a circumpolar pelagic salmonid fish, of which there is an Atlantic and a Pacific sub-species. The Atlantic sub-species is found along north-eastern USA and Canada, around Greenland, Iceland and Jan Mayen, as well as in the Barents Sea (Fig. 3.4 d).

During the winter, the Barents Sea capelin is found along the polar front and along the ice shelf in the north-west. Towards the east it has a more southerly distribution. Capelin spawn along the Russian and northern Norwegian coast from February through May. Each school of spawning capelin can contain many hundreds of tons of fish. During the summer and autumn the stock moves north towards the sea ice. When the ice builds up in early winter the stock migrates back to its winter location along the polar front. The Jan Mayen-Icelandic capelin are distributed north to north-east of Iceland and around Jan Mayen during the winter. The capelin spawn in March and April along the south and south-west coast of Iceland, and the larva drift north and north-east into the Denmark Straits and the Iceland Sea.

Capelin is the main plankton feeder in the Barents Sea, and it is a key species on which cod, other fish, seabirds, and mammals depend. Because of this, and because of the shear mass of this fish stock in good years, any alterations or damage to the capelin stock dramatically influence the entire ecosystem structure and dynamics of the sea.

Not all shifts in the Barents Sea capelin stock are attributed to human influence. The stock also goes through large-scale natural

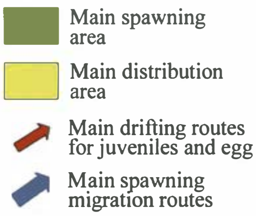
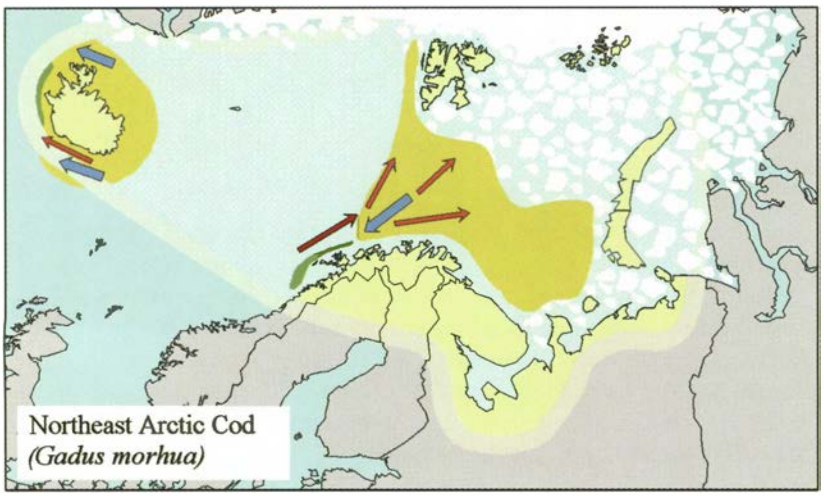
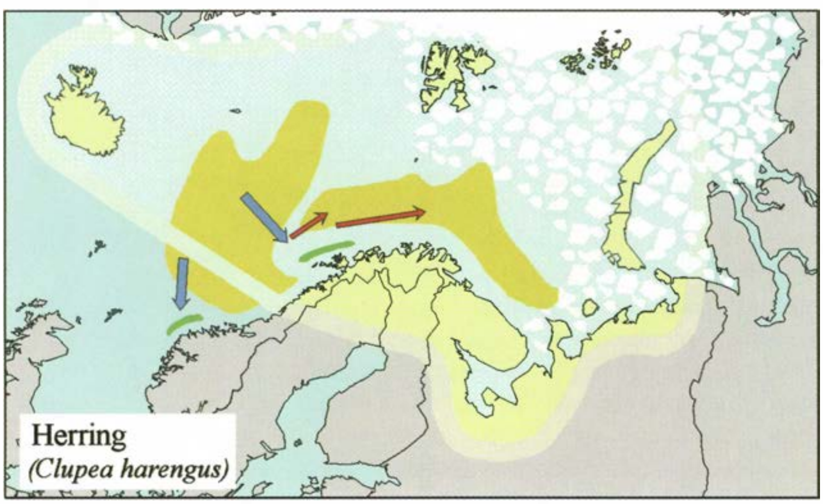


Figure 3.4 a Distribution, migration and spawning grounds of North-east Arctic and Icelandic cod stocks in the European Arctic.

Figure 3.4 b Distribution, migration and spawning grounds of herring stocks in the European Arctic.





[1] The population of cod *(Gadus morhua)* that spawns in the north-western fjords of Norway and feeds in the Barents Sea is by the ICES termed 'north-east arctic cod'. When the term 'cod' is used in this text it refers to this population of cod, and not to the different, and strictly arctic, species *Boreogadus saida* 'polar cod'.

fluctuations which are induced by shifts in sea temperatures and currents.

North-east Arctic cod *(Gadus morhua)*

Cod are found along the coast on both sides of the Atlantic Ocean. The north-east Arctic cod is commercially the most important fish (and animal) stock in the European Arctic. It is distributed throughout the southern Barents Sea, around Bjørnøya and Hopen, along the west coast of Svalbard, and sometimes as far east as Novaja Zemlja. In Iceland cod is distributed along the entire coast (Fig. 3.4 a).

The Barents Sea cod spawn along the northern Norwegian coast in late winter. The young cod migrate during the same time to the coast of Finnmark county to feed on capelin. The Icelandic stock spawns along the west coast of Iceland.

Cod feed to a large extent on capelin, and are its most important predator, but they are able to switch to other prey if necessary.

The recent growth of this stock has most likely had a severe effect on the Barents Sea capelin stock on which it feeds. The current young capelin stock is not large enough to support the large cod stock. Herring, which stocks are currently growing, has not fully substituted capelin in the cod diet. Reduced growth and increased cannibalism has been recorded in the cod stock, but the stock is expected to remain at about the current level, provided that the fishery is properly controlled (IMR 1994).

Herring *(Clupea harengus)*

Herring stocks are widely distributed in the northern Atlantic, the Norwegian and the Barents Seas (Fig. 3.4 b). There are subspecies in some fjords in northern Norway, and in the Kara and White Seas. This northern stock is part of the Atlanto-Scandian group of herring stocks, together with the Icelandic spring- and summer spawning stocks.

Herring feed mainly on zooplankton such as copepods and krill. The herring, in all its life-forms, from spawning adults through larvae to mature fish, are in turn important food sources for a range of marine animals in the European Arctic. The Norwegian spring-spawning herring has an ecological function in the southern European Arctic seas resembling that of the capelin further north. It is ecologically the most important herring stock in the European Arctic.

The Norwegian spring-spawning herring is potentially the largest fish stock in the north-east Atlantic. However, there have been major shifts in the spawning, feeding and migration patterns of this stock in recent years. It is difficult to estimate what these patterns will be in the future (IMR 1995).

The effects of large-scale fishing of mature herring before they spawn, which is currently taking place in international waters of the European Arctic, can heavily influence the population structure and dynamics of this key fish species.

In the chapter 'The Environmental Status', recent trends of the Barents Sea herring stocks are presented. The herring stock has been increasing in recent years. However, there are chances that the growing cod stock will feed heavily on the current stock of young herring since the capelin stocks are in decline. This, coupled with the current large-scale fishing of herring in international waters, threatens to reduce the Norwegian spring-spawning herring stock substantially.

Experience from a similar drastic decline of Norwegian spring-spawning herring stocks

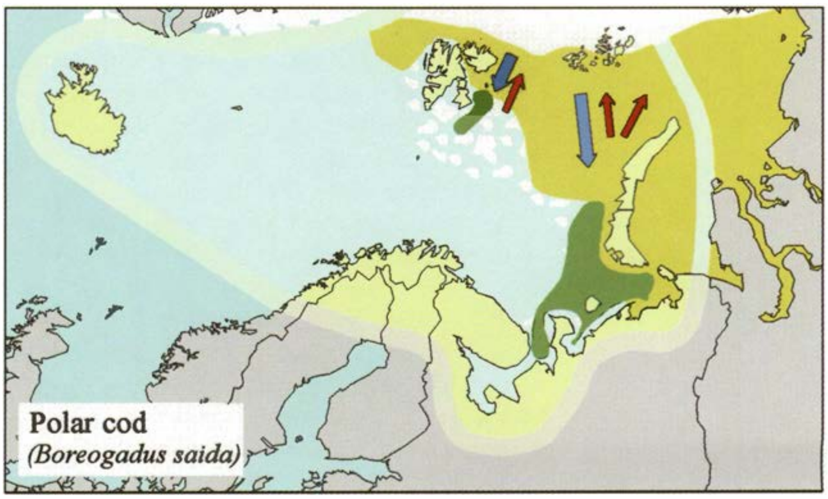
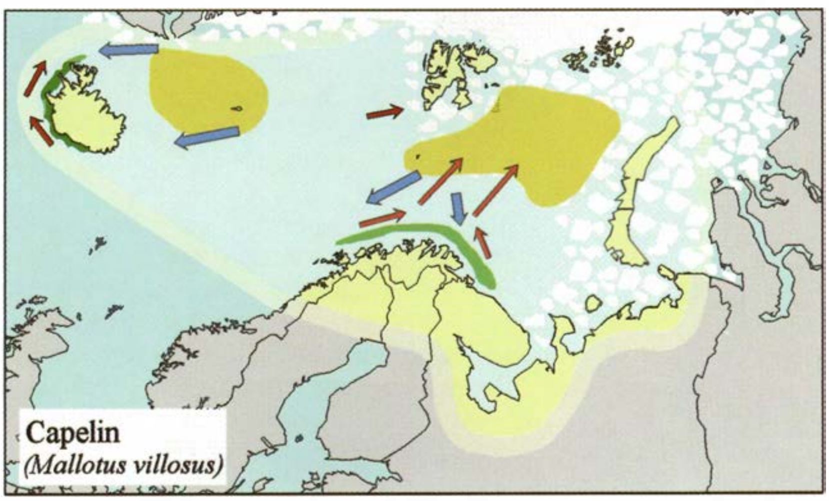


Figure 3.4 c Distribution, migration and spawning grounds of polar cod stocks in the European Arctic.



Figur 3.4 d Distribution, migration and spawning grounds of capelin stocks in the European Arctic.

BOX II – THE BARENTS SEA – AN UNSTABLE CORNUCOPIA

The Barents Sea is the central water body of the European Arctic. It covers more than 1.4 million km^2 and contains over 320,000 km^3 of nutrient-rich sea water. A large annual influx of warm, nutrient-rich water from the south, and the blending effects of winds, currents and ice melting bringing nutrient from the bottom to the surface, provide a large net input of nutrients to its waters, making it one of the most productive seas in the world. The biological production is a resource which, if managed sustainably, can be harvested well into the future.

The Barents Sea's fundamental characteristics are, first of all, that it is dynamically unstable due to large fluctuations in physical variables, and secondly that its biological responses to large-scale impacts are usually delayed. The fluctuations are primarily seasonal (variations in light, temperature, ice-cover), but they also occur over a span of years or centuries (deep water formation, reduced inflow of warm sea water), or as quick short-term shifts (due to i.a vertical mixing, cloudiness, passing of weather systems). The biological response time to environmental shifts depends on the process or organism in question. Fast-growing organisms, i.e. bacteria and phytoplankton, respond in hours to weeks. Stocks of short-lived fish, e.g. capelin, may collapse and/or recover in just a few years, whereas predators dependent upon fish can take decades or centuries to adjust to or recover from such shifts.

Relatively few species have adapted to the harsh arctic climate and large ecosystem fluctuations of the Barents Sea. However, these species can often be found in huge quantities. Their numbers are determined by the physical conditions, and by interactions between species, or between age groups of a stock.

Key species are found at each trophic level in the Barents Sea. However, the largest biomass, and thus the largest economic potentials, are found among the fish species capelin, herring, cod, saithe, haddock, and polar cod. These are food for marine mammals and seabirds, and are the base of the large-scale fisheries in the region. The key fish species predate on each other at various stages in life, and they compete for common food resources. Natural shifts in, or heavy harvesting pressures on one of the stocks directly influence the size and condition of the others.

The Barents Sea fluctuates between periods of strong recruitment to herring and cod stocks with reduced capelin stocks, and periods of smaller herring and cod stock sizes coinciding with a large capelin stock (Gjøsæter 1994). Thus, the development of herring, cod and capelin stocks is biologically strongly linked. These links and interactions are currently not well understood. Dramatic fluctuations were seen in the Barents Sea ecosystem during the 1980s. Strong year classes of cod and herring were recorded in 1983, most probably because of good climatic conditions. This entailed heavy predation on capelin from both species. This in turn, combined with commercial fishing caused the capelin stock to collapse in 1986. The collapse of capelin had dramatic effects on other components of the Barents Sea ecosystem which are dependent upon capelin as food. The effects included food shortage and poor growth of cod, mass migrations of harp seal to the Norwegian coast in search of food, and the collapse of the common guillemot population on Bjørnøya in 1986.

The shifts in temperature and water flow to and from the Barents Sea will always influence the biological production of the ecosystem and cause dramatic shifts in species composition, production, and stock sizes. With imbalances as the rule rather than the exception, the frequently used term 'ecological balance' is misleading for the Barents Sea ecosystem. The various components of the ecosystem are adapted to such variations, but human harvesting strategies are generally not. Understanding the dynamics of the Barents Sea ecosystem fluctuations is a prerequisite for securing proper long-term management strategies, and for protecting the ecosystem vitality.

in the 1960s indicates that it take nearly 30 years for the stock to recover if a total fishing ban is enforced when the stock is at a minimum.

Polar cod *(Boreogadus saida)*
The polar cod is a true Arctic circumpolar species. I lives its whole life in seas with temperatures close to 0° C. It is distributed throughout the Barents, Kara, and White Seas. The main spawning areas in the region are in the south-eastern Barents Sea along the west coast of Novaja Zemlja, and east of Svalbard (Fig. 3.4 c). Polar cod fry feed on copepods, whereas adults feed on krill, amphipods and other crustaceans.

Polar cod is a key species in the high Arctic marine ecosystem, primarily as food for larger fish, seabirds, and marine mammals. There was a drastic reduction in the Barents Sea polar cod stock in 1987, most likely because the main capelin predators (cod, seals, sea birds and whales), preyed on polar cod after the capelin stock collapsed in 1986.

Seabirds

The European Arctic is home to some of the largest seabird populations in the world. The total number of seabirds in the Barents and White Seas alone is estimated to be more than 16 million individuals, and large numbers occur also in the Norwegian and in the Kara Seas (Isaksen & Bakken 1995).

Nesting cliffs and feeding areas of the most common seabirds are distributed throughout the region (Figure 3.5).

The main groups of seabirds in the European Arctic are the alcids, cormorants, gulls, marine ducks, procellariforms (fulmars, storm petrels etc.), and terns. More than 30 species of seabirds have been registered in the Barents Sea region (Sakshaug et al.1992). Yet only a few of these constitute the majority of the biomass and are important in the overall ecology of the marine ecosystem.

Most of these birds take advantage of the rich summer production in the Arctic seas, and most of them migrate south for the winter. Exceptions include the black guillemot and ivory gull which most likely stay near the sea ice edge during the winter.

The kittiwake, fulmar, little auk, puffin, and common and Brünnich's guillemot all catch food in open water. Others, such as the black guillemot, feed both on the ocean floor, in coastal waters, and in the sea ice. Ducks, such as the common eider, feed and live near the coasts in most of the region. The glaucous gull (*Larus hyperboreus)* is the main avian predator in the Barents Sea area, whereas herring gull (*Larus argentatus*) and black backed gull (*Larus marinus*) are found in the Norwegian Sea to Iceland.

Most of the alcids and Arctic gulls, as well as the fulmar, nest in large colonies on cliffs or rocky terrain. The terns and eiders nest on the tundra near the coast or on small islands. Some of the alcid colonies can each comprise several hundred thousand individuals. There are an estimated 11 million individuals of the three species little auk, common guillemot, and kittiwake in the Barents Sea. This constitutes close to 80 per cent of all the seabirds in the area.

Brunnich's guillemots are primarily found on the islands of Novaja Zemlja, Svalbard, Bjørnøya, and Hopen, and across to Iceland. The largest numbers of common guillemot are found on Bjørnøya, Iceland, and along the Norwegian coast. The largest colonies of little auk are found in southern Svalbard and on Franz Joseph Land. The largest kittiwake colonies are found in northern Norway and on Bjørnøya.

The seabirds of the Kara Sea area have to date not been well surveyed or documented. It is likely that there are colonies of most of the Barents Sea species in the area, but the numbers are significantly lower than in the Barents Sea (Vidar Bakken 1995, pers. com.).

Seabirds are the key component in transporting nutrients from the sea to the land. This can be seen below the bird cliffs on the High Arctic islands where the vegetation is much richer than in surrounding areas. Estimates from Svalbard indicate that a colony of 70,000 pairs of little auk fertilises the

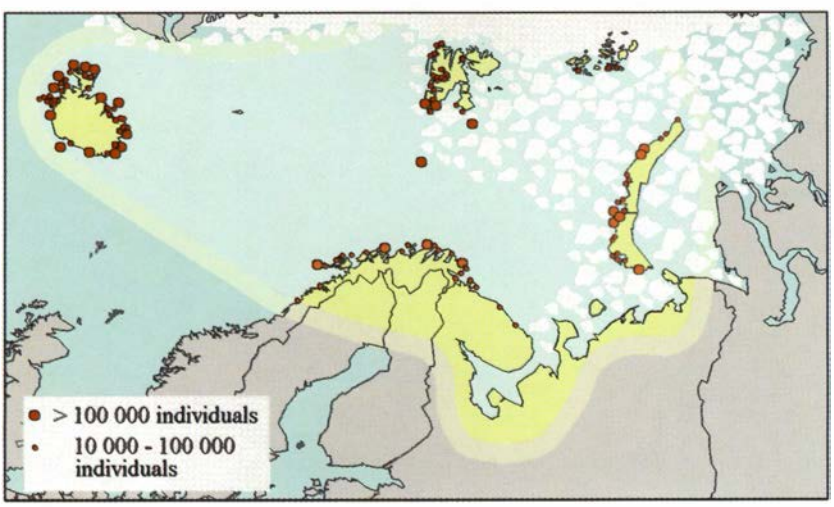


Figure 3.5 **Seabird breeding colonies** in the European Arctic. Some of the colonies are among the largest in the world. (Source: Norwegian Polar Institute).

surrounding terrestrial ecosystem with 60 tons (dry weight) of faeces per square km during the breeding season (Mehlum & Gabrielsen 1995).

Marine mammals

History

There was an abundance of marine mammals in the European Arctic seas until a massive harvest started in the early 1600s. The various species were hunted at different times, depending on the markets and on available technology.

The bowhead whale was practically driven to extinction between 1600 and 1700, as was the right whale in the eighteenth century. The blue whale, fin whale, humpback whale and sei whale populations were drastically reduced between the mid 1800s and 1920. The smaller minke whale has been exploited from the 1930s, and Norway and Iceland still harvest this species.

Walrus were hunted from the time of the first whalers in the early 1600s, but were most intensely exploited from the early 1800s until 1920. Harp and hooded seals were hunted from the mid 1800s until the 1980s, but these stocks have never been as depleted as many of the whale and the walrus stocks. There is still a limited harp seal harvest in the region.

The polar bear was hunted extensively in the European Arctic from the late 1800s. By the mid 1900s the polar bear population was threatened in the whole European Arctic region. A hunting ban on polar bears was passed in 1973 for the Norwegian Arctic (see Prestrud & Stirling 1994).

The marine environment has thus been fundamentally altered by man, and the species composition of most marine mammal populations are still affected by this.

Whales

The true Arctic whale species found in the European Arctic are the white whale, the bowhead whale, and the narwhal.

Baleen whales

A small number of bowhead whales occur around Franz Joseph Land. Bowhead whales feed on small and medium sized zooplankton. The blue-, fin-, sei-, minke-, and humpback whales migrate into the European Arctic seas during summer (Figure 3.6) . These whales primarily feed on small crustaceans and a variety of fish species, including some commercial species such as cod, herring, and capelin.

Toothed whales

The white whale is relatively common in the ice-covered waters of the region. It eats fish, mollusks, squid, crustaceans, and large zooplankton. The narwhal is sparsely distributed in the drift-ice in the western part of the region. The status of this whale in the European Arctic, and especially in the eastern parts, is unknown.

Other toothed whale species include the killer whale, sperm whale, white-beaked dolphin and harbour porpoise. These whales mainly occur in the southern, ice-free parts of the region where they prey on a variety of fish species (Figure 3.7). Sperm whales prey on squid at great depths (1,000–1,500 m). Killer whales primarily eat fish, and most often herring. Certain groups of killer whales in north-

Atlantic walrus *(Odobenus rosmarus):* The population in the European Arctic is approximately 5 000 (photo: Ian Gjertz)

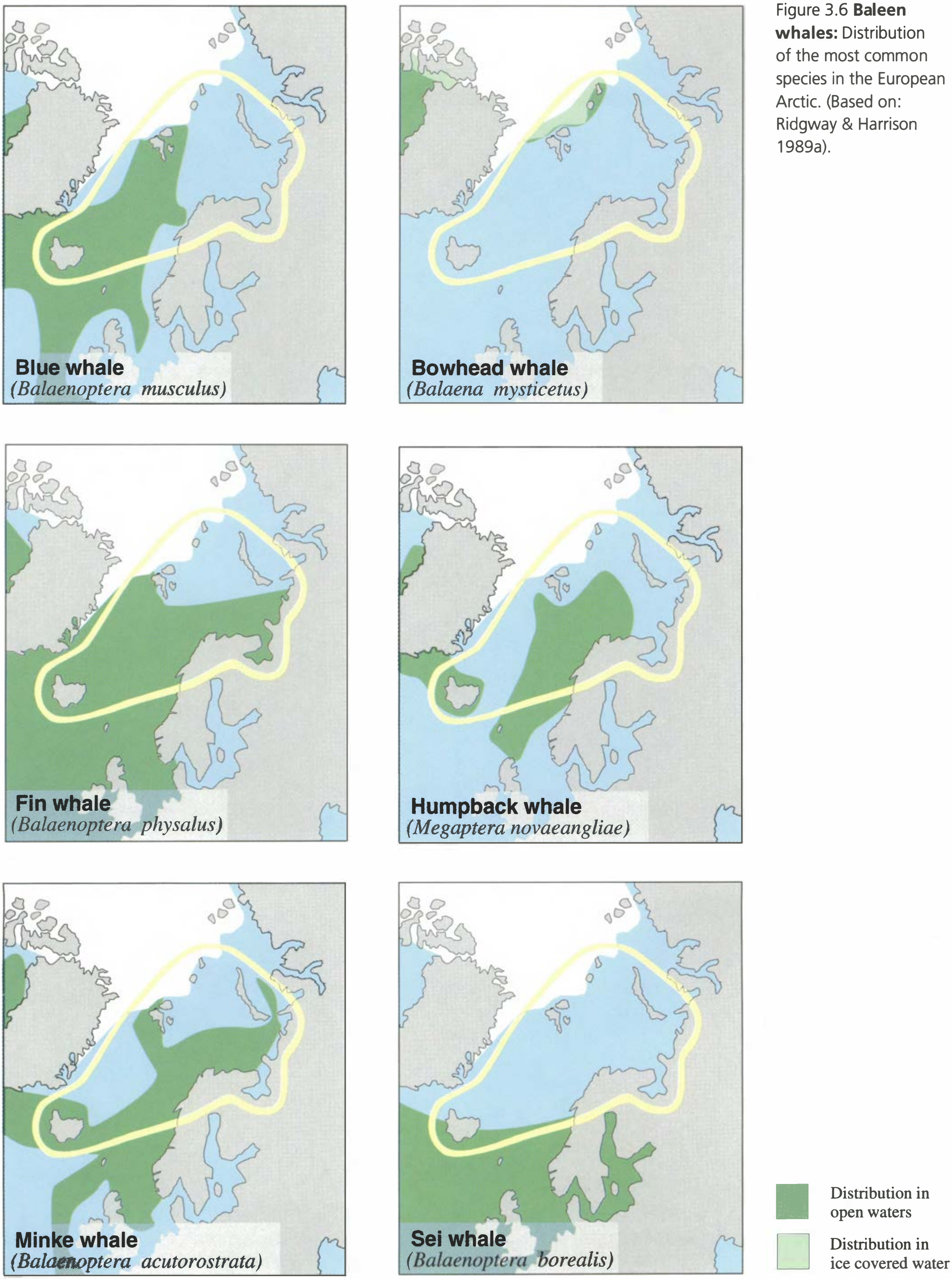


Figure 3.6 **Baleen whales:** Distribution of the most common species in the European Arctic. (Based on: Ridgway & Harrison 1989a).

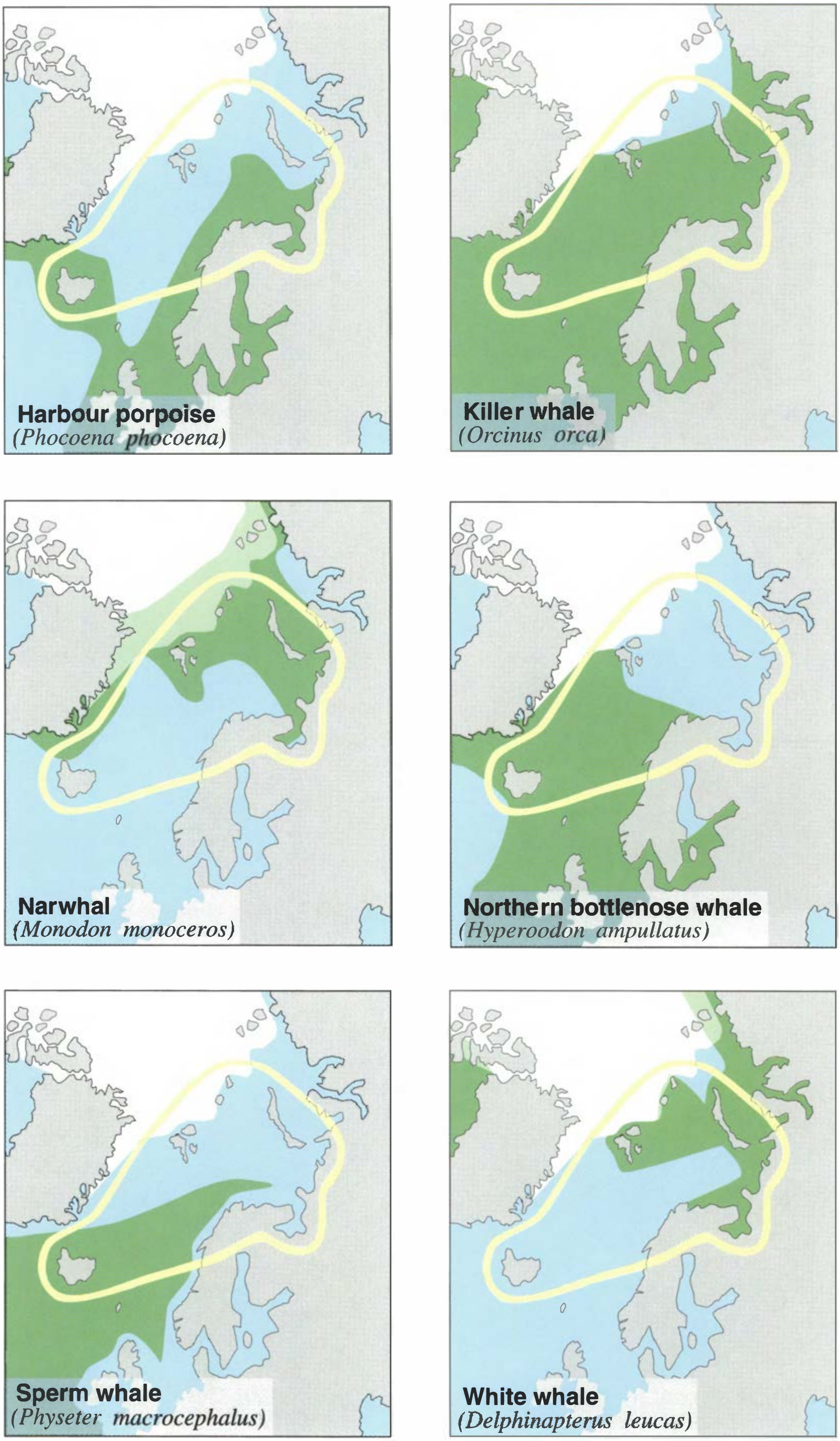


Figure 3.7 **Toothed whales:** Distribution of the most common species in the European Arctic and adjacent areas. (Source: Ridgway & Harrison 1989b).

Distribution in open waters

Distribution in ice covered water

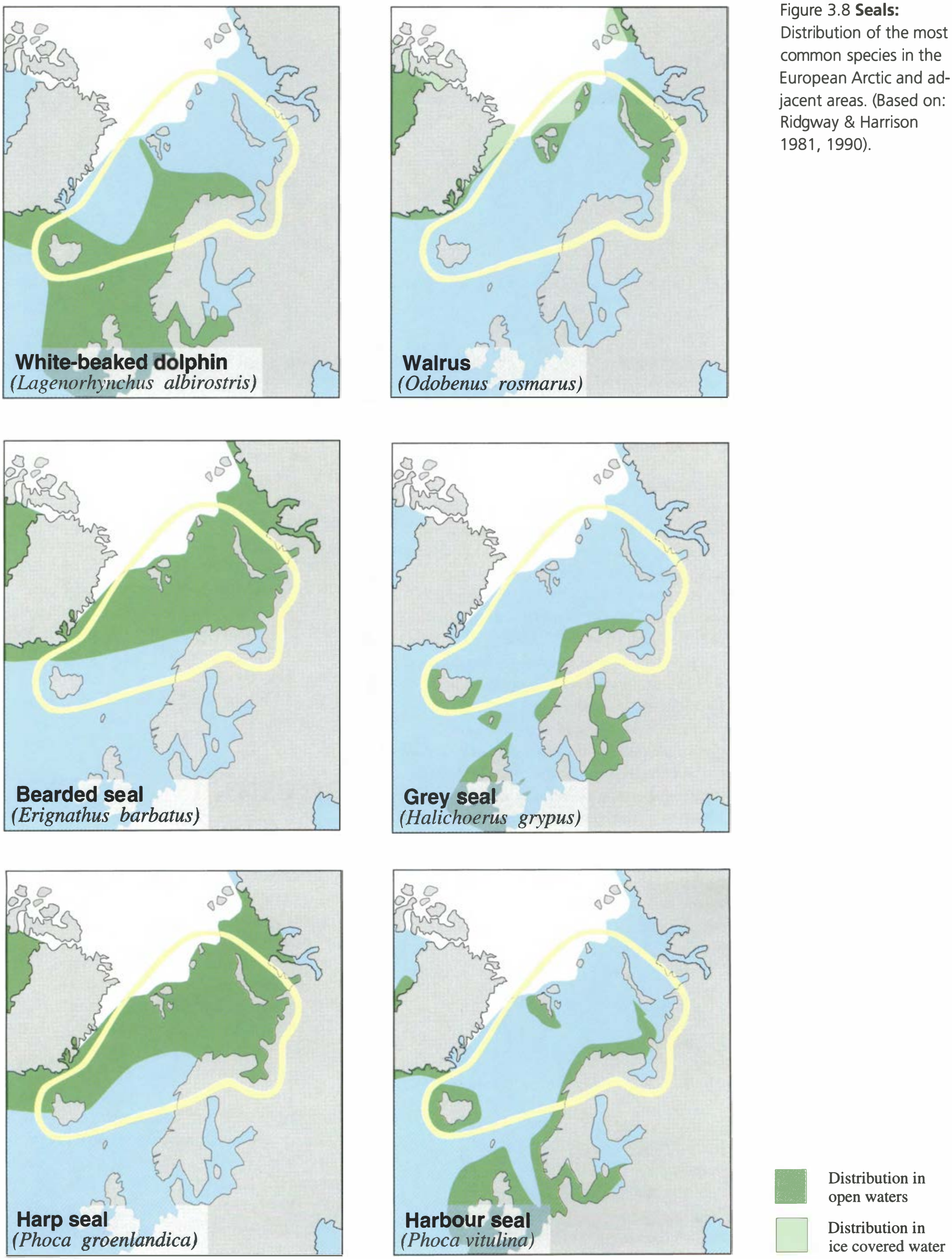
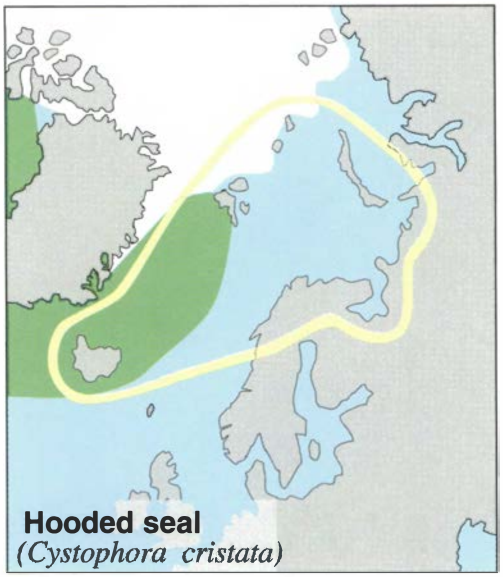
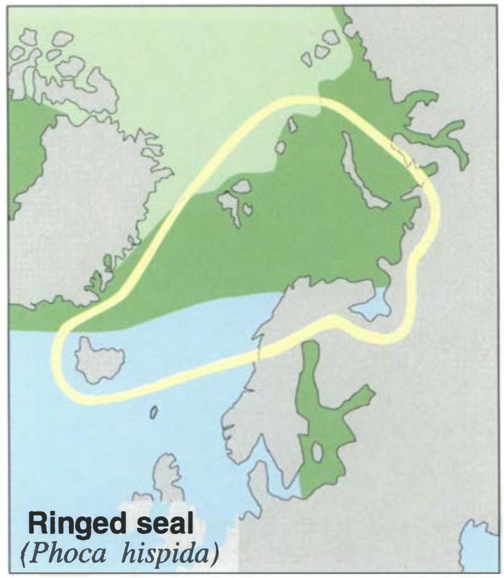


Figure 3.8 **Seals:** Distribution of the most common species in the European Arctic and adjacent areas. (Based on: Ridgway & Harrison 1981, 1990).

Distribution in open waters

Distribution in ice covered water





ern areas will also eat seals and possibly other small whales

Seals and Walrus

The seals in the region include the harp and hooded seal, which are pelagic, the ringed and bearded seal, which are coastal and strictly Arctic, and the harbour and grey seal, which are coastal and sub-Arctic (Figure 3.8). The walrus is also often included under the general heading of seals (Gjertz & Wiig 1994).

Harp, harbour and grey seals feed on a variety of invertebrate and fish species, including *Parathemisto libellula*, polar cod, cod, herring, and capelin. Ringed seals feed on pelagic organisms and under-ice fauna, mainly crustaceans and polar cod. Bearded seals and walrus are mainly benthic feeders preying on clams, snails, shrimps, crabs and benthic fish species

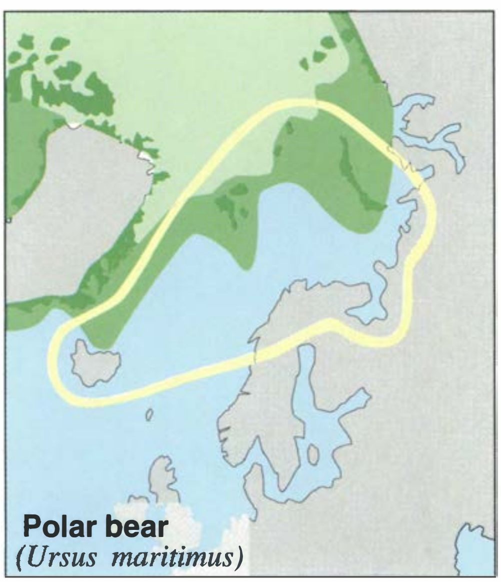


Figure 3.10 **Polar bears**: Distribution in the European Arctic and adjacent areas. (Source: Norwegian Polar Institute)

Polar bears

The polar bear is found in all European Arctic drift ice areas (Figure 3.10) The number of polar bears found between eastern Greenland and Novaja Zemlja is estimated to be approximately 5,000 individuals, whereof the Svalbard population is estimated to number about 2,000. The populations around Franz Joseph Land and Novaja Zemlja are poorly known, but probably smaller (Wiig et al. 1995).

Polar bears prey mainly on ringed seals, but may also take bearded seals, harp seals, walrus and white whale calves, birds, eggs, and carrion.

Terrestrial Ecosystems

The mainland of the European Arctic is dominated by taiga, or boreal forest, in the southern parts and by tundra in the northern parts. Other major land cover types in the region include alpine and high mountain areas, broad-leaved forests in coastal areas and valleys, marshes, and glaciers (Figure 3.11).

The natural factor which most strongly determines the landscape character in the far north is permafrost (Figure 2.2). Where there is continuous permafrost the ground is frozen up to a depth of 400 m. During the summer, all melts is an approximately one metre deep "active layer", which creates a poorly drained, often marshy landscape intersected by dry ridges. There are no trees on land with continuous permafrost. This is the land of tundra, marshes, stone, and ice.

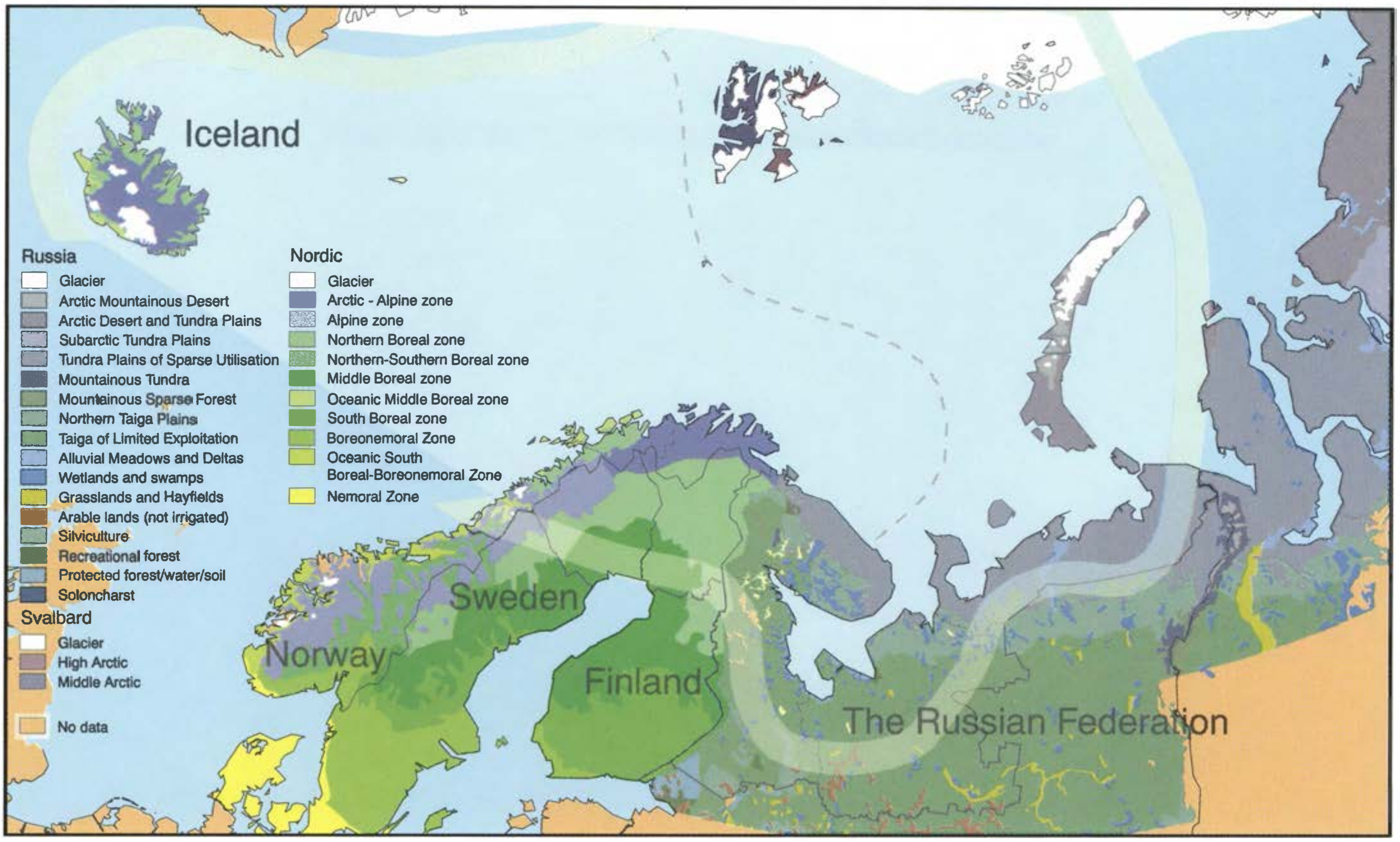


Figure 3.11 **The landscape**: Classifications of physical and geographic regions in the European Arctic and adjacent areas. Such classification systems are not internationally harmonised. The map combines several systems. (Source: Conservation of Arctic Flora and Fauna 1994).

Vegetation

Forest

The taiga is a zone of coniferous forest encircling the northern hemisphere south of the permafrost line. It represents an important commercial resource in the Russian Federation, Finland and Sweden. In particular, the boreal forests of Arkangelsk oblast, Murmansk oblast and the Karelian Republic represent a considerable portion of the Russian Federation's forest resources. Spruce (*Picea abies*), pine (*Pinus sylvestris*), and larch (*Larix sibirica*) are the predominant tree species in these forests (Gjærevoll 1973).

The plant and animal species composition is relatively uniform throughout most of the taiga. The taiga forest basically consists of one

Taiga: The dominating forest ecosystem of northern Fenno-Scandinavia. (photo: Torfinn Kjærnet)

Arctic tundra (photo: Georg Bangjord)

canopy layer, with an under-vegetation of dwarf shrubs, mainly of the heather family (*Vaccinium, Ledum, Kalmia*), crowberry, and mosses and lichens. The World's northernmost coniferous forest is found at 70° 10'N in Finnmark county in Norway.

Broad-leaved deciduous forests are found in areas of warmer or more oceanic climates. Birch (*Betula tortuosa*), aspen (*Populus tremula*) and alder (*Alnus incana*) are the predominant tree species. Iceland had large birch forests before the arrival of the first settlers in the early Middle Ages. Gradual but steady deforestation and extensive sheep and horse herding have since practically cleared the entire island of forests.

Many bryophytes, lichens, insects and other species are associated with deciduous trees. The coniferous forests are less species-rich than deciduous or mixed forests. Nevertheless, the coniferous forest's contribution to the species diversity in the boreal forest should not be underestimated (Bernes 1994).

A characteristic feature of the boreal zone is the formation of peatlands (bogs) which develop in wet areas due to poor drainage and incomplete decomposition of plant material.

At the northern limit of the taiga is the polar timberline. The boundary between the treeless areas and the taiga is marked by an intermediate zone of tundra interspersed with trees, and usually discontinuous permafrost. The regeneration of this "forest-tundra" is dependent upon the supply of tree seeds from stands further south.

Tundra

Tundra is the name of the vast treeless plains of the Arctic. Due to low temperatures, permafrost, low bacterial activity, and an almost complete lack of invertebrate soil fauna, biological material is slowly decomposed in tundra areas. Nutrients are thus not readily available for new plant growth on the tundra. The result is low production, slow plant growth, slow revegetation where vegetation has been damaged or removed, and low animal biomass per unit area.

The tundra is characterised by annual production periods of only 1.5–3 months, cool summers, continuous daylight during summer, low availability of nutrients, low precipitation, strong winds, and extreme habitat patchiness. Tundra is found in some European Arctic mountain areas, along the outer coast of Finnmark county, Murmansk county, the areas north of the Arctic Circle in Arkangelsk oblast, the Svalbard archipelago, Franz Joseph Land and Novaja Zemlja.

Dwarf birch, willows and taller heather species are predominant in the southern parts of the tundra, along with heath vegetation (*Cassiope*, *Vaccinium*, *Ledum*, *Arctostaphylos*).

The tundra vegetation of the high Arctic islands can be divided into two main flora units, (Figure 3.11); the "middle Arctic" flora unit is the most species-rich. It is found on Spitsbergen island in the Svalbard archipelago and is characterised by *Cassiope tetragone* and *Dryas octopetala*. Polar willow (*Salix polaris*) and *Papaver dahlianum* are typical for the "high Arctic" flora unit, which is found on Franz Joseph Land, the northern parts of Novaja Zemlja, and the north-eastern parts of Svalbard.

The tundra ecosystem has an important ecological function in the European Arctic. About 11per cent of the world's store of soil carbon lies in the tundra and boreal forest soil. This is important in the global balance of carbon and the greenhouse gas carbon dioxide. In the future these areas might also become important for agriculture and forestry.

Despite the low vegetation productivity on the tundra, about five million wild and domesticated reindeer live in the Arctic, whereof one million are found in the European Arctic. Reindeer are a major food source for about 250,000 people in the Arctic. Locally in the Russian Arctic, geese and ptarmigan yield greater harvests than reindeer.

Fauna

Due to the harsh climate on land and the limited plant production in the high Arctic areas, the biodiversity of the terrestrial fauna in the European Arctic is relatively poor. This applies both in comparison with the Arctic marine fauna and with terrestrial fauna further south.

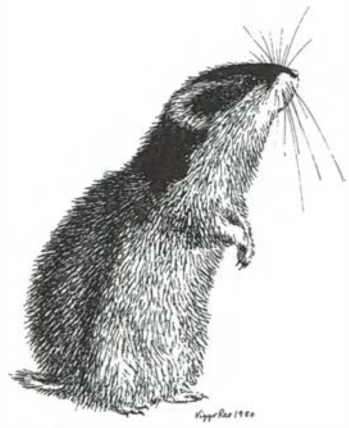
In the following, selected species will be described in more detail than others. For the purpose of this report the focus has been kept on key character species. These are species that are 1) very plentiful and thus strongly influence the ecosystem, 2) very limited or threatened and thus demand special management strategies, or 3) unique to the region.

Winter survival is usually the limiting factor for animals in the Arctic. This limits the densities of all-year animals. The resident fauna is often not capable of fully utilising the summer food resources. Migratory species thus often constitute a large fraction of the summer fauna.

Invertebrates

There is very little information available on invertebrates aggregated to the level of the European Arctic. In general it is safe to say that the region has a low diversity of invertebrates compared with ecosystems further south. In particular, many insect groups are poorly represented. However, certain species

Parabolic shaped flowers catch the heat from the sun: Dryad flower (*Dryas octopetela*) (photo: Odd Lønø)



Lemming *(Lemmus lemmus)* (drawing: Viggo Ree)

of insects, e.g. mosquitoes, can be found in enormous densities over large areas in the European north, particularly in connection with freshwater ecosystems. These insects are important as food for many higher animals, such as birds, fish, and bats.

Mammals

Mammals constitute the largest group of land animals with regards to standing biomass. The main groups of mammals in the region are:

- smaller rodents and insectivores (bats, mice, etc.)
- smaller predators (weasel, marten, fox, etc.)
- ungulates (deer, moose, reindeer)
- larger predators (bear, lynx, wolf, wolverine)

Since bats have a low tolerance for cold weather, they are only found in the southernmost parts of the region, and even then only in limited areas and numbers. There is very limited information on the bats of the European Arctic.

Common rodents are found all over the southern parts of the European Arctic, except in high alpine areas. The lemming species *Lemmus lemmus* is endemic in the Fennoscandian fauna. The lemming is also found on Novaja Zemlja.

One of the most striking biological events in the mountain and Arctic areas in parts of Eurasia, is the lemming cycle. Every three to four years these small rodents rapidly multiply and reach high densities. These rapid population explosions always end with an equally rapid population declines due to disease, stress, and acute food shortage. The populations then remain at a low level again for several years. In socalled "lemming years" (high densities) the lemming strongly effect the tundra ecosystem. In some areas they can cause striking yearly changes in primary production, nutrient concentrations in plants,

Reindeer (*Rangifer tarandus*) (photo: Georg Bangjord)

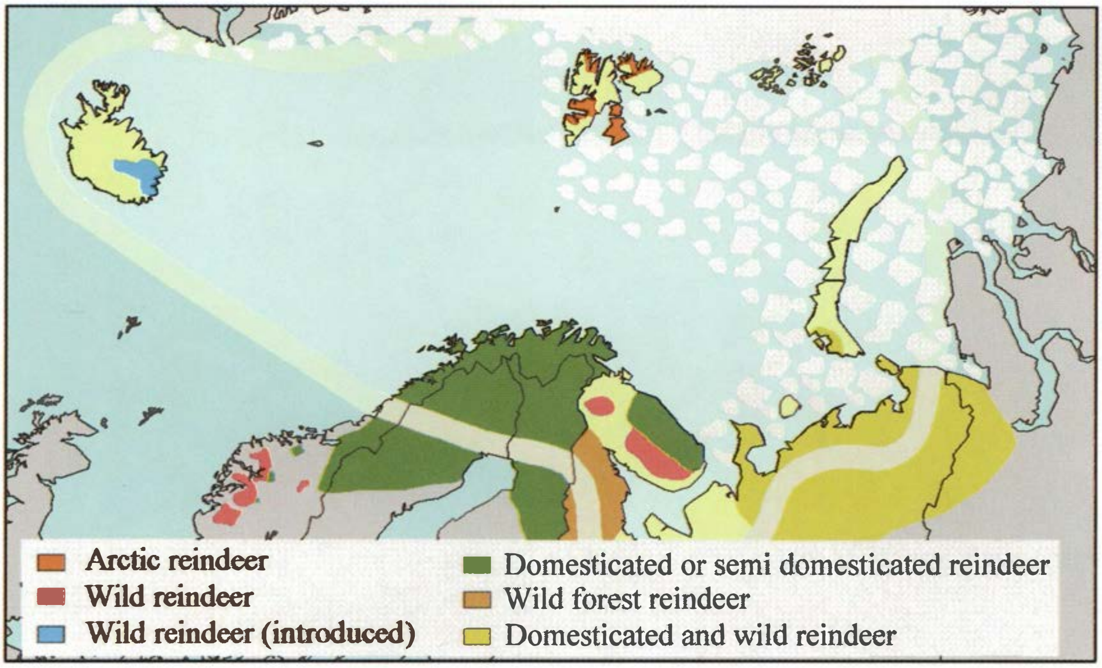
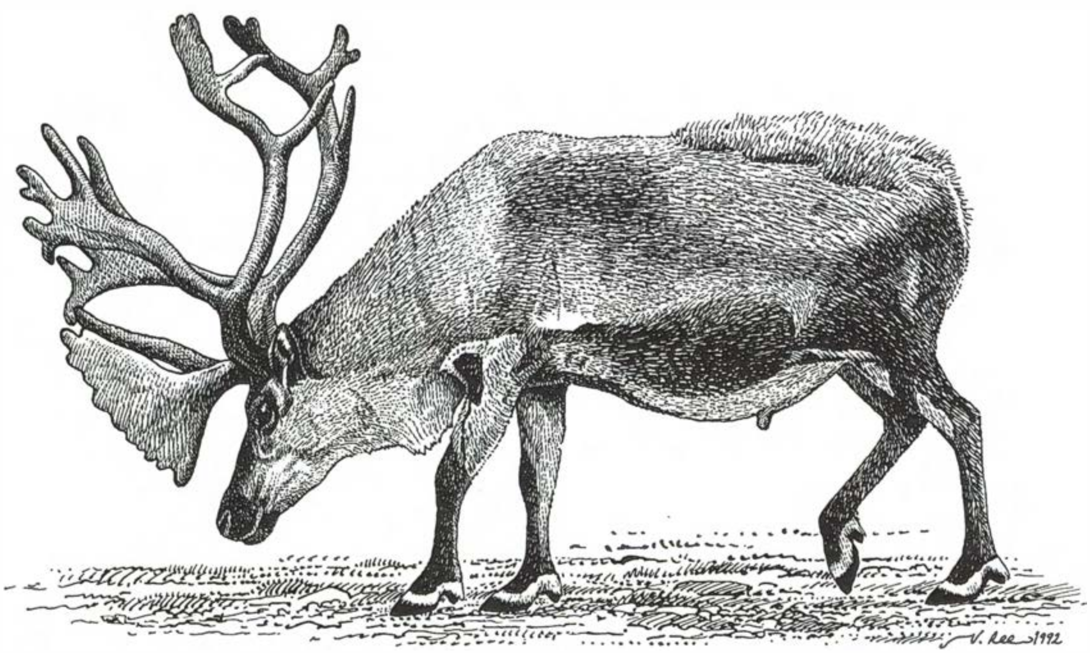


Figure 3.12 **Reindeer**: Distribution of domestic and wild populations in the European Arctic and adjacent areas. (Source: Norwegian Institute of Nature Research)

decomposition rates, and abundance of predators. Recent studies indicate that population cycles in rodents and hares are a result of the interaction between food supplies and predation (Krebs et al. 1995). In recent years, the rodent cycles in Fennoscandia have not reached high densities.

Hare and beaver are found throughout the southern parts of the European Arctic, though beaver is not found in Iceland. The eastern muskrat, found mainly in the Russian Federation, has in recent years shifted its distribution further west.

The characteristic ungulate species of the far north is the reindeer. Reindeer are strongly migratory and demand vast areas to thrive and reproduce. The expansion of herding of domesticated reindeer displaced the wild reindeer from northern Norway, Sweden and Finland in the 1600s. Most reindeer in the European Arctic are now domesticated. Reindeer management is, with a few exceptions in southern Norway and Finland, regulated by the indigenous Saami people. The number of domesticated reindeer has increased considerably during the last 10 years, and today over-



Arctic reindeer
(Rangifer tarandus platyrhynchus)
(drawing: Viggo Ree)

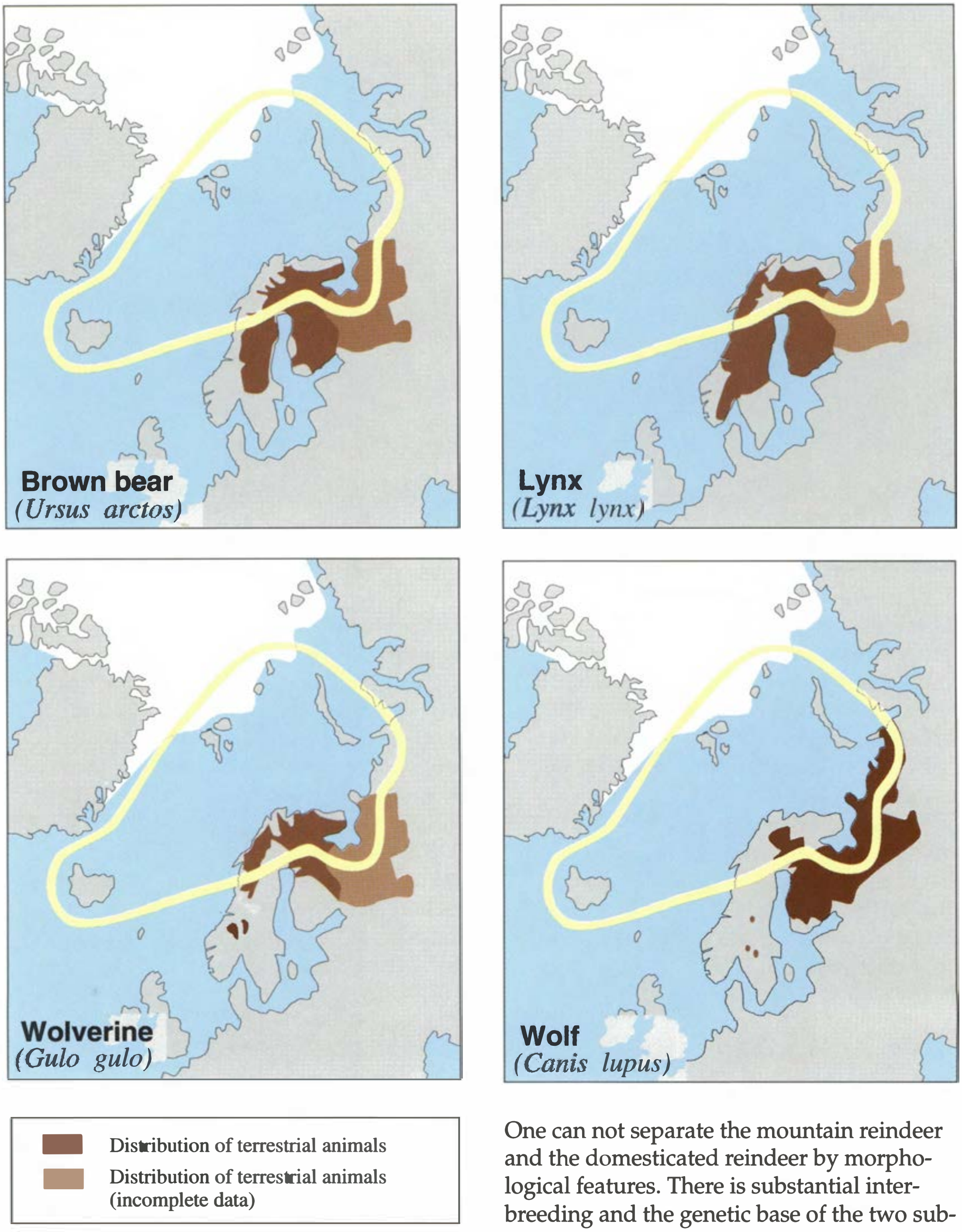


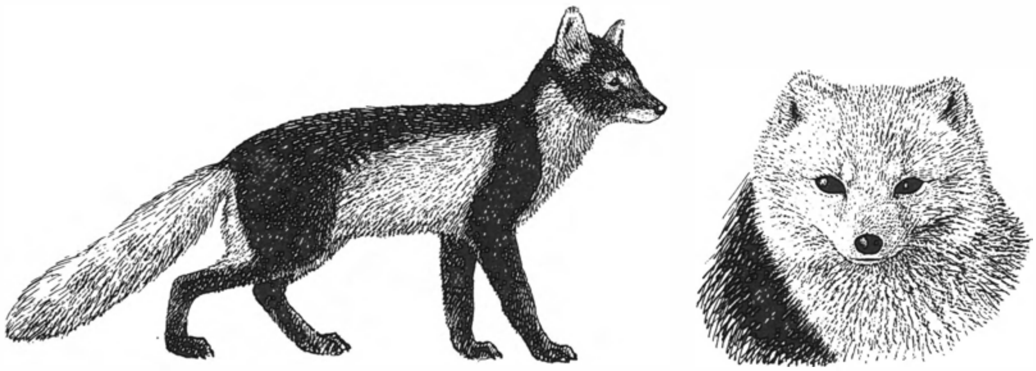
Figure 3.13 **Large predators**: Distribution of brown bear, lynx, wolverine and wolf in the European Arctic. Data from outside the European Arctic is not included (various sources).

grazing is a problem in most of the Saami areas. On the mainland of the European Arctic there are remnant wild populations of reindeer in the Karelian Republic.

The reindeer on the mainland of the European Arctic are divided into three subspecies: the Scandinavian mountain reindeer (*Rangifer tarandus tarandus*), the Arctic wild reindeer (*Rangifer tarandus platyrhynchus*); and the forest reindeer (*Rangifer tarandus fennicus*). In addition comes the domesticated reindeer.

One can not separate the mountain reindeer and the domesticated reindeer by morphological features. There is substantial interbreeding and the genetic base of the two subspecies is mixed because several of the Norwegian wild mountain reindeer populations have their origin in escaped domesticated reindeer, or because originally wild mountain reindeer populations have been blended with escaped domesticated reindeer (Figure 3.12).

The total Scandinavian wild reindeer population is managed in 24 more or less separate stocks. There is also a stock of the original wild reindeer in the central areas of the Kola Peninsula (Syraechkovski 1986). The mountain reindeer is extinct in Sweden and Finland.



Arctic fox *(Alopex lagopus)* in summer (right) and winter coat. (drawing: Viggo Ree)

In the Russian parts, there exists a small population of wild reindeer of approximately 500 individuals in Lapland Nature Reserve in Murmansk county. In addition, approximately 2300 individuals of wild reindeer are mixed with domesticated reindeer in the area (O. Makarova pers. com.)

The Scandinavian forest reindeer differs morphologically from the mountain reindeer and the Arctic reindeer. The forest reindeer is found in three different areas in Finland, and in an area in the eastern part of the Karelian Republic. The forest reindeer is extinct in Norway and Sweden (Blomquist 1994).

The Arctic reindeer exclusively inhabits the high Arctic islands of Svalbard and Novaja Zemlja. It differs from the mountain reindeer, morphologically, physiologically, and with regard to behaviour (Hindrum et al. 1995). This endemic subspecies is extremely well adapted to life on the exposed high Arctic islands. They are among the extremely few mammals able to survive in these areas based exclusively on obtaining food from the terrestrial environment. They are also adapted to not having predators, and are therefore slow-moving and not overly suspicious.

The characteristic ungulate species further south, in the boreal forests bordering the European Arctic, is the moose (*Alces alces*). It is widely hunted, but the populations are high and stable in most areas.

The smaller mammalian predators are found throughout the region in forests and on the highland plains. Many of these prey on rodents and are thus limited in their distribution to where rodents are found.

The Arctic fox is found throughout the region in alpine or tundra habitats. The mainland populations of Arctic fox are generally very small and vulnerable, and some of them are threatened (see enclosed 'Red List'). On the mainland the Arctic fox mainly eats rodents. On the high Arctic islands it gets much of its food from the marine and coastal ecosystems (birds, fish, and carrion).

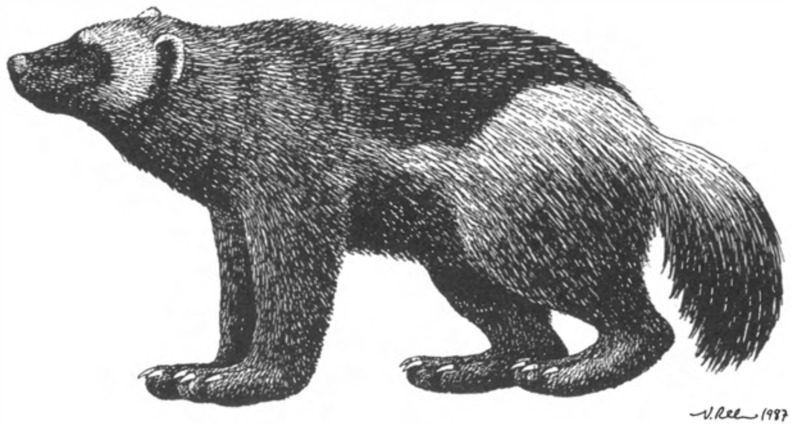
There are four large land predator species in the region: the brown bear (*Ursus arctos)*, lynx *(Lynx lynx)*, wolverine *(Gulo gulo)*, and wolf *(Canis lupus)* (Figure 3.13).

All of these require large territories to meet demands for food, shelter, and breeding. The largest European populations of these four large predators are still found in the Russian Federation (Bergstrøm et al. 1993, Semjonov-Tian-Sjanskij 1987). However, even here their numbers are low and some of the species are endangered (Appendix).

Although hunting and land use changes in the western European countries have lead to depletion of their local predator populations, particulary in Norway, immigration from the Russian Federation secures a certain number of these species in mainland Finland, Sweden and Norway.

Terrestrial birds

The species composition of the terrestrial bird fauna in the European Arctic is characterised by a strong north–south gradient, and to a lesser extent also by an east–west gradient. Many species meet their northern limits in the taiga of southern Fennoscandia and the Russian Federation. Characteristic for this area is a rich passerine fauna, woodpeckers, and several species of forest-living grouse, raptors and owls. Lakes and marshes are important components of the taiga. A large number of ducks and waders breed in these areas, and divers and cranes are also characteristic species. Unlike the more northern areas, the taiga supports a number of wintering terres-



Wolverine *(Gulo gulo)*
(drawing: Viggo Ree)

trial bird species. Most species do, however, migrate to more southern areas.

Most birds on the tundra are found in connection with wetlands. Large populations of swans, geese, ducks and waders breed here, and many of these species are found exclusively on the tundra. The passerine fauna is relatively sparse; in the high Arctic tundra the snow bunting (*Plectrophenax nivalis*) is the only common passerine. In Svalbard and Franz Joseph Land there are no breeding raptors or owls, but further south, in areas with lemmings and voles, the snowy owl (*Nyctea scandiaca*) is a characteristic species. Almost all birds breeding on the tundra are migrants. Several species of geese, ducks and waders gather in large flocks before and during the autumn migration. River estuaries and coastal areas with rich vegetation are important during this period.

The bird fauna in the alpine areas in Ural, Kola, Fennoscandia and Iceland have much in common with that of the tundra. The relative number of species in the species groups are similar, but the species themselves may differ. Iceland lacks many of the eastern species, but has a few western species not occurring further east, like harlequin duck (*Histrionicus histrionicus*) and barrow's goldeneye (*Bucephala islandica*).

Freshwater ecosystems

Due to topography and climate, the land areas of the European Arctic are rich in freshwater resources. The region includes rivers which both flow north from the Arctic, south from the Arctic, and into the Arctic from lower latitudes. Some of the world's largest rivers are located in the Russian Arctic. The rivers in the east are generally larger than those found in the west. At the same time northern Norway has the highest surface runoff in the Arctic.

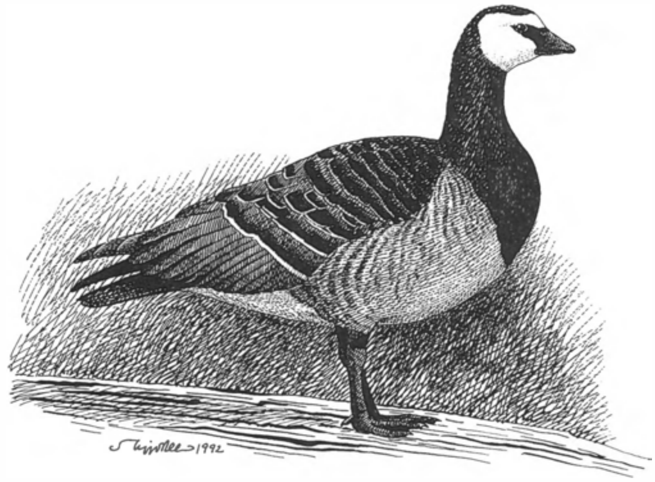
Five of the 30 largest rivers in Europe flow in or through the European Arctic, and the drainage from the region contributes more than 90 per cent of the total freshwater inflow to the Arctic Ocean. Three-quarters of the lakes found in Europe are in the region (Kristensen & Hansen 1994).

Biological diversity

Compared to freshwater ecosystems further south, the Arctic rivers, lakes and wetlands generally have lower biological diversity. Nevertheless, the river systems of the Arctic stand out as species-rich oases and dispersal pathways in the otherwise fairly species-poor taiga, tundra, or mountain ecosystems.

As a river flows, it is continuously changed by the land it flows through, and the river in turn changes the landscape. The water quality will therefore vary greatly through the river-course, through lakes and wetlands. It is normally more nutritious, the temperature is higher and the flow is slower further down along the system. River systems give rise to a variety of habitats, many of them isolated, where highly specialised and genetically distinct varieties of species may be found. Many species inhabiting freshwater do not tolerate high salinity or periods on land, and migration to other river systems is therefore difficult.

Many Arctic freshwater systems are used for breeding, resting and moulting by migrating birds, and seasonally show a high diversity. E.g., in the Karelian Kivach, a 10,460 ha large basin of the river Suna, 185 species of



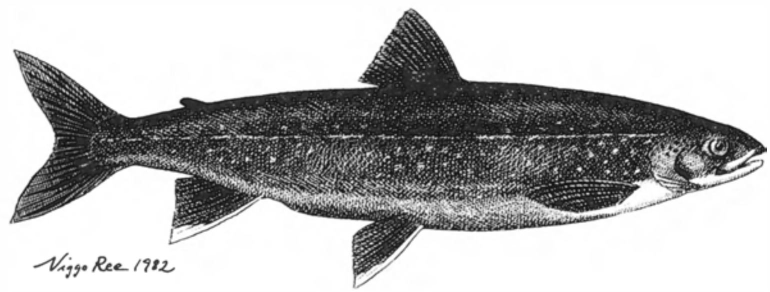
Barnacle goose *(Branta leucopsis)* (drawing: Viggo Ree)

birds occur during summer and autumn.

The freshwater systems of the Svalbard archipelago are good examples of high Arctic freshwater ecosystems. Most of the watercourses are relatively short, and many – but not all – are glacier fed during summer. With the exception of spring-fed brooks most of the running water systems have a limited animal life, but well developed algal communities are found in the numerous lakes and ponds.

The general rule that Arctic ecosystems are low in biodiversity is true also for freshwater ecosystems in Svalbard. But the biological diversity can vary greatly between localities. This is partly due to abiotic variation, but also to the postglacial immigration history, isolation and evolution, key species, and ecological interactions. The zooplankton communities usually include the taxa *Rotatoria*, *Cladocera*, and *Copepoda* (Halvorsen & Gullestad 1976, Klemetsen et al. 1985, Jørgensen & Eie 1993). The bottom-dwelling communities

Polar bear *(Ursus maritimus)* (drawing: Viggo Ree)



Arctic char *(Salvelinus alpinus)* (drawing: Viggo Ree)

lack many of the taxa which occur further south, and they are dominated by chironomid midges and some other taxa of insects and crustaceans (Styczynski & Rakusa-Susczczewski 1963).

The genetic variation between river systems is particularly noticeable in the Arctic char (*Salvelinus alpinus*). It is the northernmost freshwater fish species in the world, and the only year-round vertebrate in the Svalbard freshwater systems. This species is also found at higher altitudes in the Scandinavian mountains than any other species. The Arctic char has a circumpolar distribution, is abundant throughout the European Arctic region, and is one of the most polytypic fish species known (Balon 1980, Johnson & Burns 1984, Kawanabe et al. 1989, Skulason & Smith 1995, Klemetsen et al. 1995). The Arctic char is highly diverse at the population level also in Svalbard (Gullestad 1975, Hammar 1989, Klemetsen et al. 1985, Svenning 1993, Svenning & Borgstrøm 1995). Both open freshwater systems, which allow anadromy to develop, and closed systems, where population contacts by migration are not possible, occur along the western and northern coasts of the archipelago. The lakes of Svalbard are among the northernmost lakes with fish in the world, and they possibly include the world's northernmost anadromous char population. The diversity of life history strategies, including anadromy, mixed anadromy, residency, cannibalism and sympatry, is large and there are indications that considerable genetic variation exists in these areas.

The freshwater systems of Svalbard and the other High Arctic islands are thus natural elements of high significance for biodiversity, management, and conservation in the European Arctic.

The coasts of northern Norway and the Russian Federation have diversity of anadromous salmonid fish. Five species are found: Atlantic salmon (*Salmo salar*), sea-run brown trout (*S. trutta*), sea-run Arctic char (*Salvelinus alpinus*), sea-run whitefish (*Coregonus* spp.), and the introduced pink salmon (*Oncorhynchus gorbuscha*).

Freshwater species have immigrated to the European Arctic through three main routes, (not including birds and mammals): in from the sea, through connected river systems, or by deliberate or undeliberate human activity. Species that tolerate saltwater have colonised freshwater from the sea, e.g. trout, char, salmon, eel, and three-spined stickleback. Some of these species entered the region as early as the end of the last glacial period while the sea level was still high. These early arrivals formed populations which today are isolated from the sea by high and steep waterfalls.

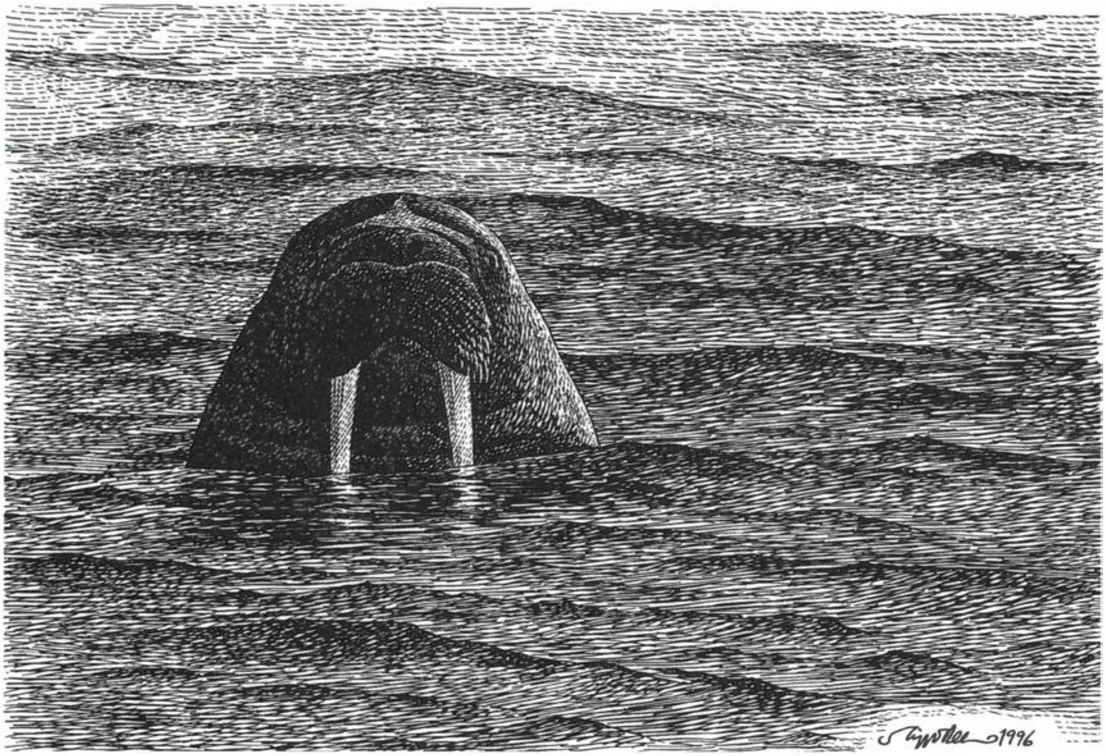
As the ice melted after the last ice age in the European Arctic, large lakes formed a more or less continuous belt of freshwater systems from west to east.

Several fish species, e.g. pike, perch, whitefish and minnow, as well as water plants, also colonised new areas along this route from east to west. Human success with importing new species, e.g. the rainbow trout and carp, and with spreading species already existing in an area to other water systems, illustrates how the main factor regulating the distribution of different species in this area is migration.

Productivity

Lakes and rivers in the Arctic are generally not very productive, partly because of the low nutrient levels in such freshwater, and partly because they are ice free for only a short period during summer. Arctic lakes are typically ice covered eight to ten months per year. Vascular water plants, which are abundant in more southern lakes, are almost non-existent in the European Arctic, mainly because ice scrapes the beaches, scurries, and shallows throughout the long winter.

It can be difficult to find any life at all in lakes and watercourses immediately down-



Walrus *(Odobenus rosmarus)* (drawing: Viggo Ree)

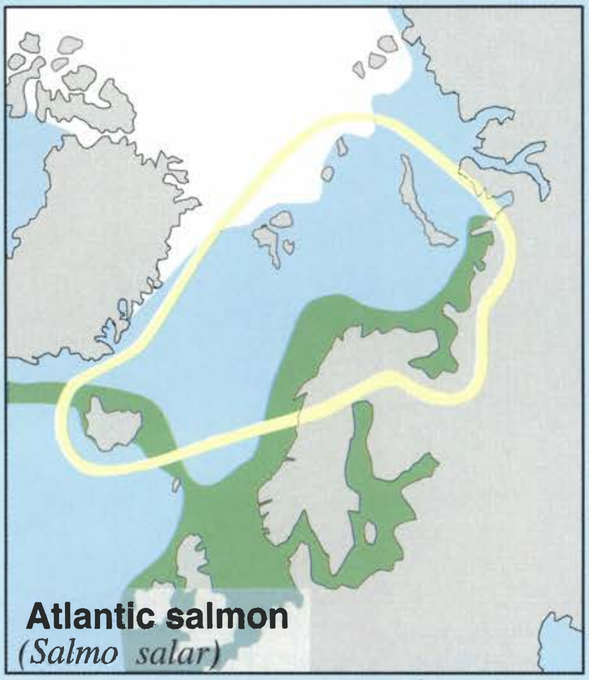
stream from glaciers. The water masses are mixed with silt to the extent that it is almost completely opaque. Most Arctic lakes however are extremely clear, and even in lakes covered by ice most of the year the light reaches deep enough to sustain a limited plankton flora dominated by diatoms, and zooplankton that feed on these. Lakes and rivers that are not too poor in nutrients generally have enough zooplankton, insect larvae and benthic fauna to support a certain fish stock.

River systems cover enormous areas and flow through remote and barren land areas. They carry large amounts of energy and sediments to the sea. Much of the sediment is deposited along the course of the river and in the estuaries. River banks and flood plains along the lower part of the rivers and estuaries therefore generally become fertile, and the biological productivity in these areas is higher. The richness of insects, other invertebrates, and vegetation found in such wetlands serve as food for many migrating waterfowl that gather there during spring, summer and autumn.

There are numerous important sites for migrating waterfowl in the Arctic. Some of the largest are located in the north-western Russian Federation. The Onezhskaya Guba at the mouth of the river Kem in Murmansk county is among the most important ones. Here hundreds of thousands of birds gather during spring and summer. The area is also important as a wintering area for eider ducks. The area is affected by large-scale seaweed harvesting, tourism and water navigation. Another important area is the Varandeyskaya Lapta Kosa in Arkangelsk oblast, a 350,000 ha area of inter-connected lakes. This is one of the most important breeding sites in the European Arctic for swans, geese and ducks. An estimated 2,000 swans, 35,000 geese and 100,000 ducks also moult here. Both of these areas are proposed as Ramsar Sites. Borgarfjordur, a 7,000 ha estuary on the west coast of Iceland, is also an important moulting area for around 100,000 eider ducks and passage waders (Grimmet & Jones 1989). Some lakes in the Arctic have above average nutrient levels. One of the best examples in the European Arctic is Lake Myvatn in Iceland. This lake is naturally fertilised with nutrients from nearby soils and rocks. An enormous production of zooplankton and black fly larvae support a large fish population in the lake. During summer it also supports one of the world's highest concentrations of breeding ducks. Lake Myvatn, which is protected under the Ramsar convention, is currently threatened by dredging operations and by tourism.

BOX III
THE ATLANTIC SALMON

The Atlantic salmon (*Salmo salar* L.) is anadromous, i.e. it lives both in salt and freshwater. It spawns in rivers and spends years in the oceans feeding. It is found in rivers along most of the European Arctic coasts, except for the high Arctic islands and east of the Pechora river. Salmon prefer rivers with a strong current, dark bottom, and stones of various sizes.



Atlantic salmon: Distribution in European Arctic seas. Spawning rivers are not indicated.

Distribution and catches in main salmon areas
The most important salmon rivers in the European Arctic are found in the Russian Federation and in Norway. Norway's largest salmon river, the Tana, has an annual catch of about 130 tons. The annual total catch of Tana river salmon, including the ocean fishery, is about 650 tons (Moen *1991*). From 1986 to 1992 the annual total river catches of salmon for northern Norway declined from 1,700 to 950 tons.

There has never been a large Russian ocean fishery for salmon, but salmon from Russian rivers have been heavily exploited by other nations. The Russian salmon population as a whole is threatened by over-exploitation, pollution and habitat destruction. The Pechora river in Arkangelsk oblast used to be one of Russian Federation's and one of the world's most productive salmon rivers. The annual production in this river has declined from a high of 450–600 tons in the 1950s, to about 160 tons by the mid-1980s (excluding sea fishery). In 1989 salmon fishing in the Pechora was terminated due to depleted stocks (Kazakov 1994).

In the former Soviet Union, river fishing for salmon was only permitted for the State, and it was largely uncontrolled until 1960. Today, salmon fishing is strictly managed in some areas, where as a result stocks are reported to have stabilised (Kazakov 1994, Kazakov et al. 1994)

In Iceland the annual catches of salmon (mainly sea catches) have increased from between 100 and 200 tons in the 1960s to about 600 tons in 1992. This is mainly due to increased catches of salmon released from fish farms. In some areas more than 75 per cent of the catches contain salmon from farms. This intrusion of exotic farm fish into the wild salmon stock is a threat to the genetic base of indigenous Icelandic salmon (Isaksen 1994).

Most of the salmon rivers in Sweden and Finland flow into the Baltic Sea. They are generally smaller than those in Iceland, Norway, and the Russian Federation. Salmon from Finnish and Swedish rivers do not migrate out of the Baltic Sea, and thus do not interact with the salmon in the Atlantic. Almost all of the fishing of Finnish and Swedish salmon is done in the Baltic Sea, and these stocks are threatened by over-exploitation and pollution (Karlssen & Karlström 1994). Most of the salmon stocks in these areas are based on restocking from hatcheries.

Main threats

The overall stock of north-east Atlantic salmon is currently in decline. This can partly be because temperatures have declined in important ocean feeding areas, thus decreasing food availability and increasing mortality during migrations. Human impacts no doubt also have a strong effect on the salmon stock. The main current threats towards the wild Atlantic salmon are:

- Over-exploitation;
- Destruction of natural river flow patterns, by damming and irrigation;
- Channelling and draining of rivers;
- Industrial waste, acidification, runoff from agriculture, logging, and other pollution or contamination which destroys water quality;
- The parasite *Gyrodactylus salaris* which kills young salmon in Icelandic, Russian, and Norwegian rivers (spread with domesticated Baltic salmon from hatcheries);
- The M-74 syndrome in the Baltic Sea, which kills young salmon (first observed in Swedish hatcheries in the 1970s);
- Genetic contamination and spread of disease from escaped or released salmon from fish farms.

Exploitation and management

In the last 100 years the thrust of salmon fishing has moved from the rivers to the seas. Efficient line- and drift-net fishing developed in this century, replacing old technology. This new industry threatened both the salmon stocks and the traditional fishing industries. Regulations were introduced, but the exploitation increased. In 1983 a treaty was signed through the North Atlantic Salmon Conservation Organization (NASCO) prohibiting salmon fishing in national and international waters in the north Atlantic. In addition to NASCO in the north Atlantic, the Baltic Sea Commission works for the regulation of the Baltic salmon. The International Council for the Exploration of the Seas (ICES) also provides advisory services on salmon protection and management.

Ancient Saami reindeer rock carvings: The Saami people has lived in Finnmark for 10,000 years – in 20 years the reindeer pastures have been ruined (photo: Georg Bangjord)

4 Human activities and impacts

The European Arctic is sparsely populated. The total population of the area is 4.2 million, of which the majority is found in the Russian Federation. The indigenous populations in the European Arctic descend from ethnic groups that migrated from central Asia prior to and during the early Middle Ages. Descendants of the so-called Finnish branch, are found in the northern parts of Scandinavia and in the Arkangelsk oblast in the Russian Federation, while descendants of the Samojed branch inhabit the areas further northeast in Arkangelsk oblast.

The main economic activities of the region are: ocean fisheries, forest industry, agriculture, hunting, mining, metallurgic industry, petroleum exploration, military activity and tourism. These activities have a relatively large impact on the Arctic environment. Physical disturbances due to activities such as the development of infrastructure, construction of production facilities, and non-sustainable harvest of forest, contribute to the deterioration of the last terrestrial wilderness in the European Arctic. Over-fishing, off-shore petroleum exploitation and production, dumping of radioactive waste from civic and military activities, may cause depletion and massive contamination of one of the most important fish stocks of the world.

Pollution sources outside the Arctic are a threat to the European Arctic environment. Persistent organic pollutants (POP) are transported northward by air, sea and possibly river water, and accumulate to hazardous levels in the food chain. Long-range transported sulphur dioxide (SO_2) may cause «Arctic haze». Heavy metal emissions from industry in the region cause serious contamination locally and regionally. Improperly stored and handled radioactive materials are a major threat to the region, but so far contamination levels are very low and European reprocessing plants are the main source of radioactive pollution in the European Arctic.

Human population

The European Arctic has always been one of the least populated regions of the world. Northern Fennoscandia and Iceland have had, and still have, a fairly scattered rural population structure. The population in these areas has been stable for the last decades and will most likely remain stable in the foreseeable future.

The population densities of the Russian European Arctic areas increased during the 20th century, as the areas' political and strategic importance grew. The future development of the population structure in these areas is not easy to predict.

Current population structure

There are approximately 4.2 million inhabitants living within the European Arctic, of which 80 per cent live in the Russian Federation. Most of the population is urban with the highest levels of rural population in the northern Norwegian counties and in Finland's Lapland (30 per cent), and the lowest in Sweden (20 per cent), the Russian Federation (20 per cent), and in Iceland (15 per cent) (SCB 1994).

The Russian high Arctic islands do not have a civilian population. Svalbard, which is a part of the Kingdom of Norway, has about 1250 Norwegian and 1650 Russian inhabitants (mid-1995 figures).

Indigenous peoples

The indigenous peoples inhabiting the European Arctic today have lived in the area for a long time, in some areas long before the arrival of European cultures. The peoples referred to as 'indigenous', populated the territories following migrations from central Asia prior to and during the early Middle Ages. The current indigenous cultures of the European Arctic belong to the Ural tribes which

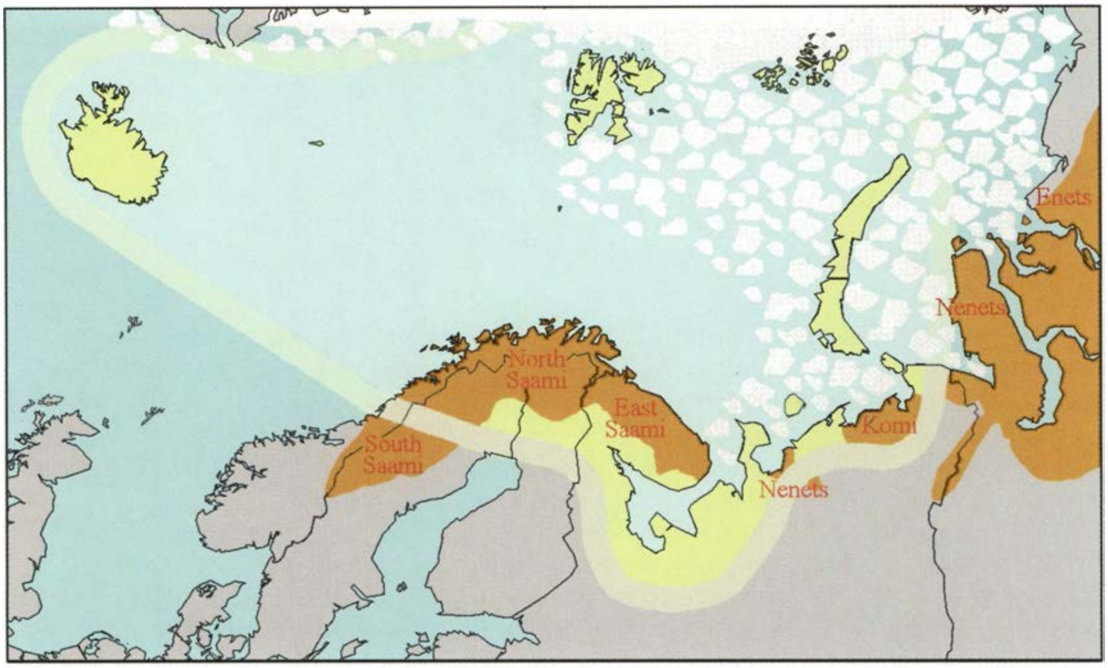


Figure 4.1 **Indigenous peoples:** Areas in the European Arctic traditionally populated by indigenous peoples. The areas have also, to a varying degree, been populated by non-indigenous Europeans for a long time.

descend from ancient Ural-Altaic language groups. These groups primarily live in the northern territories of Europe west of the Yenisey river (Figure 4.1).

Moving from west to east, the indigenous peoples of the European Arctic include:

- the Finnish branch (Saami/Lapps and Komi), who live in northern Norway, Sweden, Finland, Murmansk oblast and Arkangelsk oblast.
- The Samojed branch (Nenets/Yuraks, Selkups, Entsy and Nganasans), who live in northeastern part of Arkangelsk oblast, around the deltas of the Ob and Yenisey rivers, and east along Taimyr.

Most of these peoples are minorities in their regions today, the Komi being an exception.

The various groups have fundamental historic and linguistic differences, yet they share many of the same cultural traditions. This is because the Arctic conditions necessitate certain adaptations regarding food production or collection, clothing, and securing shelter. Geographic and climatic conditions shape the individual groups' means of food production, clothing and housing more than the ethnic ties. Ocean, fjord, or inland fishing, hunting, and reindeer herding are all traditional practices amongst most of the groups, while agriculture is mostly practised by the southern groups, i.e. the Komi (Vakhtin 1992, Dallmann 1994).

Indigenous groups in the European Arctic are all more or less influenced by the industrialised societies surrounding them. Since the latter part of the Middle Ages the nation states' efforts at political control and economic integration have strongly affected the way of life of the local indigenous peoples. Although these groups today are mostly integrated into the surrounding European communities, they are also often culturally and economically strongly tied to the natural resource base of the region. In recent years their claim of stronger control over the exploitation of this resource base has increased in strength.

Main Human Activities

Mining and manufacturing employ most of the people in the European Arctic. About 320,000 were employed in these two sectors in the region in the early 1990s.The main manufacturing activities include forestry, wood products and fabricated metal production (SCB 1994).

The fisheries and fishing industries employ about 100,000 persons in the Russian European Arctic, 15,000 in northern Norway, and 10,000 in Iceland (Hoel 1994, MEI 1992). The rest of the work force is evenly distributed in other sectors, such as services, construction, and the military.

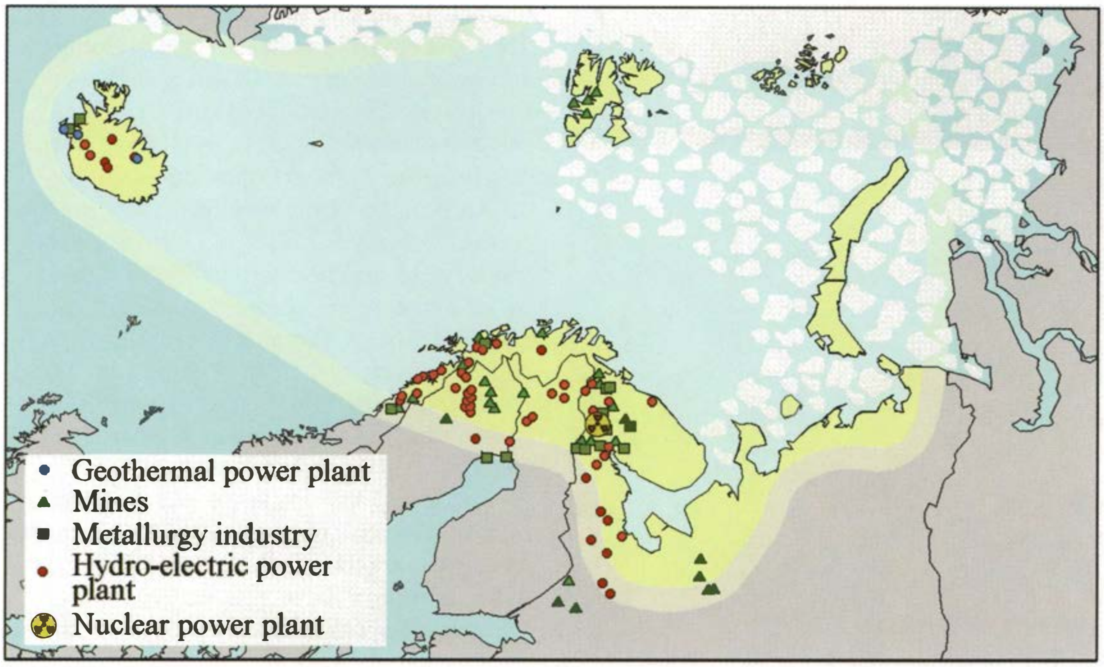


Figure 4.2 **Industry and power:** Major mining activity, metallurgical industry and power plants in the European Arctic. (Various sources).

Mining and associated heavy industries

The European Arctic is rich in mineral resources. Mining, mineral processing, and metallurgical industry are found across the entire region (Figure 4.2). The largest scale mining and metallurgical industry is found in the Russian Federation, particularly in Murmansk oblast.

The mining companies of Murmansk produce millions of tonnes of apatite concentrate each year. They produce 80 per cent of the Russian Federation's phosphate, 60 per cent of its phlogopite, and 35 per cent of its nepheline. In addition, the region produces a large amount of the Russian Federation's iron concentrate, and about 30 per cent of the Russian production of nickel.

The largest deposits of bauxite in the European Arctic are found in Severoonzjk and Plesetsk in Arkangelsk oblast. The northern region's largest producers of building materials, such as cement and limestone, are found in Pletsetsk. There are 18 coal mines in operation in the north-east of the Komi Republic.

In Sweden, there are large iron ore mines in Kiruna and Malmberget, and processing plants in Kiruna, Malmberget and Svappavaara. There are two large copper mines in Kiruna, and a lead mine in Laisvall, Europe's largest open pit copper mine, is found in Aitiken and Gällivare (CAN 1995).

The Kemi mines in Finnish Lapland contain one of the world's largest chromium deposits, with ore reserves of approximately 150 million tonnes. The primary product is upgraded lumpy ore and metallurgic concentrate for use as raw material in the ferro-chrome works in Tornio. These works produce upwards of 500,000 tonnes of ore annually. A stainless steel production plant is also located in the Tornio-Kemi area (Høifødt et al. 1995).

Norway has considerable mining activities within the Arctic. In Finnmark county, three mines are located in Bjørnevatn, whereof two are in operation. The annual production of iron ore totalling 3.7 million tonnes is delivered to Kirkenes for production of Fe-pellets. On Stjernøya in south-western Finnmark there is nepheline production with an output of 280,000 tonnes (1993). In Nordland county, 700,000 tonnes of ore per year are excavated from a mine in Balangen. The bulk sulphide concentrate extracted here, consisting of nickel, copper and cobalt, amounts to about 30,000 tonnes per year. The Rana mines consist of two mines and one pit of iron-ore. The excavation is about 800,000 tonnes of slag. Fundia Norsk Jernverk is located in Mo i Rana. They use scrap iron in the production of steel used in ship construction and armoured steel. Bleikvassli mining is situated in the southern part of Nordland county. The production in 1993 was approximately 4,000 tonnes of lead concentrate and 80,000 tonnes of zinc concentrate. Expected production in 1994 is 196,000 tonnes of ore.

The Russians and the Norwegians each have three mines in operation in Svalbard.

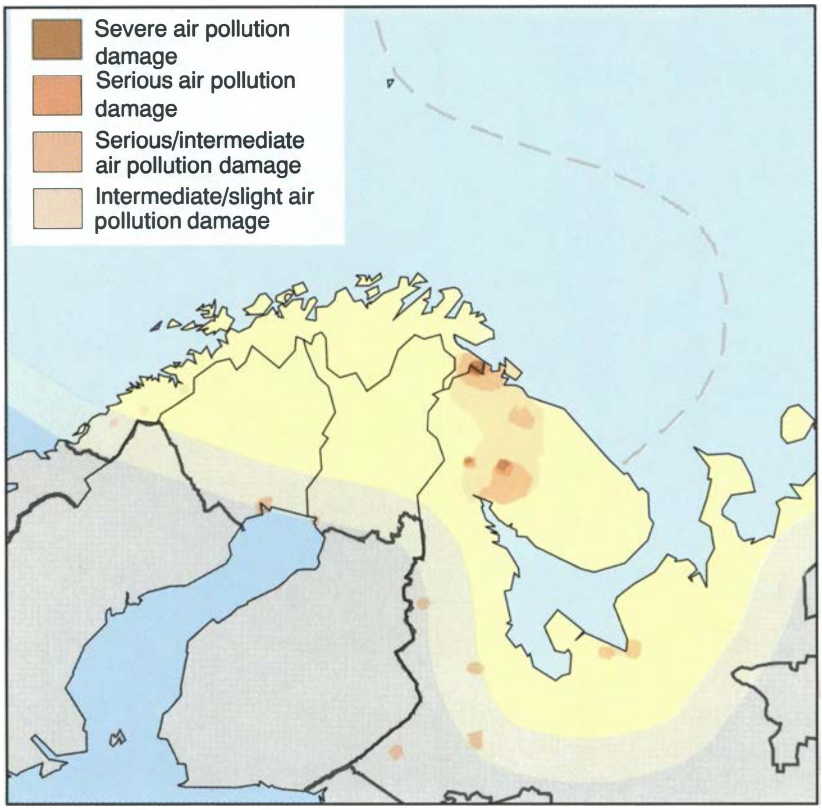


Figure 4.3
Environmental degradation due to air pollution: Impacts on vegetation by emissions to air from metallurgical industry in the Kola area. (Source: NORUT 1994).

The Norwegian coal production was 340,000 tonnes in 1994, whereas the Russian production was 580,000 tonnes. The coal is shipped during the summer to mainland Europe and the Russian Federation .

Due to readily available geothermal power, Iceland has established several heavy industry plants producing aluminium, cement, fertiliser and diatomite. There is no ore mining in Iceland.

Impacts of mining and metallurgy

The main environmental effects of mining and heavy industry are linked to air pollution, physical landscape disturbances, and soil and water pollution from seepage from slag heaps and other contaminated areas.

Air pollution from metallurgical industry contains mainly SO_2, NO_X, CO, hydrogen sulphide, PAH, and heavy metals, of which nickel and copper are found in the highest concentrations. Other metals found in high concentrations in such air pollution are aluminium, cadmium, iron, titanium, vanadium, chromium, and zinc (Stanner & Bourdeau 1995).

Impacts of acidification and metal contamination which can be traced to metallurgical industries, are found at all ecosystem levels in the European Arctic. Depending on the volume of the emissions, their concentrations, and predominant wind conditions, acidic compounds and heavy metals can damage forests and other vegetation both locally and in wide areas around the source (Figure 4.3). Destruction of the vegetation can also initiate soil erosion.

The direct deposition of acidic compounds and metals in water, as well as runoff from land, can be damaging to aquatic organisms. Acids increase the release of certain metals, such as aluminium, into the watercourse. This is harmful to fish and important food organisms. River and lake acidification and contamination can result in the disappearance of lower fauna and, in turn, fish species like trout and Arctic char.

Landscape fragmentation: Exploratory mining in Lovazero, Kola Peninsula (photo: Torfinn Kjærnet)

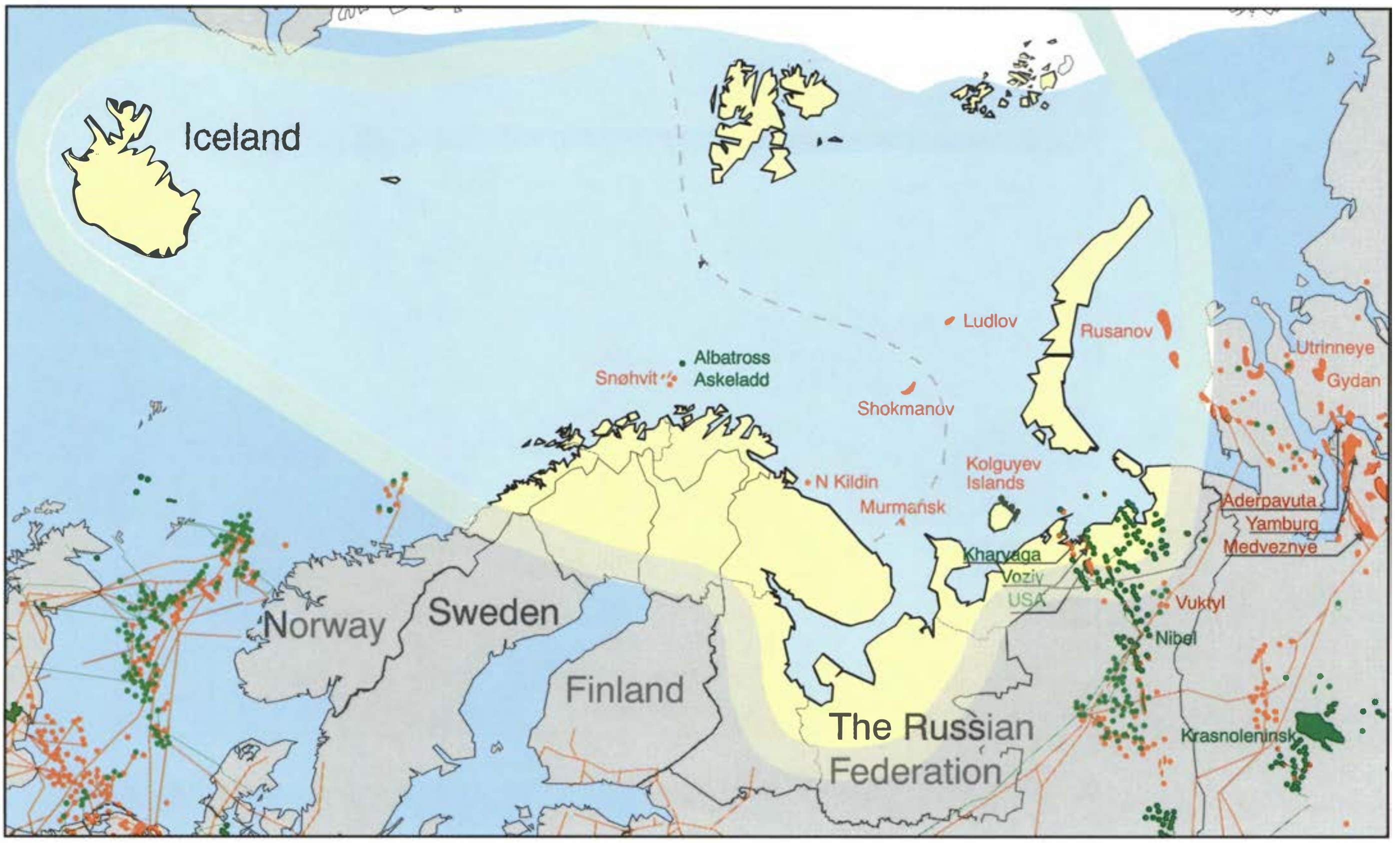


Figure 4.4 **Oil and gas development** in the European Arctic and adjacent areas. Only a small fraction of the huge oil and gas reserves in the Russian western Arctic has yet been developed. No profitable oil fields have so far been found on the Norwegian continental shelf. (Source: GRID Arendal).

Oil
Gas

Micro-decomposers work slowly and inefficiently – if at all – in acidified areas. This further decreases the already low Arctic primary production. The impacts of acidification increase the biota's susceptibility to other stresses, e.g. the general harshness of the environment, injuries caused by insects, or diseases.

Other impacts of mining and heavy industry include the conversion of land areas for new mining areas and transport facilities, fragmentation of wilderness areas by roads, railroads, pipelines, and power lines, and local dust pollution. For example, in areas with open coal mining and storage, up to 2 per cent of the exported coal can be lost as dust through wind dispersal (MEM 1995).

Petroleum exploration and industry

Off-shore activities

Oil exploration, and to a lesser extent production, occur both in the Russian and the Norwegian sectors of the continental shelf in the Barents Sea. These activities do not currently employ large numbers of people in the region, but they involve major capital and infrastructure investments and have the potential of generating large incomes. The activities have a significant influence on the economies of the countries involved. There is currently no off-shore production in the Russian sector, but extensive exploration has been carried out (Figure 4.4).

In the Russian part of the Barents Sea, including the Pechora Sea, about 19 fields have been drilled (Moe 1994). Large reserves of natural gas have been found in two of the fields. Even larger reserves have been found at the Shotckmanovskoye and Murmanskoye fields north-east of Murmansk. Ice covers these areas six months of the year, making production difficult and expensive. Enormous oil reserves have been discovered close to shore in the Prirazlomnoye field in the southern Pechora area. This field currently has the greatest production potential in the Barents Sea.

Three fields have been drilled in the Kara Sea. Large natural gas reserves (larger than Shtockmanovskoye), have been found in the Rusanovskoye field east of Novaja Zemlja. The Leningradskoye field, south of Rusanovskoye, also contains large gas reserves.

There are two alternatives for transporting oil and gas in the Russian Federation: 1) classified tankers, or 2) pipelines under or above the sea. The pipeline solution is less costly, but will cross and disturb land used for

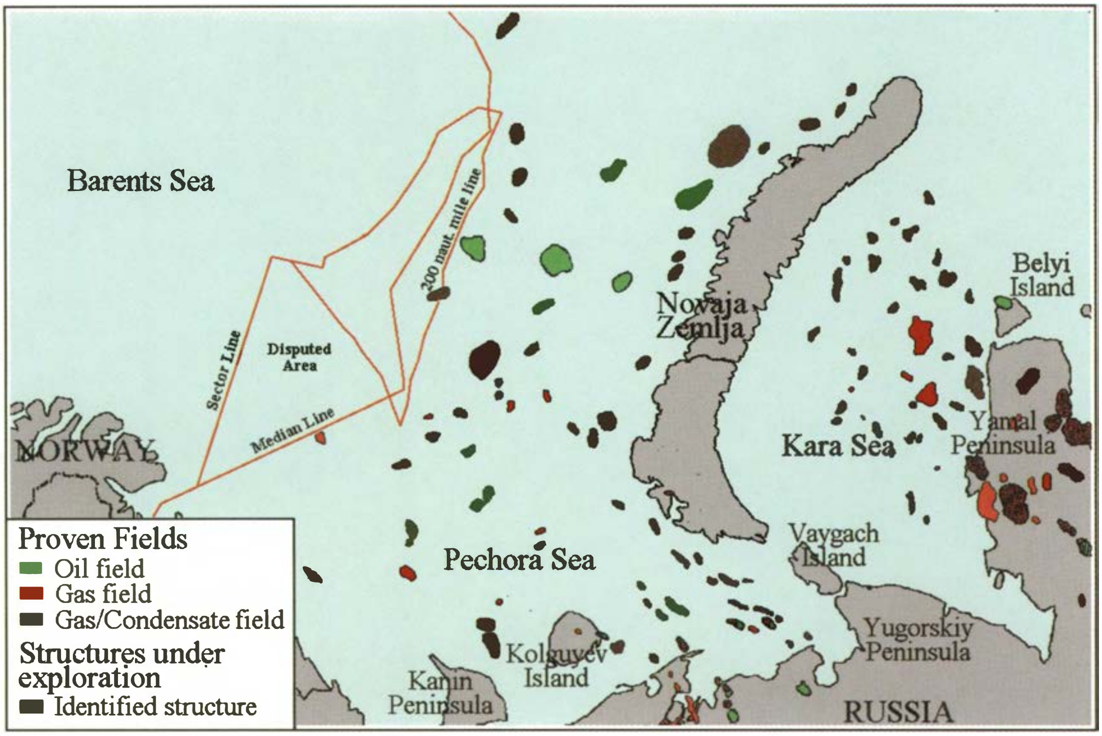


Figure 4.5 **Known hydrocarbon structures** in the eastern Barents, Pechora and Kara Seas by 1995. (Revised after map by Finnish Barents Group)

reindeer herding, as well as other transport routes to the coast.

There are plans to build a gas storage terminal in Teriberka, east of Murmansk. A submerged 600 km pipeline would then connect Teriberka to the Yamal-Europe pipeline.

From 1980 to 1994 about 35 exploration licenses were distributed for the Norwegian part of the Barents Sea, and 54 wells were drilled. Reported results indicate small or medium sized oil reserves, none of which are currently considered economically viable, and some larger gas reserves. The largest gas reserve, Snøhvit, is reported to contain about 110 billion m^3 of natural gas (MTEN 1995).

On-shore oil and gas exploitation

The only country with significant on-shore petroleum exploitation in the European Arctic is the Russian Federation (Figure 4.5). However, in the period between 1963 to 1994, 17 localities were explored for petroleum and gas on the Svalbard archipelago without any important finds.

The main on-shore activity in the Russian Federation is in the Nenets autonomic area of Arkangelsk oblast, but oil is also extracted to a limited extent on Kolguyev Island. The only oil field in full production is Kharyaga in southern Nenets. Crude oil from Kharyaga in the Komi Republic, and from the Vozey and Usa fields further south, is transported by pipeline south to Usinsk.

Transporting oil and gas in the Russian Federation poses problems, mainly because the general condition of existing pipelines is deplorable. Lack of maintenance and problems involving the crossing of administrative borders all affect the efficiency and safety of delivery.

Still, almost all of the on-shore oil and gas produced in the Russian Federation is transported by pipeline. A 139 km long pipeline in the Nenets and Komi republics is reported to be in particularly poor condition. The pipeline system goes south across the Usa river and joins other pipelines through the city of Pechora. The transportation system between Golovnie and Kharyaga is about 750 km inland from the Barents Sea, following the Kolva, Usa and Pechora rivers. Oil spills from the pipeline will eventually enter these rivers and flow into the Barents and Kara Seas. The pipeline from Usinsk in the Komi Republic to Uktha and Yaroslavl is reported to be in relatively good condition (UN 1994).

Impacts of petroleum exploration and industry

The impacts of the off-shore oil activity upon the marine environment are mainly related to pollution and seismic activity.

Pollution

Pollution from off-shore oil activity in the Barents Sea is primarily related to potential

Exploratory drilling in Arctic tundra, Vassdalen, Svalbard (photo: Torfinn Kjærnet)

accidental oil spills and to operational discharges of oil and chemicals. The probability of a blow-out or oil spill in the Barents Sea has been estimated to be one event per 1,800 exploration wells (Klungsøyr et. al. 1995). Gas blow-outs are estimated to be more frequent, but are not expected to cause the same harmful effects.

Operational discharge volumes from production may well exceed accidental spills, in particular where safety standards are low, as currently in parts of the Russian oil industry. Annual operational spills have been estimated at one million tonnes.

Ship transport of oil normally imply operational discharge volumes from accidental spills. In the Arctic, environmental conditions will also increase the general risk for accidents.

Seabirds and some marine mammals in the European Arctic are considered particularly vulnerable to oil pollution. Only small amounts of oil can reduce the insulative capacity of feathers or fur, and the animal will die directly from the cold or because it is unable to obtain enough energy (food) to keep up its body temperature. At least for mammals, raw oil is also toxic. An oil spill that reaches flocks of moulting birds in late summer/autumn, feeding birds in winter darkness, or areas close to a bird cliff, can potentially kill a large part of a population (Børresen et al. 1988).

If an oil spill enters drift ice areas in the European Arctic, the potential harm to animal populations may be even greater. Under such conditions, oil will be protected against degradation, dilution, and evaporation of the lighter (toxic) fractions by ice floes that counteract wave action. The oil is easily trapped under and between ice floes and is thus «conserved» for much longer periods than under warmer conditions. Oil will also be transported from underneath ice floes to the surface by capillary effects. In sum, this may prolong the «life» of an oil spill considerably, and thus prolong the period during which it inflicts damage to the environment. The drift ice, and in particular the marginal ice-edge, is important for higher Arctic marine life. In the spring when large numbers of seabirds, polar bears and seals concentrate in these areas, oil in the ice can affect large numbers of animals.

Seismic activity

On-shore petroleum exploration and production also causes substantial environmental impacts. In North America and in Svalbard, advanced equipment and careful procedures reduce both these impacts and the potential for accidents (see e.g. Hansson et al. 1991).

A productive ecosystem: The Barents Sea support large fisheries

The Russian oil activity in the European Arctic does not appear to use the same high standards.

Habitat is often destroyed in the construction and production area, by waste disposal, and by the extensive roads and tracks connected with the activity. Soil and watercourses may be polluted by operational spills and by discharges of oil and drilling fluids. Forest fires may be started both by accident or on purpose to clear new land.

The impact of seismic activity on fish resources is still a matter of debate, although there are indications that geophysical surveying is among the most disturbing factors on marine life in the Barents Sea (Matishov 1993). Larval stages of marine organisms have proven to be vulnerable to seismic activity close to the source. In addition, adult fish can be frightened away from fishing grounds by seismic activity (Dalen 1994).

Ocean fisheries

Major fisheries

Ocean fisheries are among the major industries in Iceland, northern Norway, and the north-western part of the Russian Federation. Both pelagic and bottom-dwelling fish are traditionally important resources in the European Arctic. Financially, the most important species in the region is the north-east Arctic cod.

The annual catches of this bottom-dwelling fish have fluctuated widely in recent years. The total reported catches from the Barents Sea cod fishery were 583,000 tonnes in 1993 and 780,000 tonnes in 1994 (Table 4.1). The total reported catches of cod from Icelandic waters in the same years were 252,000 and 179,000 tonnes, respectively (IMR 1995, HRS 1995).

Other important fisheries in the European Arctic are those based on north-east Arctic haddock, north-east Arctic saithe, and two species of redfish. The quotas for the Barents Sea in 1994 were 130,000 tonnes of haddock, and 160,000 tonnes of saithe, and the recommended catch of redfish was 12,000 tonnes.

The largest fisheries connected with pelagic fish in the region are based on capelin and herring. The landings of herring increased considerably from 1992 (about 90,000 tonnes reported), to 1994 (about 440,000 tonnes reported). Over 25,000 tonnes of herring were reported caught by vessels from Iceland and the Faroe Islands in 1994 (Table 4.2).

The reported landings of capelin from the Barents Sea amounted to 586,000 tonnes in 1993 (Table 4.3). In 1994, 886,000 tonnes of capelin were reported caught in Icelandic and Jan Mayen waters (Table 4.4).

	1985	1986	1987	1988	1989	1990	1991	1992	1993[1]	1994[2]
France		0,6		2,6	1,9	0,6	1,0	0,3	3,6	5,4
The Faroe Islands	13,4	18,7	15,0	15,3	15,7	9,6	9,0	11,7	12,4	6,6
Norway	211,1	232,1	268	223,4	159,9	88,7	126,2	168,5	221,8	296,0
Russian Federation	62,5	150,5	202,3	169,4	134,3	74,6	119,4	182,3	244,9	316,0
Spain	7,8	5,5	16,2	10,9	7,8	8	3,7	6,2	8,8	14,8
United Kingdom	3,3	7,6	11,0	8,1	8,7	3,4	4,0	6,1	11,3	16,9
Germany	5,4	11,6	8,0	3,4	3,6	1,6	2,6	3,9	5,9	4,8
Others	4,3	3,5	2,5	1,9	1,3	0,5	3,3	4,5	19,3	99,5[3]
Total	307,9	430,1	523,1	434,9	333,2	187	269,2	383,5	532,5	760,0
Unreported overfishing						25,0	50,0	130,0	50,0	25,0
The Barents Sea	111,2	157,6	146,1	166,6	163,9	62,3	71,0	124,2	195,7	
Bear Island/Svalbard	21	69,8	131,6	58,4	19,2	25,3	41,2	86,5	67,6	
The Norwegian Sea	173,6	202,7	245,4	209,9	150,1	99,5	157	172,8	269,2	

[1] Preliminary numbers. [2] Prediction. [3] Incl. tabulated countries landings in Russian zone. Sources: Institute of Marine Research

Table 4.1. **Northeast arctic cod** *(Gadus morhua)*: Landings (1000 tonnes) by country and area (excl. landings of coastal cod).

In addition to the above come the unreported catches. Such catches were estimated at about 130,000 tonnes in 1992, and more than 100,000 tonnes in 1993.

The Barents Sea capelin stock is currently at a minimum. In 1994 all commercial fisheries for capelin in the Barents Sea were closed in an attempt to rebuild this essential stock.

The Barents Sea is of crucial importance to the fishing industry in the area. An estimated 100,000 people in the north-west of the Russian Federation work directly in the fishing industry. There are about 10,000 full-time fishermen in northern Norway, with about 5,000 people employed onshore in the fishing industry (Hoel 1994).

Fishing is most essential to the Icelandic economy as a percentage of the GNP, though the actual number of persons employed is low compared to other large fishing nations. There are about 7,000 full-time fishermen in Iceland, with about 9,000 persons employed in the shore-based fishing industry (MEI 1992).

The Norwegian and Icelandic fishing industries consist of a large number of smaller fishing vessels, and a limited number of large ones. The fisheries industry of the north-western part of the Russian Federation is dominated by a group of fishery associations. 'Sevryba' is the dominant association, and controls the processing industry, shipyards, and more than 300 trawlers. There is almost

Year	Catches of adult herring			Bycatch
	Norway	Russia	Iceland/Faroe Islands	
1985	66,550	90		4,497
1986	102,429	24,200		156
1987	93,819	18,889		181
1988	105,038	20,136		127
1989	78,650	15,123		57
1990	66,604	11,807		8
1991	68,683	11,000		50
1992	86,088	13,337		23
1993	194,762	32,645		50
1994[1]	360,000	76,000	26,000	

[1]preliminary figures. Sources: Institute of Marine Research, Norway.

Table 4.2. **Herring**: *(Clupea harengus)* Landings (tonnes) in the Norwegian Sea, by country.

Table 4.3. **Capelin** *(Mallotus villosus)*: Landings of capelin (1000 tons) in the Barents Sea, by country. Source: Institute of Marine Research, Norway

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Norway	453	72	-	-	-	-	559	693	402	-
Russia	398	51	-	-	-	-	354	406	170	-
Other	17	-	-	-	-	-	20	24	14	-
Total	868	123	-	-	-	-	933	1123	586	-

Table 4.4 **Capelin** *(Mallotus villosus)*: Landings (1000 tons) in Iceland and Jan Mayen waters by country. Source: Institute of Marine Research, Norway

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Iceland	994	895	812	912	663	696	258	787	939	756
Norway	193	200	142	69	109	85		113	128	114
Faroe Islands	66	65	65	49	14	18		19	24	14
Others	16	5						1	10	2
Total	1269	1165	1019	1030	786	799	258	919	1101	886

no smaller-scale coastal fishing in the Russian Arctic.

In addition to fish, there is also a large shrimp fishery in the Norwegian Arctic territories.

Impacts of ocean fisheries

The large-scale ocean and coastal fisheries are the human activities with the most significant impacts on the European-Arctic marine ecosystem.

The main impact is the direct effect of fisheries on the size and population dynamics of the harvested stock. If more is harvested than the annual new production of the stock, both the total stock size and its ability to produce new harvestable surplus will be reduced. This has happened several times to several species and stocks (cod, herring, capelin and others) in the European Arctic seas (Klungsøyr et al. 1995)

Reduced catch as a result of previous over-harvesting may result in increased harvest pressure to compensate for reduced income. This may be directed at younger year classes, smaller stocks or immature parts of the stock, and thus further reduce the future reproductive potential of the stock.

Non-commercial fish species may be significantly affected by by-catching in commercial fisheries. As by-catch volumes are rarely reported and non-commercial species rarely monitored closely, such indirect effects may develop into substantial ecosystem alterations before they are detected. The large and partly unregulated fisheries in this area pose potentially serious threats to the biodiversity of the European Arctic marine ecosystems.

Depletion of commercial or non-commercial stocks may have serious consequences for other species that prey on them. Examples include the Brünnich's guillemot population, which was reduced by 80–85per cent along the Norwegian coast and on Bjørnøya, and the harp seal mass migration and starvation during the cod and capelin crash in the Barents Sea in the late 1980s.

Some fishing techniques such as bottom trawling and scraping for clams can destroy substantial areas of bottom habitat and thus future production and biodiversity there (Matishov 1993). Ordinary quill-nets catch and drown thousands of diving birds annually on the European Arctic coast.

The Barents Sea ecosystem naturally fluctuates between periods of strong growth of either cod, herring or capelin stocks, with corresponding reductions in the other stocks. Large-scale commercial fishing for such stocks may intensify these natural fluctuations.

The Barents sea and the Norwegian Sea includes international territories with no strict regulations regarding the exploitation of resources. The main bodies of such international waters within the region are the so-called "Loophole" and "Donuthole" areas (Figure 4.6).

The unregulated fisheries in international and disputed waters have increased in recent years. The harvesting potential for the fleet involved in these fisheries is so large that it may cause a serious depletion of key stocks and species within a short period of time if fhe fishers is not regulated. This would fundamentally damage the European Arctic marine ecosystem.

The population of common guillemot (*Uria aalge*) in Bjørnøya dropped from 245,000 pairs in 1986 to 36,000 pairs in 1987, probably due to the collapse of the Barents Sea capelin stock. (photo: Vidar Bakken)

Sub-region	1985	1990	1991	1993
Nordland, Troms, Finnmark				0.4
Norrbotten	3.9	3.5		3.4
Lappland	3.9	3.5		4.5
Murmansk		1.1	0.8	
Karelia	12.2	10.8	8.9	
Arkangelsk	25.0		18.0	8.0

Table 4.5. **Logging**: Annual volumes of timber (million m³) in the European Arctic. (Source: Høifødt et al. 1995)

Forestry and forest industry

Forest-based industry has been a key economic activity in the Nordic countries and in the Russian Federation since industrialisation. The wood-processing industry has become very important in Sweden, Finland, and in the Russian Federation. The Norwegian forestry industry in the Arctic is smaller, and produces primarily for the home market (Table 4.5).

Iceland was once forested, but was completely deforested by humans centuries ago. Today the high density of sheep grazing on Iceland effectively prevents the re-establishment of forests on the island (MEI 1992).

By far the largest forest resources in the European Arctic are in the Russian Federation.

The boreal forests in Arkangelsk and Murmansk oblasts and the Karelian Republic represent a considerable portion of the Russian Federation's total forest resources. These regions supplied more than 35 million m^3 timber in 1985, which then was about 25 per cent of the annual harvest within the Russian Federation. The volume is now down to about 8 million m^3 (Høifødt 1995).

Forest based activities are the most important economic activities in these areas in terms of numbers of employees. In the Karelian Republic, more than 40 per cent of the industry is based on timber. In Arkangelsk, about 150,000 people are engaged in the forest industry (SCB 1994).

The forest resources exploited consist mainly of spruce, pine and larch in the east and south east, and of some deciduous species, such as birch, in the western and northern areas.

Forestry and timber industry have a much smaller scope in terms of volume in the Nordic areas of the European Arctic than in the Russian Federation, yet they are the cornerstones of many smaller communities, and they are important in the respective national economies. In these areas timber generally is transported by road and rail. The forest industry employs about 6000, 4500 and 4000 people in Sweden, Finland and Norway, respectively (SCB 1994).

The harvesting and production of timber products in the Nordic countries are technically advanced. The Russian forest industry utilises less advanced technology and suffers from lack of investments in modern equipment (Høifødt 1995).

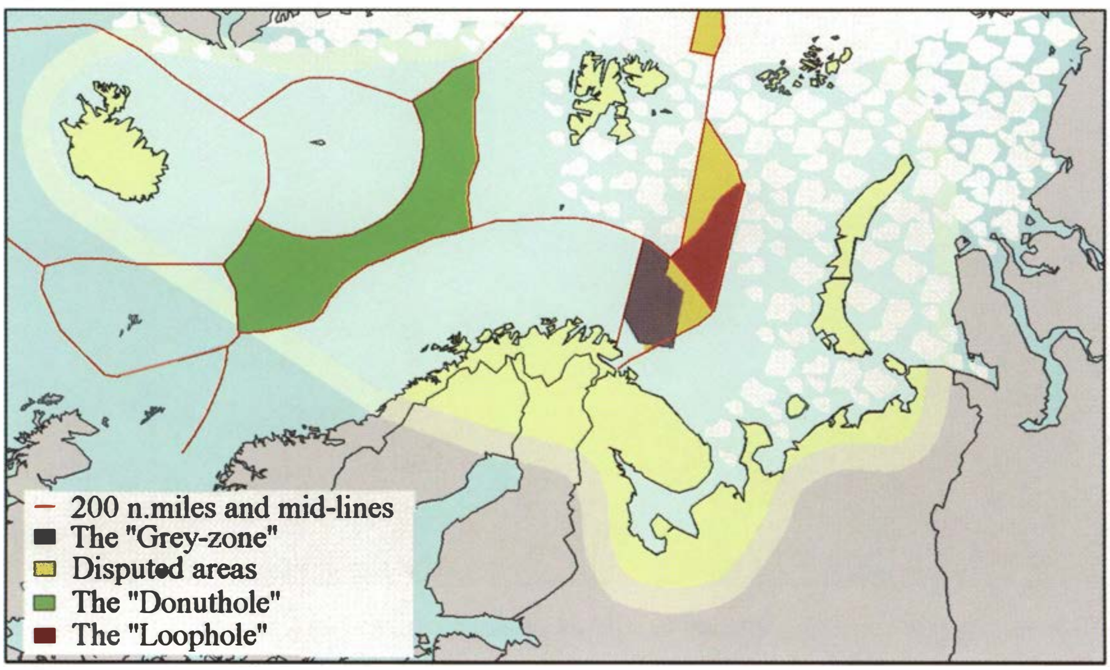


Figure 4.6 **Legal complexities** in the European Arctic seas and adjacent areas. Rich fisheries in some of the disputed areas cause international conflicts regarding management and quota setting. (Source: GRID Arendal, Norwegian Ministry of Foreign Affairs)

Fragmentation of wilderness areas: Logging practices are becoming more ecologically sound in the Nordic countries, but forestry still accounts for the decrease of mature old-growth forest areas (photo: Steinar Myhr/Samfoto

Impacts of forestry and forest industry

The main environmental impacts connected with forestry in the European Arctic are:

- Encroachment; physical disturbances.
- Harvesting; effects on species abundance and diversity.
- Pollution; effects on ecosystem health.

The *encroachment effects* usually involve:

- Loss of wilderness and pristine forest to clear-cutting or intensive forest management.
- Habitat fragmentation due to access roads and other infrastructure.
- Landscape and habitat destruction caused by wood processing mills and factories.

The *harvesting effects* usually involve:

- Depletion of natural forest structure and stand dynamics.
- Introduction of commercial, fast-growing species in monoculture.

The *pollution effects* are usually linked to:

- Air, solid waste, and water pollution from wood processing and paper and pulp industry.
- Eutrophication due to accumulation of wood and pulp in watercourses.

In the Russian Federation, most of the timber is transported by river or rail. Poorly developed road systems prevent harvesting of timber in areas not accessible by rail or river.

Large-scale clear-cutting, such as is reported to be common in the Russian Federation, transforms the natural forest ecosystem. The general effects of such practices are compounded in Arctic areas where forest growth and regeneration is very slow. Landscapes can be altered, the local climate can be altered, and the natural diversity of the forest disrupted. Several typical taiga bird species, such as capricaille, owls and woodpeckers, are dependent on old forest stands with mixed age structures, dead trees for nesting holes, and decaying trees for food insects. Extensive road-building and drainage of marshes are often part of large-scale mechanised forestry.

Large areas of planted and intensively cultivated forest areas create monocultures of single tree species of uniform age. This eliminates many plant and animal species adapted to a natural multi-age, multi-species taiga forest environment. This often also includes extensive drainage of bogs and marshes in order to create new areas for forest-growth. Such areas also disrupt the visual experience of the landscape. For some species, such as the moose, the habitat developed by a mosaic of clearcuts of various age and nature forest is favourable.

Agriculture, harvesting and hunting

There is relatively little non-livestock based agriculture in the European Arctic. This is primarily because the climate is not conducive to intensive agricultural production. Most of what does exist is oriented towards the home markets. To a certain extent livestock is kept in all the Arctic European countries . Icelandic agriculture, based on sheep farming, has the highest per capita production in the European Arctic.

Domestic reindeer herding is found in most of northern Norway, Sweden, Finland, the north-eastern parts of the Kola Peninsula, and the northern part of Arkangelsk oblast. The reindeer herds are semi-domesticated. In Sweden and Norway reindeer herding is practised by the indigenous Saami people.

Few people today survive solely on hunting and gathering in the region, but most families still support their economy by harvesting natural resources. Today, the populations of all the hunted animals and game in the area are in effect controlled by human hunting and harvesting.

Hunting wild animals for meat, furs, and for the protection of livestock has age-old traditions in the European Arctic. Historically, the main conflicts were between reindeer herding and predators such as the wolf, brown bear, wolverine and lynx.

Harvesting other natural products, such as berries, mushrooms, roots, fruit, and fodder, is also widely practised throughout the region.

Norway has the largest aquaculture industry in Europe. The industry has seen a rapid growth in recent years. The production in northern Norway was about 40,000 tonnes in 1990. There is still growth potential in this market (LENKA 1990).

Sea-based aquaculture activities are currently limited in the north-western part of the Russian Federation, primarily due to lack of investment funds (Larsen et al. 1994).

Impacts of agriculture, harvesting and hunting

The main environmental impacts of agriculture, hunting and harvesting in the European Arctic are connected with either encroachment into wilderness areas, unsustainable harvesting practices, or pollution.

The *encroachment effects* relate to:

- The conversion of wilderness to agricultural and grazing lands.
- The displacement of species.
- Sea- or landscape alteration caused by physical installations.
- Displacement or extermination of local, indigenous species through introduction of new, exotic species, such as the loss of otters in connection with fish-farming.

The most significant impact in the European Arctic from reindeer herding, and sheep and horse herding (in Iceland) is seen in areas where the density of animals exceeds the carrying capacity. This depletes the vegetation cover in the grazing areas. Erosion problems are enhanced by the increased use of fences and motor vehicles in the herding industry.

The environmental impacts of hunting and harvesting are mainly related to the unsustainable outtake of species from their natural environment.

Historically, hunting and harvesting have been the main factors affecting wildlife populations in the European Arctic, particularly the large predators and the whales. Recently, hunting regulations and protection measures have reduced these impacts, but illegal hunting, habitat destruction, and increased accessibility to many areas prevent many of the populations from recovering (Bernes 1993).

The pollution effects of agriculture, hunting and harvesting are mainly related to:

- Eutrophication or poisoning of watercourses due to run-off from fertilised land.
- Eutrophication of coastal waters in connection with fish-farming.
- Release into natural ecosystem of antibiotics and other medicines or chemicals used in fish- or other farming.
- Genetic contamination of natural populations due to release or escape of domesticated animals or plants.
- Spread of diseases, pests, and parasites from domesticated animals into natural ecosystems.

Escaped salmon from fish farms may bring diseases and parasites that wild fish are not adapted to, and thereby cause mass-death in wild populations. Escaped domesticated fish that interbreeds with wild fish may contribute to "dilution" of local genetic adapta-

Military training in northern Norway: The cold war is over, but large military forces are still concentrated in the central European Arctic. (photo: Ole Åsheim/ Samfoto).

tions and thus to making the wild population less well adapted to its environment.

Military activities

One of the major employers in the European Arctic has, for several decades, been the military. The north-western parts of the current Russian Federation had a central strategic position during the cold war, especially the Russian Fleet, with headquarters in Severomorsk. This was, and still remains, one of the world's largest concentrations of naval military power.

The Nordic countries, also recognising the region's strategic importance, established several military units as well (NAC 1995).

These efforts are currently being reduced or changed, though the region will continue to be of vital strategic importance for the Russian Federation. Many of the installations, facilities, and vessels remain in the area, though the manpower has been reduced. Maintenance and management of military installations in the region will be a challenge affecting all the European Arctic countries in the near future.

The Russian Federation has substantially reduced the number of military units and personnel in its large Northern Fleet in recent years. In the ten-year period from the early 1980s to the early 1990s the number of Russian 'fighting vessels' in the Northern Fleet was reduced from 350 to 250, the number of submarines from 200 to 120, and the number of helicopters and aircraft from 400 to 270. In addition, between 1993 and 1994, 18 submarines and surface ships were taken out of service (NAC 1995, Skorve 1994).

A total of 132 nuclear tests have been conducted on Novaja Zemlja. The test field, which was opened in 1954, covers 90,000 km^2 including the sea area. About 87 tests have been conducted in the atmosphere, three under the sea, and 42 under ground (MFA 1994).

The Russian Federation declared a moratorium on nuclear testing in 1993, but stopped nuclear testing in 1990 (NATO 1995). The main challenges and activities connected with these experiments in the future will be the monitoring of the test site areas.

Under the Soviet State Programme of Peaceful Application of Nuclear Explosions, nine (of 115) underground explosions with a total equivalent of 100 Kt were detonated in the Russian Arctic. The largest (equivalent to 40 Kt) was detonated in the Nenets autonomous district. No radioactive emissions from

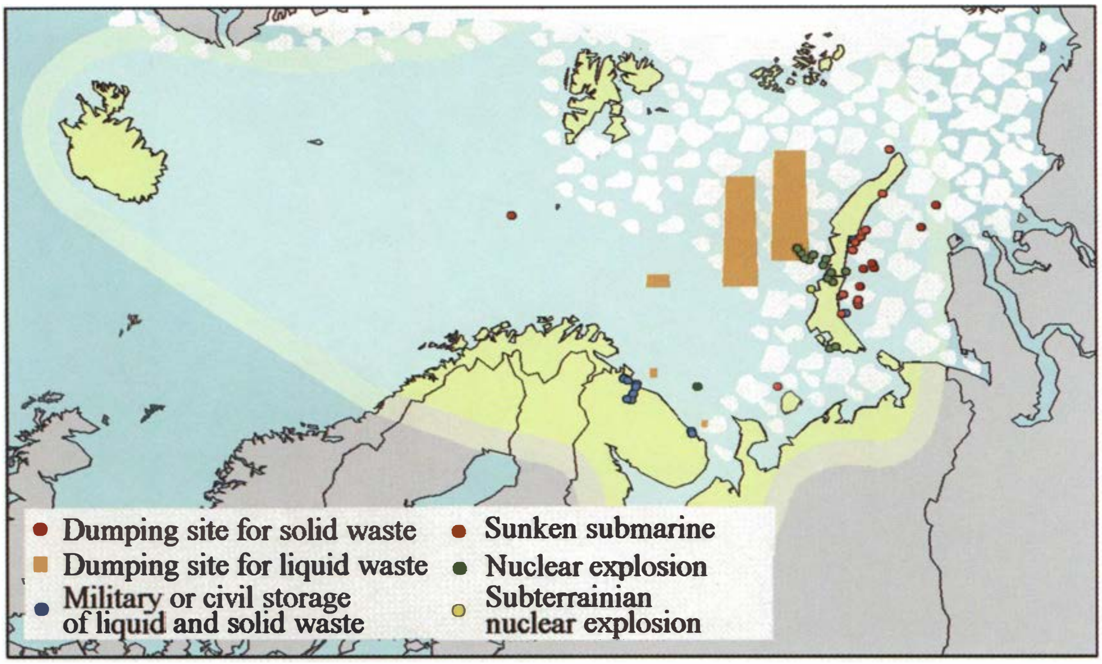


Figure 4.7 **Radioactive wastes:** Location of marine dumping sites and on-shore storing sites of solid and liquid radioactive wastes from civil and military use. (Source: GRID-Arendal).

these tests have been documented (Yemelyanenkov & Popov 1992, Igamberdiev et al. 1995).

Impacts of military activity

Military activity causes actual impacts as well as a potential for very serious impacts in the European Arctic, notably in the Kola area.

Physical impacts are caused by marine bases, harbours, shipyards as well as army camps, roads and installations on land. Further impacts are caused by training, manoeuvres of army vehicles, test fields, etc.

Waste disposal and pollution from regular military activity can affect local areas, in particular emissions from abandoned/stranded navy ships.

The impacts of release in the European Arctic of improperly stored chemicals for military purpose (many or most unknown) are potentially serious, in particular the large stores of radioactive wastes.

Energy production

In the Russian part of the European Arctic, nuclear energy and coal are the primary energy source, although the figures for the electricity production are not known.

Most of the energy in Scandinavia and Finland is produced by hydro-electric power (Figure 4.2). The largest production is generated in northern Norway and Norrbotten county in Sweden, where annually approximately 32 and 20 twh are produced, respectively. Iceland produces both hydro-electric power and geothermal power. The most important use of geothermal energy in Iceland is for heating of buildings. Electricity production using geothermal energy accounts for about 6.4 per cent of the total generated electricity in Iceland.

Impacts of energy production

The impacts of nuclear power plants are discussed under radioactivity below. Hydroelectric power development has been controversial in the Nordic countries. This is mainly due to large landscape encroachments (dams, roads), the alteration of hydrological regimes in rivers, and the potentially negative consequences for fish as well as other wildlife associated with the river systems that are being developed (Bernes 1994). The effects of thermal energy production are primarily connected with coal mining and oil production (see oil impacts), climatic effects of CO_2 emissions (see climatic change), and with other types of air pollution, such as SO_2 (see acidification) and soot.

Processing, transporting and storing nuclear waste

Almost all of the radioactive waste in the European Arctic is located in the Russian Federation. Considerable amounts of this waste are stored on and around the Kola Peninsula. This includes waste from the Kola reactors, the reactors of the Russian Northern

Fleet, and from civilian nuclear icebreakers. There are about 100 nuclear submarines, and about 60 decommissioned submarines on the Kola Peninsula (NATO 1995).

Most of the fuel elements are stored at the naval and civilian icebreaker bases. The waste is stored in decommissioned submarines, on board barges, floating vessels such as the storage ship "Lepse", and in store-houses on land (Figure 4.7). A recent report indicates that nuclear waste is in some cases stored outdoors in old containers (Nilsen et al.1995).

Some of the storage vessels are in poor condition, and safe decommissioning of the reactors using current nuclear waste handling technology is reported to be difficult. None of the storage methods satisfies current international safety requirements.

The storage capacities of the Russian Northern Fleet and the available icebreakers are nearly completely utilised, and the Russian Federation faces severe challenges in dealing with used nuclear fuel in the future.

Since the reprocessing plant started charging market prices for their services in 1991, the concentration of nuclear waste in the area has increased. The Northern Fleet is unable to pay for the shipping and reprocessing and the run-down temporary storage facilities are being filled beyond capacity.

Spent nuclear fuel from the nuclear icebreakers, which presently is being stored on board, is meant to be transferred to land when the on-board storage is full. The Russian government is planning a central land based storage facility for nuclear waste.

Since 1960 nuclear waste has been dumped in five defined areas in the Barents Sea, though some waste has been dumped outside these areas. The Murmansk Shipping Company stopped dumping radioactive waste in 1984, whereas the Russian Northern Fleet was still dumping waste in the Barents Sea in 1991 (Yablokov et al. 1993).

Low and medium intensity radioactive solid wastes have been dumped on the east coast of Novaja Zemlja and in the Novaja Zemlja trench. Most of the waste is in metal containers, but larger objects have been dumped separately or are stored in ships which have been dumped.

Nuclear waste is usually deposited directly or reprocessed. The highly radioactive waste from reprocessing is converted to a jelly consistence, enclosed and stored in rock. There is still no safe and reliable end-storage method for highly radioactive waste.

Transportation, infrastructure and tourism

The expected development of petroleum and other industry in north-west Russian Federation will cause a great demand for new roads, pipelines, runways, harbours, road traffic and, in particular, ship traffic.

Environmental impacts of transport and infrastructure

The environmental effects of infrastructure are primarily connected with physical encroachments through the construction of the infrastructure, and with destruction or fragmentation (including "boundary effects") of wildlife habitat (CAFF 1994).

The main effects of transportation and related activities include pollution and contamination (oil, radioactive material, etc.) caused by ship-, railroad-, car-, or other accidents. The probability for accidents is usually directly related to the level of transportation activity. In the European Arctic, the potential for such accidents is dramatically increased by harsh winter conditions, winter darkness, and, for ship traffic, the presence of sea ice. Particularly in the northern and eastern parts of the region emergency response organisations and facilities are limited.

Transportation activity is also known to disturb or frighten away some species of birds and terrestrial and marine mammals, thus reducing the size of their undisturbed range.

Tourism

Tourism is a significant business in northern Scandinavia, Finland, Iceland, and is increasing in north-west Russian Federation. The potential for in particular wilderness tourism there is great.

Tourism in the High Arctic islands has long traditions. Regular cruise traffic to the Svalbard archipelago started already around 1890. Tourism in Svalbard is increasing, and approximately 10,000 people visited the main town of Longyearbyen in 1993. In addition, about 20,000 cruise tourists visited the archipelago the same year.

Regular tourism to Novaja Zemlja and Franz Joseph Land does not exist. On the other hand, the Murmansk Shipping Company runs infrequent cruises between north-west Russian Federation and the North Pole using nuclear-powered ice-breakers, and to the large Siberian rivers Yenesey and Ob.

Tourism in the High Arctic islands is a

potential growth industry. More countries are now building small ice-classified cruise vessels designed to meet the growing market for "extreme tourism". Important "products" in the central and eastern part of the European Arctic are the North Cape in Norway, the Svalbard archipelago, and the large Siberian rivers. In 1995 the Murmansk Shipping Company planned ten international cruises with more than 1,000 tourists to the North Pole and to the Antarctic continent (Derbisjeva 1994).

The Icelandic tourist industry is showing strong growth. The main attractions include the unique landscape with its volcanoes, glaciers, hot springs, and wilderness in general. In 1980 about 63,000 tourists visited the island, whereas the numbers in 1994 were close to 180,000 (Gísladóttir et al. 1995).

The main environmental impacts connected with tourism and scientific expeditions in the European Arctic relate to encroachment into wilderness areas or to local pollution.

The *encroachment effects* include:

- Occupation of space and disturbance of wildlife for recreational or scientific purposes.
- Destruction of natural habitats in connection with construction and development of facilities.
- Fragmentation of landscapes and habitats in connection with access roads and transportation facilities.

The *pollution effects* are primarily related to:

- Increased motorised traffic in the Arctic.
- Water pollution and solid wastes in connection with large tourist groups.

Arctic wildlife represents both a large and a vulnerable attraction for tourism. Illegal hunting and other fauna crime, such as the stealing of eggs and nestlings of birds of prey, are sometimes a result of the increased access to virgin areas.

Tourism can enhance social and cultural conflicts in the European Arctic. Influences from outside the region cause changes in value systems, behavioural patterns, lifestyles, and the creative expressions of the indigenous peoples (Vittersø 1994).

Tourism can, if properly managed, also lead to an improved awareness of local cultures and the natural environments of the European Arctic.

Pollution sources outside the Arctic

There are certain environmental impacts in the European Arctic which arise from a range of human activities, and mainly from activities which take place at great distances from the recipient of the impact. The main groups of such impacts are radioactivity and persistent pollutants which are transported to the region from industrial and agricultural areas further south.

Nuclear activity and releases

The major sources contributing to the present level of artificially produced radionuclides in the Barents and Kara Seas are:

- Fallout from nuclear weapons testing (atmospheric, underwater, underground).
- Fallout from the Chernobyl accident.
- Marine transport of radionuclides discharged from European reprocessing plants.
- River transport of radionuclides originating from global fallout, or from releases from nuclear installations.
- Direct discharge of liquid radioactive wastes and leakage of radionuclides from dumped solid radioactive wastes

The two nuclear reprocessing plants at Sellafield, England and Le Hague, France, are the main sources of radioactive products transported along the Norwegian coast to the Arctic seas. The transport time to the Barents and Kara Seas is estimated to be 4–6 years.

The Ob and Yenisey rivers transport radioactivity from nuclear installations at Krasnoyarsk and from the nuclear installations in Tomsk and Mayak, as well as from the nuclear accident in Kyshtym. It is, however, difficult to estimate the total input of radionuclides to the Arctic seas from river waters, especially prior to 1961, because the data in the available literature are inconsistent (MFA 1994).

Long-range transport of pollutants

A group of pollutants currently causing concern in the European Arctic is the persistent organic pollutants (POPs). POPs are chemicals which are resistant to biological degradation. They are characterised by low water and high lipid solubility. They are thus easily stored in adipose (fatty) tissue. This leads to increasing concentration of POPs in the fatty

Arctic tourism: Disturbance may cause walrus to abandon traditional haul-out sites. (photo: Ian Gjertz)

tissue of organisms for each higher level in the food chain (Savinova et al. 1994).

POPs include many polychlorinated pesticides (DDT, hexachlorocyclohexanes (HCHs), chlordanes, toxaphenes), industrial compounds such as polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), and dioxins. These chemicals have harmful effects on natural ecosystems, including human health.

The pollution effects of POPs include:

- Accumulation upwards in the marine food chain.
- Effects on the central nervous system and possibly on the reproductivity of top predators in the Arctic.

Knowledge of the effects of POPs on the Arctic environment is limited. In polar bears, PCBs seem to reduce the level of thyroid hormones and retinol and they may have effect on their reproduction.

Although the use and production of some POPs have been banned or restricted in a number of countries, they are still widely manufactured and used throughout the world.

Long-range transported air pollution also include heavy metals. The metals that currently cause most concern are arsenic, cadmium, chromium, copper, mercury, nickel, lead, selemium and zinc. The sources are many, e.g. power plants, industrial combustion, extraction and distribution of fossil fuels, solvent use, road traffic, waste treatment, agriculture, and some natural processes (ESC 1994).

As for some POPs, heavy metals accumulate in marine and terrestrial food chains. They affect animals in numerous ways, for example by inducing cancer and by injuring the central nervous system.

Sources and pathways

The atmosphere is considered the main transporter of POPs to the Arctic environment. Since POPs are semi-volatile they may move over long distances and condense in colder regions such as the Arctic. The main sources are the industrialised and agricultural areas of Asia, Europe and North and Central America (Figure 4.8).

Recent studies on the origin of Arctic air

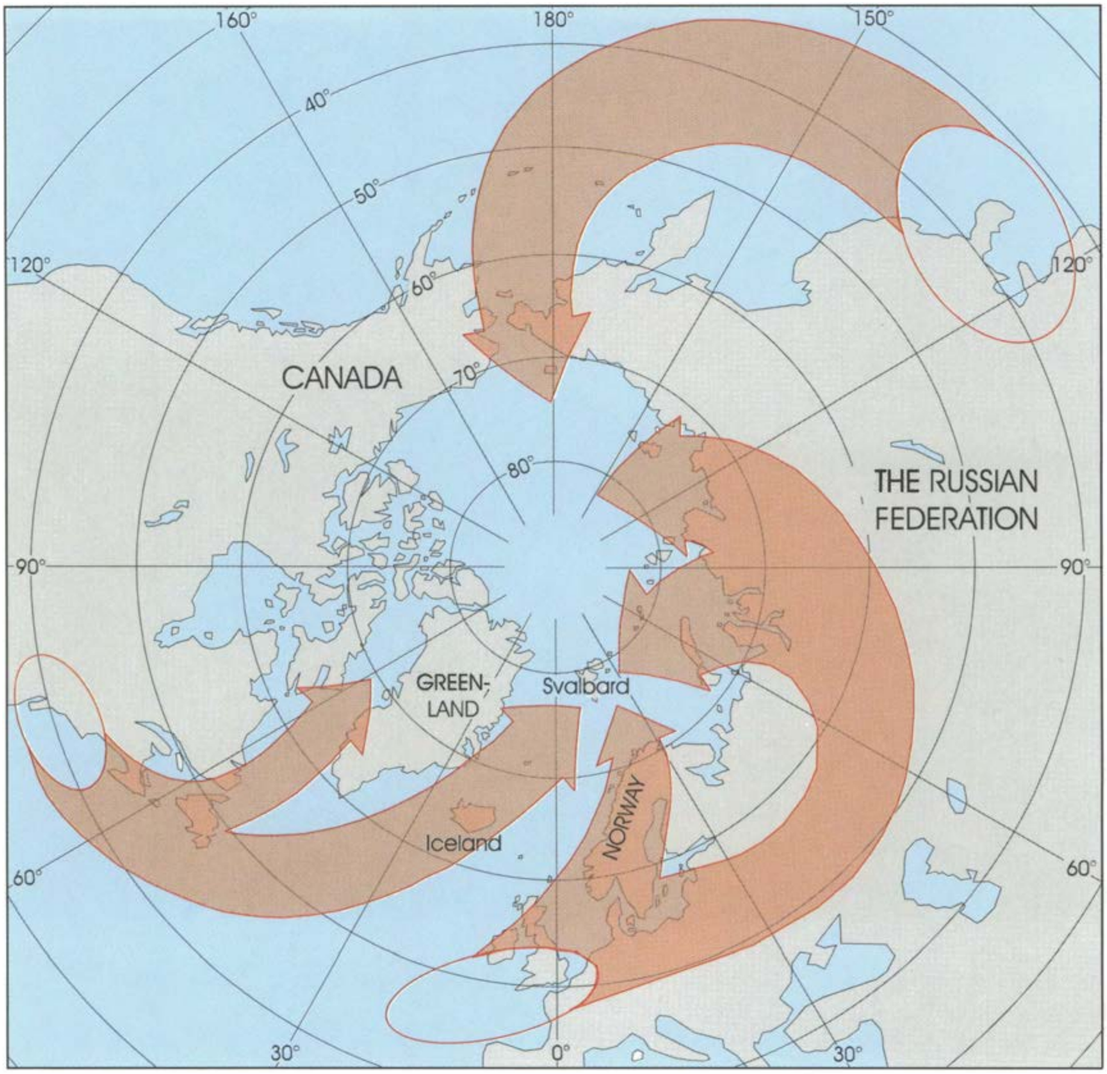


Figure 4.8 **A pollution "sink":** Predominant wind directions in the northern hemisphere indicate a one-way transportation of air-borne pollutants from the industrialised areas in the mid-latitudes to the Arctic. (Source: Rahn & Shaw 1982).

pollution conclude that during winter, 60 per cent of the heavy metals is transported to the region from sources in the former Soviet Union. The rest is from Europe and North America. During the summer, the contribution from sources in Europe can be as high as 75 per cent. Up to 6per cent of the total emissions of arsenic, cadmium, lead, zinc, vanadium, and antimony in all of Eurasia is deposited in the Arctic.

The Russian rivers Yenisey, Lena and Ob account for 65.,5per cent of the river drainage into the Arctic Ocean (Aagaard & Carmack 1989). Pollutants from centres of industrial and agricultural activity along these rivers are transported to the coastal Arctic seas and possibly further to the European Arctic (Figure 4.9).

Arctic haze

Arctic haze, which occurs in the Arctic region, consists of numerous man-made aerosol pollutants in the higher levels of the atmosphere. These are transported to the polar region through global atmospheric circulation during winter, mainly by strong south to north transportation from Europe, Asia, and North America. Arctic haze is mainly observed from December to April, when the pollutants are less efficiently removed from the cold and stable winter atmosphere by physical processes. The vertical extent of the haze is typically below 1 km from the ground. Further haze layers at elevations up to 5 km or more are due to sources far outside the Arctic air masses. Models show that sulphur dioxide emissions from highly industrial parts of the former Soviet Union prevail at the lower atmosphere levels, while other European sources contribute more to the concentration at higher altitudes (2–3 km). Pollution in Arctic haze at higher levels are mainly transported from North America (Ottar et al. 1986).

According to Barrier et al. (1989) sulphur

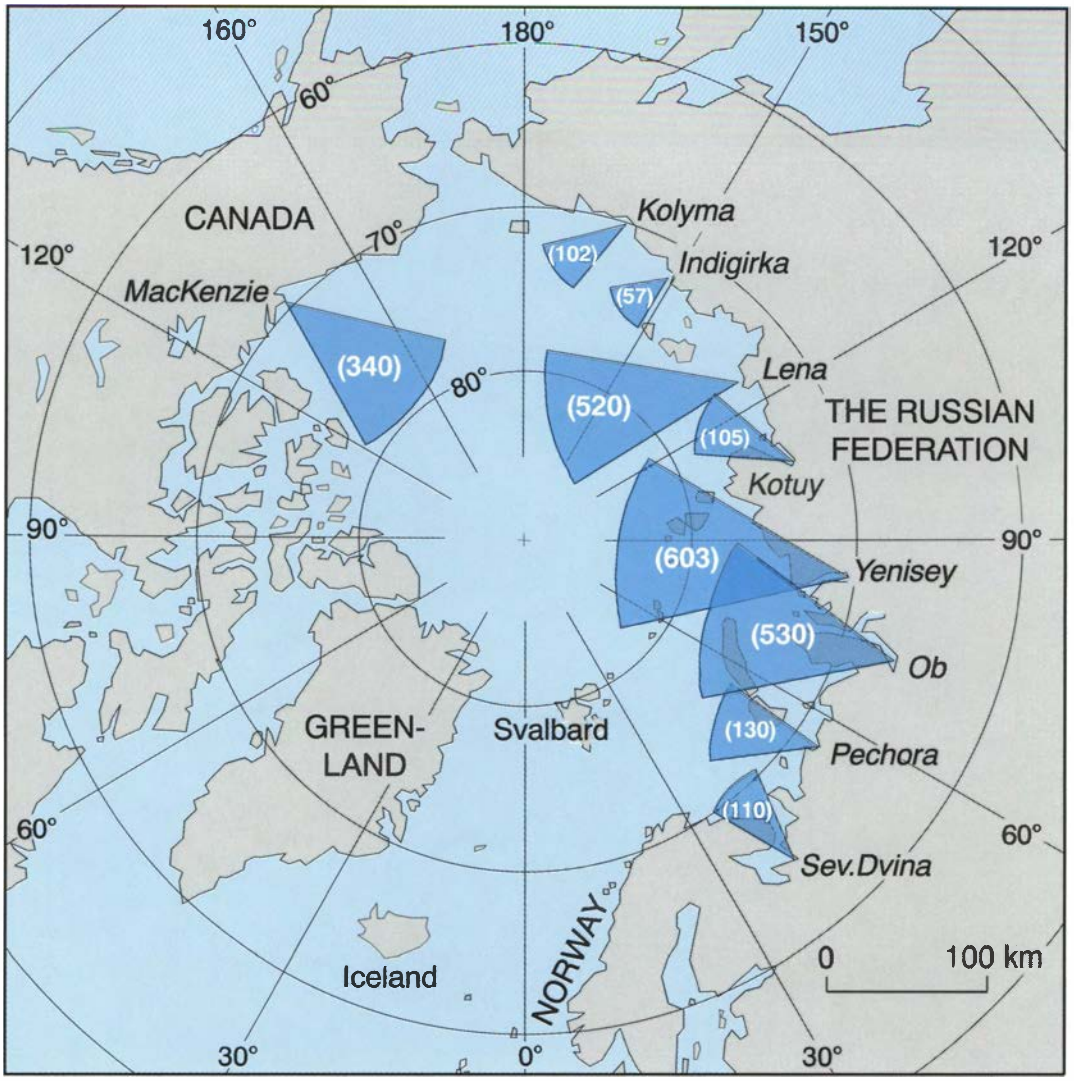
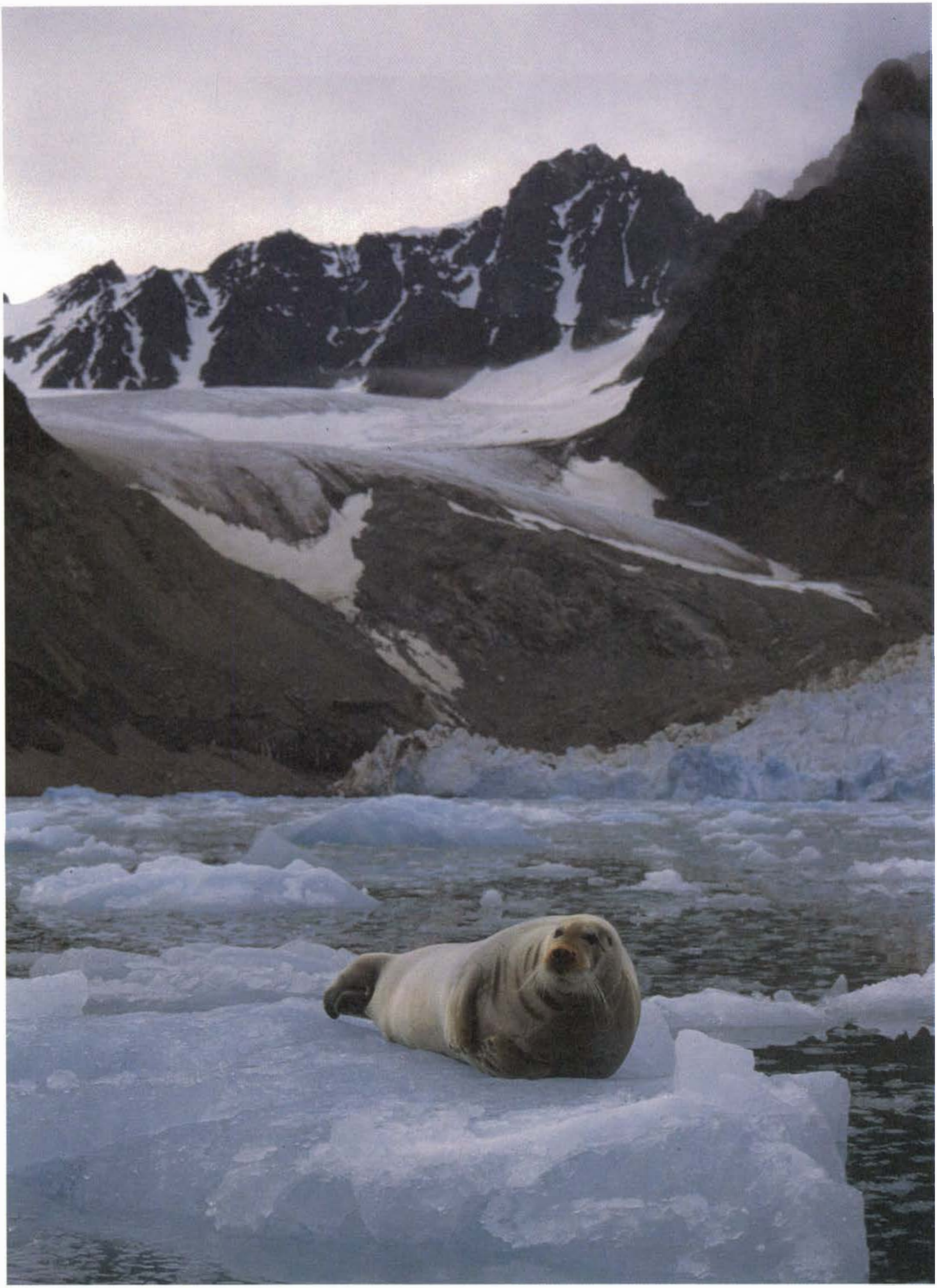


Figure 4.9 **Riverine transport:** Volumes (km³) of freshwater annually entering the Arctic ocean from major rivers. These rivers may potentially transport pollution to the Arctic from indutstrialised areas further south in the enormous catchments. (Source: Aagaard & Cormac 1989)

pollution constitutes a major part of Arctic haze. About 5per cent of sulphur emissions in the northern hemisphere, about 3 million tonnes, were transported to the Arctic in the year 1979–80. The contribution from Eastern Europe and the former Soviet Union was 69 per cent, western Europe 25 per cent, and North America 6 per cent. In addition came the contribution from the more than 2 million tonnes of sulphur emitted north of the Arctic Circle in the north-west Russian Federation.



Perfectly adapted: Bearded seal (*Erignathus barbatus*) in an Arctic fjord (photo: NP)

5 The Environmental Status

Despite low human population densities, and limited industrial, economic, and other activities, even remote parts of the European Arctic are affected by long range pollutants. There are severe environmental problems in parts of the north-western parts of the Russian Federation, and there is also pressure on parts of the marine, taiga and tundra ecosystems elsewhere in the region due to exploitation and physical encroachments. There is a need for improved marine habitat protection, in particular in the drift-ice zone in the Barents Sea.

Still, the European Arctic environment is characterised by having the largest areas of near-pristine wilderness in Europe. Most of the marine, and substantial parts of the terrestrial ecosystems, are intact, with undisturbed habitats and vegetation, and viable, unharvested populations of fish, birds and mammals. Such qualities, which are of global importance, are becoming exceedingly rare elsewhere, and they contribute to making the environment in the region outstandingly valuable to all of Europe. The state of the European Arctic environment can be summarised as follows:

The High Arctic islands

(Svalbard, Franz Joseph Land, the northern part of Novaja Zemlja and the surrounding areas of the Barents and Kara Seas)

- Are "sinks" for long-range transboundary air and marine pollution.
- Contain large, undisturbed wilderness areas.
- Have marine and terrestrial ecosystems that are largely regulated by natural processes.
- Have large populations of naturally occurring species.
- Have low human population densities, and limited human activities and impacts.
- Are highly valuable as scientific and environmental reference areas.
- Are important in climatic processes, and as indicators of other globally important environmental changes.

The north-eastern seas and tundra

(Eastern Barents, Pechora and Kara Seas, adjacent coastal and tundra areas and large river estuaries)

- Are important pathways (rivers, sea ice, ocean currents) for pollutants (radionuclides, hydrocarbons, persistent organic pollutants (POPs), heavy metals etc.) to the European Arctic.
- Contain large amounts of radionuclides dumped in the Kara and Barents Sea.
- Have high persistent organic pollutants levels in top predators in the Svalbard area.
- Have depleted capelin stocks (a key species) in the Barents Sea.
- Have areas with oil contamination of soil and watercourses.
- Have substantial areas where the wilderness has been degraded (oil/industry infrastructure encroachments).
- Are home to indigenous peoples.
- Have large marine, coastal and tundra wilderness areas.
- Have highly productive (the Barents Sea) and healthy marine ecosystems and unique drift ice ecosystems.
- Contain large populations of naturally occurring species, including seabirds, seals, and characteristic Arctic species (e.g. polar bear, walrus).
- Are of high value as scientific and environmental reference areas.

The north-western seas

(Icelandic waters, the Greenland Sea and northern Norwegian Sea)

- Contain expanding populated, cultivated and industrialised areas in Iceland.

- Contain unique geological landscape features in Iceland.
- Is completely deforested (historically; overgrazing).
- Have over-exploited cod stocks, while herring stocks are recovering.
- Still contain large marine areas that are highly productive, with healthy and economically important marine ecosystems.
- Have large populations of naturally occurring species, including seals and seabirds.
- Are home to viable populations of large baleen whales.
- Are of high value as scientific and environmental reference areas.
- Have low levels of contamination.
- Are a region of globally important climatic processes (atmosphere – sea ice – ocean).

The Fennoscandian region

(Northern Scandinavia and Finland, Kola Peninsula/ Murmansk area, and the White Sea).

- Is severely affected by pollution in the central Kola area (watercourses, estuaries, soil, vegetation, human health) as well as in other Kola rivers and the Pechora and Dvina.
- Has potential for large-scale environmental disasters from improperly stored radioactive waste, petroleum development, new infrastructure and over-exploitation of biological resources.
- Has comparatively large human populations, as well as industrial and other activities.
- Is home to indigenous peoples.
- Contains large areas of relatively undisturbed nature: Tundra, taiga, parts of large river ecosystems and estuaries.
- Has large populations of naturally occurring marine and terrestrial species.

Introduction

In this chapter, four qualitative aspects have been chosen to illustrate the general environmental status of the European Arctic. These are:

- Wilderness quality in relation to physical disturbances and encroachment.
- Species abundance and diversity in relation to harvesting and exploitation.
- Ecosystem health in relation to pollution and contamination.
- Human health in relation to industries, pollution and urbanisation.

Wilderness quality

Humans have lived in and influenced the Arctic environment for millennia. The harsh climate, great distances, and lack of access routes have, however, prevented the development of large settlements. The Arctic has always been among the areas on earth with lowest population densities, and thus also with low levels of urban or industrial infrastructure. In contrast to southern Europe, with age-old urban traditions, it is only in recent years that large-scale physical installations which disrupt, destroy, fragment, or otherwise physically interfere with the natural environment have been established in the region.

Yet, certain areas of the region have already been thoroughly urbanised and industrialised, some to the extent that large areas are rendered completely lifeless. The most extensive and damaging encroachments involve mining and metallurgical industries, petroleum exploration and production, and the large military build-up during the cold war.

The region has, although to a much smaller extent than further south in Europe, also been fragmented by transportation and communication lines. The areas most fragmented, or otherwise influenced by man, are the coastal regions of Scandinavia, the Kola Peninsula, and the Arkangelsk area.

The main physical impacts and encroachments altering the wilderness character of the region during hundreds of years of human presence have been small-scale and extensive rather that large-scale and intensive. Such activities include:

- extensive forestry, which alters the landscape and vegetation cover,
- reindeer herding, and the eradication of wild reindeer in herding areas,
- systematic depletion of large predator populations, particularly in Scandinavia,
- harvesting and active management of game and other wilderness resources.

Activities and impacts such as the above have resulted in large parts of the European Arctic being more of a 'wilderness-like' cul-

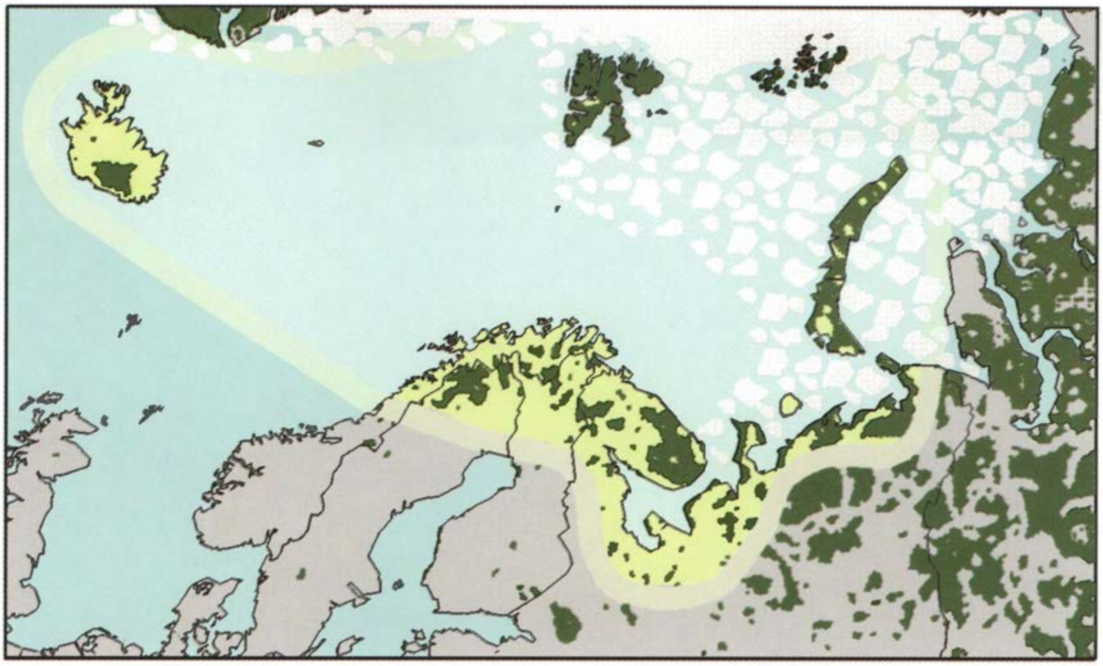


Figure 5.1 **Remaining wilderness in** Europe: Green colour indicates areas more than 60 km from the nearest road or other human installation in 1995. The extent of wilderness areas is rapidly decreasing. (Source: GRID-Arendal).

tural landscape than a 'pure' wilderness area, as implied by being totally without human influences.

Yet, using 'absence of large physical human structures' as a description of 'wilderness', the region still represents by far the largest remaining wilderness area in Europe (Figure 5.1). This applies particularly to the Russian taiga, the mountains of Scandinavia, the highland plains of northern Norway, Sweden and Finland, central and north-eastern Iceland, and the high Arctic islands.

The wilderness areas of the region are characterised by large, unfragmented areas, healthy, relatively intact, and – in the Barents Sea – highly productive ecosystems. They have large populations of terrestrial birds and mammals, including the large predators.

In no other places in Europe, and only in a few places on earth, are there equally large expanses of land and sea where the ecosystems are in such a natural state, and where population dynamics and structures of key, character species are regulated naturally and not by man.

Nature conservation

Some of the wilderness is protected by law, though large parts are not protected. Active management is needed in non-protected areas to avoid the detrimental effects of urban, industrial, military, agricultural, or other developments.

Under the Rovaniemi Process, the Conservation of Arctic Flora and Fauna programme (CAFF 1994) evaluates and advises on the circumpolar development of an Arctic protected areas network. The goal of CAFF is to secure protection of areas representative of all of the most important environmental categories in the Arctic. Existing and planned or proposed protected areas are being evaluated with regard to their coverage of key habitats and ecosystem components in order to identify important ecosystem components which are not represented in the current protected areas network. In 1996, CAFF will propose international guidelines for further protection of Arctic habitats to the governments of the eight Arctic countries.

Initial results from the CAFF studies indicate that coastal and marine areas are seriously under-represented in the current protected areas in the Arctic. In the European Arctic, the unique and ecologically rich drift-ice areas need to be protected against adverse impacts, i.a. through a dynamic management regime that ensures necessary protection while allowing for sustainable uses.

Protected areas

The countries in the region have various protection programs for parts of their wilderness areas.

Following is a brief status on protected areas development in the European Arctic (CAFF 1994) (Figure 5.2):

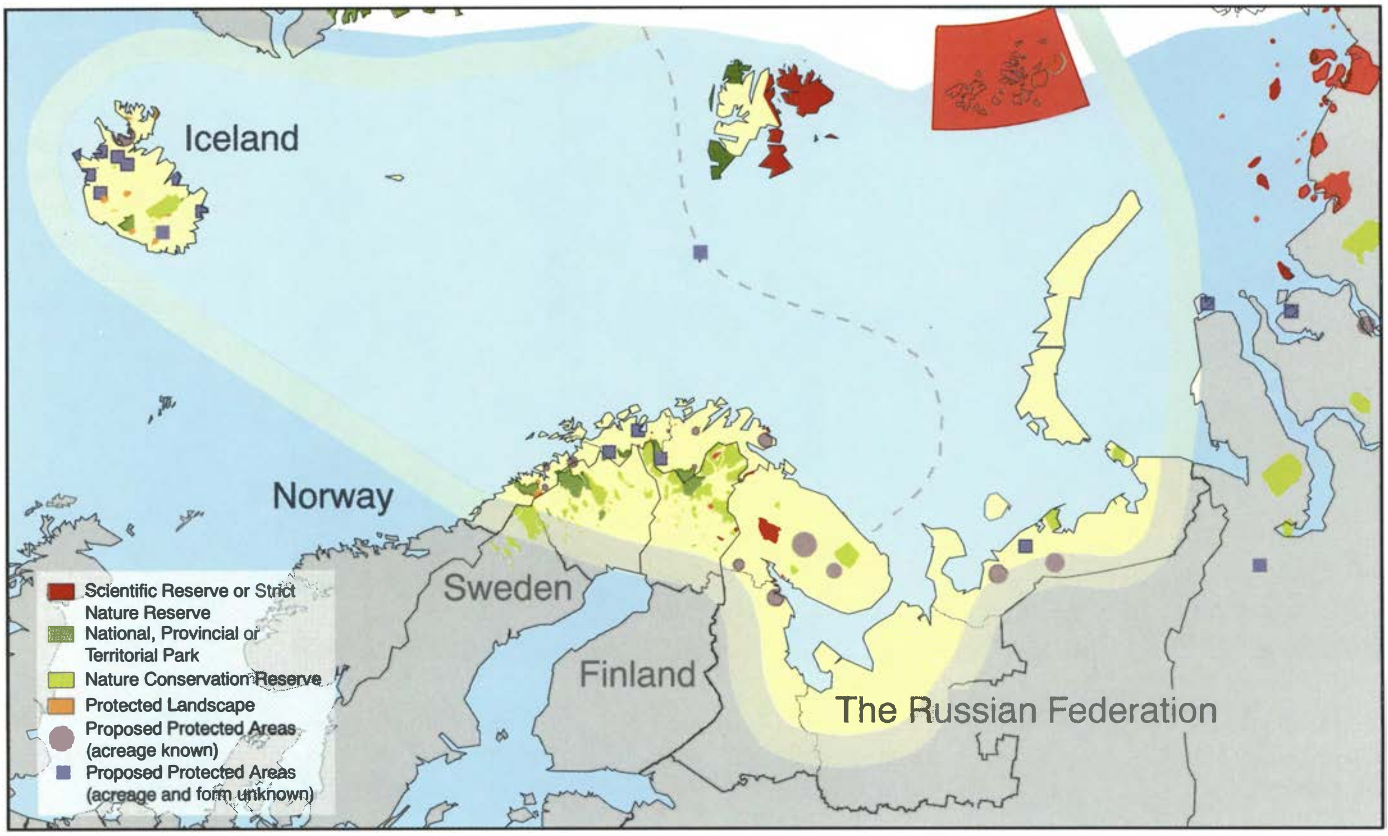


Figure 5.2 **Area protection**: Areas proposed for protection and protected areas included in the IUCN management categories I-V; areas greater than 10 km² are covered, as well as islands smaller than 10 km² where the entire island is protected. (Source: Conservation of Arctic Flora and Fauna).

The Russian Federation:

Protected areas in the IUCN categories I–V constitute about 4.3 per cent of the total Russian Arctic land area of 272,240 km². Approximately 196,000 km² of tundra, including Arctic tundra, moss-lichen tundra and bush tundra are protected. This amounts to 3.1per cent of the total protected areas in the Russian Federation. About 27,500 km² of mountain tundra, forest tundra, and northern taiga are protected, along with 42,000 km² of glaciers and polar deserts on Novaja Zemlja, Franz Joseph Land and the other high Arctic islands. A total of 25 protected areas and habitats are distributed north of the Arctic Circle in the Russian Federation. About ten of these sites are found within the European Arctic region. The Russian Federation has only one Ramsar site (70 km²) and one Biosphere Reserve (2,684 km²) (Laplandsky NR); both of these are in Murmansk county.

Protected areas exist in nearly all main types of Arctic landscapes in the Russian Federation. However, eleven new protected areas of IUCN categories I and II, covering 31,000 km², are proposed in Murmansk and Arkangelsk oblasts. Furthermore, there are proposals to include two territories as Ramsar sites in Nenets district (Arkangelsk oblast).

Sweden.

The Swedish protected areas in the Arctic consist primarily of treeless mountain terrain, sub-montane birch forests, mires, virgin coniferous forests, and lakes and streams. The total protected area is about 20,000 km², or close to 19 per cent of the Swedish Arctic. The largest protected area is 5,500 km². In addition, Sweden has five Ramsar sites totalling 2,547 km², and one Biosphere Reserve covering 965 km² (Lake Torne Träsk).

Sweden has gaps in the main land cover features represented, since major wetlands and forests in southern and north-eastern parts of the Swedish Arctic are not represented. This will be improved once the current proposal of two new protected areas covering 4,700 km² for mire/wetland and mixed mountain systems is approved.

Norway.

The largest protected areas in the Norwegian Arctic are found in Svalbard, where 22,000 km² of glaciers and 12,900 km² of tundra are protected. On the Norwegian mainland, most of the protected areas consist of treeless mountain areas (2,940 km²). Some birch forests (797 km²), and only minor amounts of coniferous forests (99 km²), fjord/coastal areas (60 km²), and freshwater (168 km²) on the mainland are protected. Altogether, 41,611 km² land areas in the Norwegian Arctic are protected, which constitutes 25.4 per cent of the total Norwegian Arctic. Norway has six Ramsar sites with a total area of 21 km², and one Biosphere Reserve covering 19,030 km² (Northeast Svalbard nature reserve).

The major gaps in the Norwegian protected areas system are found on the mainland. These include coastal and fjord systems, northern/oceanic coniferous forests, and northern alpine areas. In the recently revised Norwegian National Park Plan, 13 new large protected areas are proposed, along with enlargements of six of the eight existing national parks in the Norwegian Arctic by the end of 2010. There are also systematic conservation plans at the county level, which together with a proposed national plan for protection of marine areas, will secure representative terrestrial and marine biodiversity and natural landscapes in the Norwegian Arctic.

Finland.
About 32.6 per cent, or 26,000 km² of Finland's Arctic area (north of the Arctic Circle), is protected. The protected areas are distributed on 53 different sites. Most of these areas fall under IUCN category IV, i.e. managed reserves, and are protected for their special mires or forests. About 85 per cent of the protected forest is more than 100 years old, which is substantially older than other Finnish forests. The Finnish Arctic does not have any international Biosphere Reserves, but there is one Ramsar Site, which covers 314 km².

The gaps identified in the Finnish protected areas system include primarily old-growth forest in the southern Arctic areas. The Finnish government plans to fill the gaps through its programmes of Valuable Cultural Landscape.

Iceland.
About 9 per cent, or 9,160 km² of Iceland is protected by law. The protected areas are distributed in 25 different sites. More than half of the sites are managed nature reserves (IUCN cat. IV), about 25 per cent of them are protected seascapes or landscapes (IUCN cat. V), and about 20 per cent are national parks (IUCN cat.II). Iceland has two Ramsar sites which together cover 575 km². The main habitats protected in Iceland are geological formations, relict birch forest, and volcanic craters.

The gaps identified in the Icelandic protected areas system include marine parks, special vegetation communities, volcanoes, rivers and watersheds, and waterfowl sites. There is no action plan for filling the gaps, but the Nature Conservation Council has at least nine specific proposals for new nature reserves, one new national park, and enlargement of another. Among these are a large marine reserve on the south-west coast (Breiðafjörður), and several wetlands.

Species abundance and diversity

With regards to biological diversity and abundance, the condition of the European Arctic region can be described as being relatively good. In large parts of the region the animal and plant populations are mainly influenced and regulated by natural processes, not by human intervention.

However, humans have influenced large parts of the region, through harvesting and land use, for hundreds of years. The main biological resources in the region which traditionally have been exploited are:

- taiga forest,
- tundra and alpine grassland/ lichen (grazing),
- marine, anadromous and freshwater fish,
- marine mammals,
- terrestrial mammals.

A brief environmental status of these resources, along with examples of other key ecosystem components, is presented below.

Terrestrial vegetation

Much of the tundra and grassland areas of the European Arctic evolved along with the indigenous wild reindeer herds, and are adapted to moderate grazing. But in the most intensively used reindeer herding areas in northern Finland and Norway, the lichen cover has been depleted by reindeer in winter pasture areas (Figure 5.3). The conditions are severe in northern Lapland and parts of Finnmark. Overgrazing is also observed in Sweden. (Johansen & Tømmervik 1993, Johansen et al. 1995). It is estimated that well over 10,000 km² of land in Finnmark, 6,000 km² in Lapland, and 450 km² in Norrbotten counties are under severe grazing pressure. Almost all of Lapland county shows signs of medium grazing

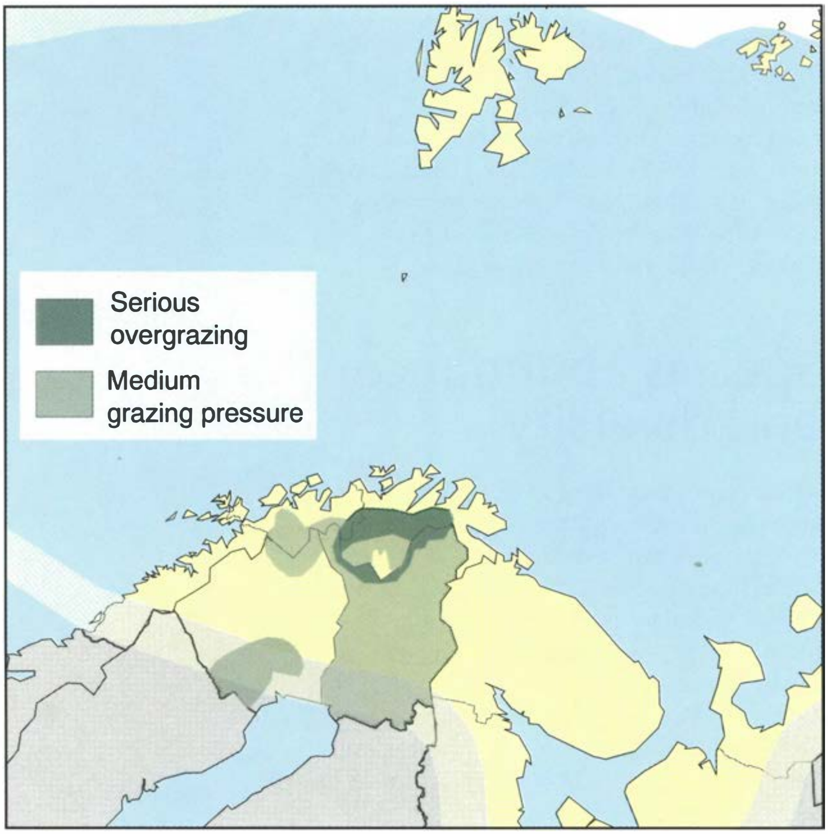


Figure 5.3 **Over-grazing:** Areas impacted by domestic reindeer grazing in the European Arctic. Several domestic herds have grown to a level substantially exceeding the carrying capacity of their areas. (Source: NORUT 1994).

pressure. Despite high numbers of reindeer, only insignificant signs of over-grazing are observed in Russian areas, most probably due to more sustainable herding routines (Tømmervik pers. com.).

No data have been available on the distribution of vegetation in the Russian areas of the European Arctic.

Forests currently cover about 50 per cent of northern Finland, 20 per cent of northern Sweden, and 15 per cent of northern Norway. These resources have been harvested for decades, and today most of the forests are not strictly natural. There are few stands of mature old-growth forest in these areas. Some of them are protected, but expanded protection of this nature type is needed.

Much of the forest in the Russian Federation has been 'protected' merely due to their lack of infrastructure. These areas have served as a "species reservoir» for the more populated and intensely managed taiga areas in Scandinavia. In the Murmansk and Arkangelsk area, however, there has been extensive forestry (up to 25 million m^3/year). Despite a recent drop in logging volumes, there is considerable national and international interest in increasing the exploitation of Russian forest resources. This development may pose a serious threat to important parts of the boreal taiga forest of the European Arctic.

See the enclosed 'Red List' over threatened species in the region for a more detailed list of threatened plants (Appendix).

Terrestrial animals

Insects, other invertebrates, and rodents are often inconspicuous, but the distribution and abundance of these small animals are often ecologically more important than that of large birds and mammals. For instance, the population cycles of the endemic Norwegian lemming (*Lemmus lemmus*) strongly influence the reproduction and movements of several large predators and raptors in the area.

However, information on the status in the European Arctic of such small species has not been readily available. This section thus concentrates on larger birds and mammals, as the status of such species are strong indicators of the status of the ecosystems within which they live.

Terrestrial birds

Modern forestry based on large clear-cuttings in all forest types is the human activity that effects bird populations most significantly in the taiga areas. Several species depend on old-growth forest with a considerable amount of dead and dying trees. Modern forestry often systematically destroys such habitats over large areas and results in a fragmentation of remaining areas of old-growth forest. In northern Scandinavia, this has caused a reduction in the population of typical forest species, such as three-toed woodpecker (*Picoides tridactylus*), Siberian jay (*Perisoreus infaustus*) and Siberian tit (*Parus cinctus*) (Helle & Järvinen 1986, Ekman 1994, Tomialojc 1994).

As forestry moves into previously undisturbed areas in the Russian parts of the region, a similar development will take place there.

Largely as a result of pressure from major customers of forest products, there is a growing interest among foresters in Scandinavia for forestry methods that are more ecologically sustainable. However, the large scale results of this remain to be seen.

The large populations of wildfowl and waders breeding in the European Arctic is dependent on the conditions in southern staging and wintering areas. Habitat destruction, pollution and hunting in these areas are the most

Location	Brown bear	Lynx	Wolverine	Wolf
Nordland (Norway)	1 - 5	> 70	70 - 90	migratory, no. unknown
Troms (Norway)	7 - 17	> 60	100 - 120	migratory, no. unknown
Finnmark (Norway)	6 - 11	2 - 7	6 - 20	migratory, no. unknown
Norrbotten (Sweden)	~140	~ 20	~ 60	migratory, no. unknown
Lappland (Finland)	150 - 160	> 50	> 50	30 - 40
Murmansk (Russia)	200 - 400	no. unknown	145	30 - 40

Table 5.1. **Estimated populations** of brown bear *(Ursus arctos)*, lynx *(Lynx lynx)*, wolverine *(Gulo gulo)*, and wolf *(Canis lupus)* in the European Arctic.

important threats to many of these species. Some species have increased due to active conservation measures in these areas, as well as in the main breeding areas. An example of this is the Svalbard population of barnacle geese (*Branta leucopsis*), which has increased from probably only a few hundred birds in the 1940s to the current level of about 12,000 birds (Mehlum 1990, Kirby 1995). The lesser white-fronted goose (*Anser erythropus*) is an example of the opposite trend. The population size and breeding range of this species has declined dramatically during this century, and it is now classified as globally threatened (Collar et al. 1994). The Fennoscandian breeding population has now been reduced to only about 50 pairs (Madsen 1994). Oil spills from the expanding oil industry may pose new and serious threats to wildfowl and waders both in inland breeding areas and in coastal breeding, staging and wintering areas. In Kola and other areas where acidification kills fish and other food organisms, some species of divers, ducks and waders may be seriously affected.

Reindeer and other ungulates

From the mid-1970s to the late 1980s the official numbers of domestic reindeer in northern Norway more than doubled. In Norway the population grew from about 90,000 to about 210,000 animals.

In the most intensively used reindeer herding areas, the numbers of animals far exceed the carrying capacity of the vegetation cover (see e.g. Johansen et al. 1995). The most significant impact is the removal of lichen cover in winter pasture areas. Erosion problems are enhanced by the increased use of fences and motor vehicles in the reindeer herding industry. In northern Lapland and Finnmark there is a need for a strong reduction in reindeer populations.

There are no wild reindeer in Sweden and northern Norway. In the Karelian Republic of the Russian Federation, and in the bordering areas in Finland, there is some interbreeding among domesticated reindeer and wild forest reindeer. The populations of wild Arctic reindeer in Svalbard has grown slowly during the last decades, while the situation for this subspecies in Novaja Zemlja is unknown. The population status for the introduced wild reindeer in Iceland is satisfactory. There is a regular reindeer hunt in Iceland and Svalbard.

In Sweden, Finland and Norway, modern forestry and the low densities of predators create optimal moose habitat. The European Arctic moose populations are now relatively large, and they sustain a substantial annual harvest.

Large predators

Large predators on the European Arctic mainland have been hunted by man since his arrival in the area, primarily for furs and to protect the livestocks. In the Nordic countries, the populations of brown bear, wolf and wolverine have declined steadily throughout the last century. The wolf is in reality extinct in Norway, and the Swedish population is very vulnerable (Table 5.1 and Fig. 3.13).

The wolverine and lynx populations are less threatened, but still small (Bergstrøm et al. 1993). Protection measures and regulations contribute to the survival of these populations and have reduced the pressure on them somewhat. However, illegal hunting, habitat destruction and liberal regulations with regard to killing animals that kill or threaten livestock prevent some populations from recovering. The status of the large predators in the Russian European Arctic is not well known, but the populations are reported to be relatively large. They are an important source of recruitment to the vulnerable populations in the countries further west. None of these four species occur in Iceland (Appendix).

The Arctic fox is threatened in mainland Scandinavia, and the population in the Finnish Arctic areas is relatively small. The status in Russian Federation is unknown, but Arctic

Reindeer overgrazing: Fence separating grazing area and natural vegetation in Fjordfjellet, Finnmark (photo: Torfinn Kjærnet)

fox is relatively common in Iceland and common on the high Arctic islands, where it also is hunted.

Alien Terrestrial animals

There are particularly two species of larger mammals that are currently spreading in the region. Racoon dog (*Nyctereutes procyonoides*) is a predator of East-Asian origin. It is well established in the north-western part of the Russian Federation, Finland and Sweden, whereas some few individuals are observed in Finnmark county in Norway. The species constitutes an increasing predator pressure on other terrestrial mammals as the population grows. The racoon dog is a spreader of rabies, and is feared in Norway.

The Muskrat (*Ondatora zibethica*) is a small vegetarian that is spreading in the region from where it is raised commercially in Finland. It is a North American species mainly tied to eutrophic freshwater systems.

Freshwater species

Only rivers (11 per cent) in Iceland, Norway, Sweden and Finland are considered to be "wild", i.e. undisturbed by human impacts. These rivers have an average length of 75 km, and all of them lie in the Arctic region. The total length of these rivers in Sweden is 1,355 km, in Finland 965 km, in Norway 855 km, and in Iceland it is 815 km. No "wild" rivers are found in the European part of the Russian Federation (probably due to the definition of "wild"). Approximately 72 per cent of the total length of "wild" Russian rivers are found in northern Siberia.

The extensive Norwegian fish-farming industry poses two serious threats to the natural Atlantic salmon populations in the area. The first relates to the fact that large numbers of salmon escape from fish farms every year. Fish from farms infested with *Gyrodactylus salaris* spread the parasite to wild salmon populations. It will eventually kill the whole population, and may spread to other rivers. Infested rivers are therefore treated with rotenone which kills all fish and thus eliminates the parasite, so that new, non-infested fish populations can develop. The second serious threat stems from escaped fish that also interbreed with wild fish, thus mixing genes with the locally adapted populations. The long term effects of such "genetic pollution" are not yet clarified, but may imply a serious "dilution" of specialised natural adaptations (e.g. migration patterns and the identification of home territories), and thereby of reproduction and survival.

In several Russian rivers the salmon catches, and probably production, have been reduced during recent years. In Kola rivers the 1993 catch was approx. 1/6 of the 1989 volume, and the average salmon weight decreased from 3.7 kg to 2.6 kg. On average, the total decrease in freshwater fish catches from 1987 to 1993 in the Murmansk and Arkangelsk oblasts was approx. 50 per cent and 60 per cent, respectively. The reasons for this development include dam construction on spawning rivers, water pollution, timber floating and water level decrease due to irrational logging (ACCEN 1993, ACCEN 1994, MCCEN 1994).

Migrating waterfowl are often highly selective in their choice of breeding, moulting and wintering areas. They are often found in high concentrations within small areas along Arctic river and lake systems during summer. Thus, changes in these areas could affect a large part of the population. Several duck, geese and swan species have been affected by this. For example, during their migration, 10,000–15,000 barnacle geese (*Branta leucopsis*) rest in Eylendid, which is an extensive complex of rivers and associated marshes and grassland in Iceland, and a large number of waterfowl breed here during the summer.

Many of the major rivers in the Arctic have also been used to generate hydroelectric power. Such development often changes whole river systems and destroys many of their habitats. Long-range transboundary air pollution also contributes negatively to the water quality in the European Arctic.

Alien freshwater species

Of particular interest are the introductions of salmon species in the north-western part of the Russian Federation, particularly on the Kola Peninsula. However, only the Pacific species pink salmon (*Oncorhynchus gothuscha*) seems to have had some success in the Russian rivers.

Several non-native fish species have been caught in Norwegian and Icelandic rivers. Commercial farming of salmon in Norway has introduced the parasite *Gyrodactylus salaris*. This parasite is currently found in one river in northern Norway. *Gyrodactylus salaris* quickly decimates whole populations of salmon in infected rivers. There is a danger of the parasite also spreading to and within north-western Russian and Icelandic rivers, whereas it is native in Swedish and Finnish rivers and fish are more adapted to it.

Marine invertebrates and fish

The primary production in the region's marine ecosystems does not, to a significant extent, appear to be negatively affected by human activities. The status of large numbers of non-commercial benthic and invertebrate species in the ecosystems is poorly known, but they are generally not affected directly by current fisheries or levels of contaminants. There are indications that the North Atlantic and Barents Seas are facing a period of lower water temperatures, which will probably lower the primary production. This may cause reduced production and survival of key species such as cod, capelin and herring, as well as secondary effects for other species.

Shrimp

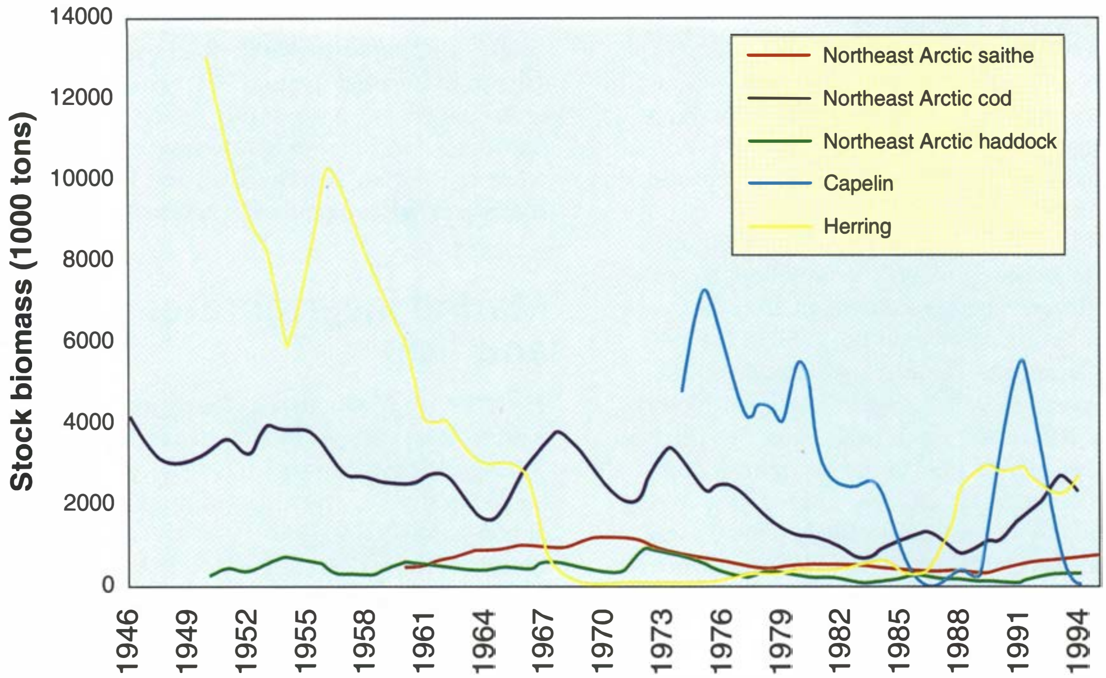
Commercial harvesting of shrimp in the Barents Sea began in 1975. The harvest has been largely unregulated since, and in recent years both catches and population estimates in the European Arctic have been low. This is likely due to increased predation from a growing cod stock and from intense human commercial harvest.

Marine fish

Large-scale fishing of the key commercial species in the region, along with natural ecosystem fluctuations, has led to a general reduction in fish stocks in recent years both in the Barents Sea and around the Icelandic waters. Stocks of cod, herring, capelin, Greenland halibut, coalfish, and haddock have all had negative trends since the 1950s (IMR 1995) (Figure 5.4, 5.5).

The stocks of north-east Arctic cod and the Icelandic cod, which commercially are the most important fish (and animal) in the region, have seen an unsteady decline in recent years. The stock in the Barents Sea fell from about 6.5 million tonnes harvested in 1950, to about 1–2 million tonnes in the 1990s. Currently the cod stock seems to be on the increase. Since cod prey on herring and capelin,

Figure 5.4 **Commercially important fish stocks in the Barents Sea:** Development of total stock biomasses in the Barents Sea. (Source: Institute of Marine Research, Norway).

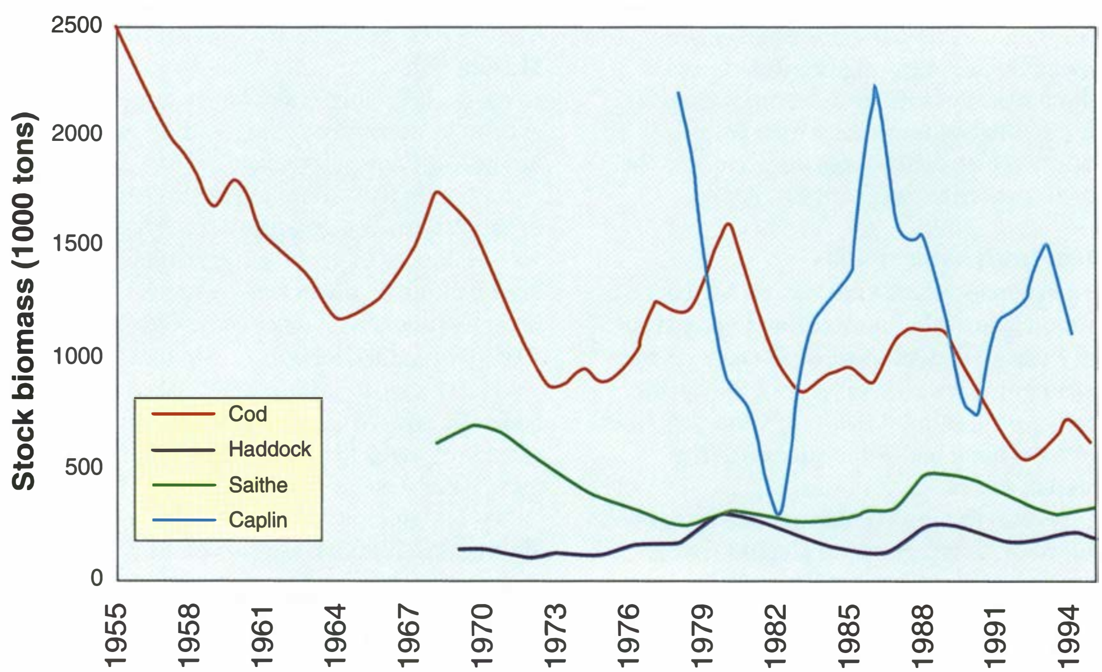


this increase will effect these stocks as well (IMR 1995, HRS 1995).

Until the late 1960s, the main stock of Norwegian spring-spawning herring used to migrate between Norway and Jan Mayen. It was then estimated to be over 12 million tonnes. This stock collapsed in the 1960s due to over-harvesting. It took 25 years to recover to about 3 million tonnes, and the stock started migrating into the Norwegian Sea in 1993–1994 (IMR 1995).

Capelin is the main plankton feeder in the Barents Sea ecosystem. It is in turn a key species on which cod, other fish, seabirds, and mammals depend. From the early 1980s the Barents Sea stock was reduced from 7.3 million tonnes to 0.2 million tonnes. It then grew to 5.6 million tonnes in 1991, but is now again at a very low level. Predation, fisheries, competition, and ocean climate most likely share in contributing to this development. However, the reproductive potential of capelin is large, so the stock may recover relatively soon.

Figure 5.5 **Commercially important Icelandic fish stocks:** Development of total stock biomasses in Icelandic waters. (Source: Hafrannsóknastofnun, Iceland)



Species	Scientific name	Estimated population in NE Atlantic	Estimated population around Iceland	Trend
Blue whale	*Balaenoptera musculus*	20-30	442	unknown
Bowhead whale	*Balaena mysticetus*	50-100		increasing
Fin whale	*Balaenoptera physalus*	100	15 614	unknown
Harbour porpoise	*Phocaena phocaena*	1 000		unknown
Humpback whale	*Megaptera novaeanglia*	1 000	1 816	unknown
Killer whale	*Orcinus orca*	?		unknown
Minke whale	*Balaenoptera acutorostrata*	80 000	28 000	stable
Narwhale	*Monodon monoceros*	?		unknown
Sei whale	*Balaenoptera borealis*	20-30	10 600	unknown
Sperm whale	*Physeter macrocephalus*	2 000		unknown
White whale	*Delphinapterus leucas*	>100 000		unknown
White-beaked dolphin	*Lagenorhynchus albirostris*	100 000		unknown
Bearded seal	*Erignathus barbatus*	> 50 000		unknown
Grey seal	*Halichoerus grypus*	> 4 000	12 500	unknown
Harbour seal	*Phoca vitulina*	1 000	30 000	unknown
Harp seal	*Phoca groenlandica*	500 000		stable
Ringed seal	*Phoca hispida*	> 200 000		unknown
Walrus	*Odobenus rosmarus*	> 5 000		increasing
Polar bear	*Ursus maritimus*	3 000-5 000		stable

* Including the Barents Sea.

Table 5.2. **Marine mammals**: Estimated population sizes and trends of common marine mammal species in the Barents Sea and Icelandic waters. Based on various sources, compiled by Norwegian Polar Institute.

Marine mammals and birds

From the 1600s to the early 1900s the marine mammals of the European Arctic were heavily exploited. The bowhead whale was nearly driven to extinction, whereas other species were reduced to numbers which did not render large-scale hunting economically viable. The populations of the other large baleen whales also suffered greatly, as did the walrus and polar bear populations.

Since hunting of these species was banned in the region, most populations have grown, but to a varying degree. All marine mammal populations cover very large areas, and they often migrate within and out of the region. All population figures for the region are therefore rough estimates (Table 5.2).

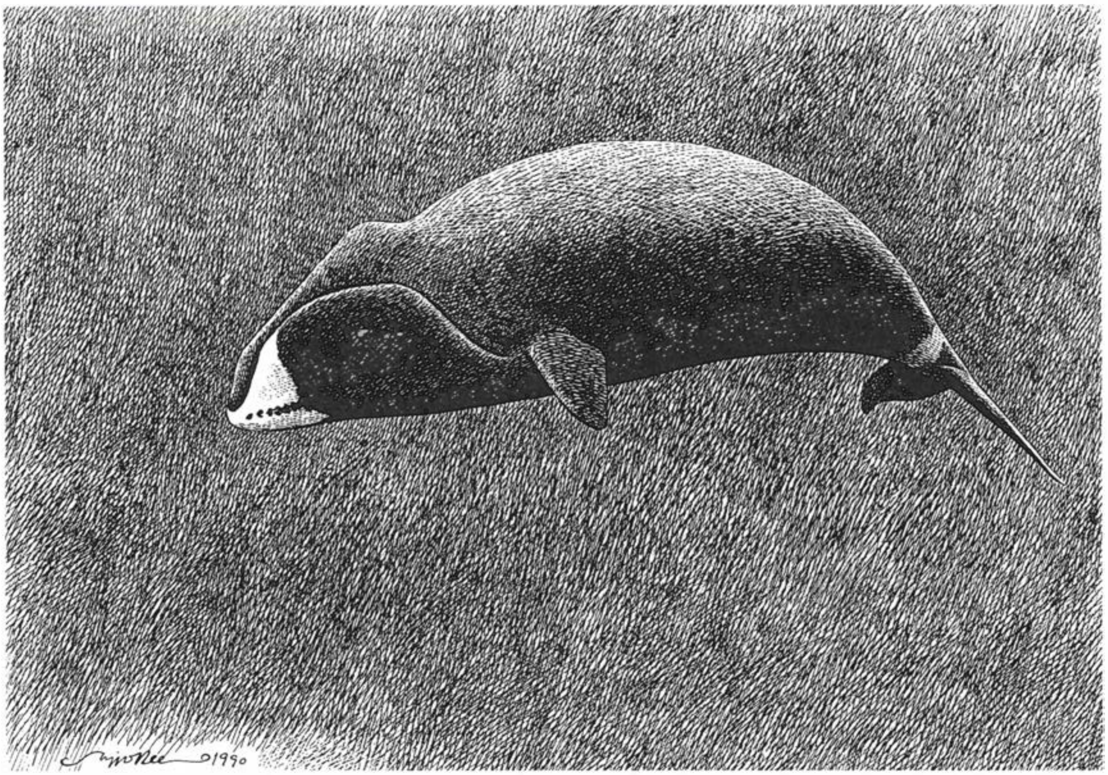
Toothed whales

In the ice covered waters of the European Arctic the white whale is relatively common. These relatively small whales are probably not much affected by human activity, but very little is known about their population dynamics and actual numbers. Narwhales are observed occasionally, but have never been common in the area. In ice free waters white-beaked dolphins are widespread, but status and population data is not available. The same applies for killer whales, which are less numerous, but not uncommon. Sperm whales occur regularly outside Norway and around Iceland. The harbour porpoise is common outside Norway and Iceland, but the population status is unknown.

There is practically no hunting of toothed whales in the region. Living near the top of the marine food chain toothed whales may, however, be vulnerable to POPs and other contaminants. Commercial fishing equipment regularly kills harbour porpoises in Norway, and possibly other small toothed whales. As there is limited knowledge and no regular monitoring of these species, potential effects of human impacts, including possible reduction of the food basis for whales due to fisheries, will be hard to detect.

Baleen whales

The population of bowhead whale has never recovered from the hunting during the last three centuries in the Barents Sea. With a rem-



Bowhead whale
(Balaena mysticetus)
(drawing: Viggo Ree)

nant population of perhaps 50–100 individuals around Franz Joseph Land and westward, it is among Europe's rarest species.

Blue-, fin-, humpback- and sei whale populations are probably also still far below pre-whaling numbers, but the populations in Icelandic waters seem viable. The reason for the failure of these populations, and that of the bowhead whale, to grow more despite the current protection measures is unknown, but it may relate to competition from other species and changes in the food base. There are two minke whale populations in European Arctic waters. Both of these are viable and relatively large. Most baleen whales, except the bowhead whale, migrate south of the region for part of the year. There is currently a limited, but internationally controversial, Norwegian hunt for minke whales.

Seals

Except for a limited Russian and Norwegian harp seal hunt in the White Sea, there is no commercial seal hunt in the European Arctic, and very limited private hunting.

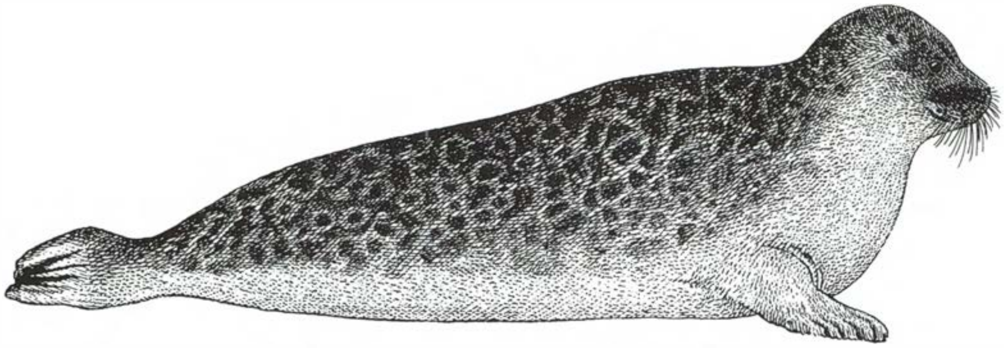
The most common seals in the area today are the Arctic species harp seal, ringed seal, bearded seal and hooded seal. Walrus occur in smaller numbers. The more southern species harbour and grey seals occur in limited populations mostly along the Nordic coasts. Due to conflicts with coastal fisheries in Norway, there is some pressure to keep harbour and grey seal populations artificially low.

In 1987 more than 100,000 harp seals from the "West Ice" north of Iceland migrated to the coast of Norway. Of these, 60,000 to 80,000 starved to death or drowned in fishing nets during the migration. The reason for this migration was probably lack of food during the breakdown of the cod and capelin stocks in those years. The harp seal populations have since then grown large again. The levels of contaminants in European Arctic seals are poorly known.

The earlier over-harvesting of walrus in Svalbard waters reduced the population from many thousands to a maximum of a hundred animals by the early 1950s. The population was saved from extinction by a hunting ban in 1952. Since then it has increased to about 2,000 animals, which is a shared population with Franz Joseph Land (Gjertz & Wiig 1994). In some places the walrus on Franz Joseph Land and on Svalbard may be disturbed by increasing tourism and fishery.

Polar bears

The polar bear populations in the region have most likely grown substantially since the 1973 international protection measures (see Prestrud & Stirling 1994), and it is now probably larger than the 1986 estimate of max. 6,700



Ringed seal
(Phoca hispida)
(drawing: Viggo Ree)

individuals between East Greenland and Novaja Zemlja. This is among the largest populations of a large predator in the world, and a symbol of the good environmental status in the European Arctic. However, the very high levels of PCB recorded in polar bears in the area are strong indicators of the continuous contamination of the Arctic. Individual or population effects have not been demonstrated, but reproduction and behaviour might be affected (Wiig et al. 1995).

Seabirds

Seabirds are often indicators of the state of the marine environment since they are closely connected to the condition of the stocks of fish and marine invertebrates. Variations in the stocks, especially of capelin, herring, and polar cod, or in their reproduction or migratory patterns, can affect the seabird populations dramatically.

In the European Arctic there are currently four nesting cliffs registered with more than 100,000 pairs of sea birds along the coast of northern Norway, six in Svalbard, six on the west coast of Novaja Zemlja, and thirteen in Iceland.

In the Barents Sea, the common guillemot probably feeds its chicks almost exclusively on capelin. The population of this bird on Bjørnøya was estimated at 245,000 pairs in 1986. One year later the number of pairs attending the breeding sites was only 36,000. This was most likely because of the drastic reductions of the capelin stock in 1986. The population has since increased somewhat.

Along the coast of Norway, towards the southern limit of the European Arctic, certain large puffin colonies have suffered repeated reproductive failures, probably due to lack of herring larvae in the area. Reproduction and population trends have been satisfactory for most of the other alcid populations in the European Arctic, although there is little data available on status and trends in the Kara Sea.

In the High Arctic islands, most alcid, gull and sea-duck populations seem to be in good condition, and for instance the fulmar population in Svalbard may be growing (KCS 1993, Isaksen & Bakken 1995) (Table 5.3).

On the other hand, the alarmingly high levels of PCB found in glaucous gulls on Bjørnøya demonstrate that seabirds are vulnerable to human impacts (Savinova et al. 1995). Also the prospect of large-scale petro-

Table 5.3 Seabirds: Estimated population size and trends of common seabird species in the European Arctic. Source: Norwegian Polar Institute.

English name	Scientific name	Iceland	Trend[1]	Norway	Trend	Svalbard	Trend
Fulmar	*Fulmarus glacialis*	2-4 mill	↑↑	6 000	↑	200,000-2 mill	?
Kittiwake	*Rissa tridactyla*	1,2-1,6 mill	↑	900,000-1,3 mill	↓-O	540, 000	O-↑
Common Guillemot	*Uria aalge*	2,2-2,6 mill	O	20,000-40,000	O	400 000	O-↑
Brünnich's Guillemot	*Uria lomvia*	1,2-1,6 mill	O	2 000-4 000	O?	2,6 mill	O-↑
Razorbill	*Alca torda*	600,000-800,000	O	34,000-72,000	↓?	200	O?
Black Guillemot	*Cepphus grylle*	20,000-40,000	O	40,000-60,000	↓	40,000	O?
Little Auk	*Alle alle*	4-6	↓	0		> 1 mill	?
Puffin	*Fratercula arctica*	4-6 mill	O-↑	3,8 mill	↓	20,000	?

[1] Population trend: ? = unknown; O =s table; ↑ = increasing; ↑↑ = large increase; ↓ = decreasing

leum exploration and development in the region is a large potential threat to seabirds (Fjeld & Bakken 1993, Matishov 1993).

Alien marine species

The ocean is an open system with extensive exchange of species and their eggs and larvae. The concept "alien" is less precise in this system than i.e. in freshwater systems.

The introduction of the red king crab, also known as Alaska king crab (*Paralithodes camtschatica*) in the north-western part of the Russian Federation has resulted in the spread of this alien species to Finnmark county in Norway. How this enormous crustacean will interact with and affect the local marine ecosystem is yet unknown.

Pollutants – contents and effects in the environment

The pollution situation in the European Arctic clearly shows how the global environment is interconnected and how human activities and emissions can affect areas far removed from the source. It also demonstrates how substances designed for technical human purposes can turn out to have detrimental effects on the environment. Such effects are still far from sufficiently identified and understood.

In particular we may find new, long term effects of substances that resemble hormones and may affect behaviour and reproduction (such as POPs), as well as synergistic and cumulative effects of different substances and impacts. The effects of oil pollution, on the other hand, are well known from other areas. There is little disagreement that oil in drift ice areas and Arctic winter conditions will be potentially even more harmful than in more southern areas. So far, however, a full scale test of this assumption has luckily not been reported.

Long range pollutants

POP contamination

The combined effects of ocean currents, river drainage and atmospheric transportation result in the Barents Sea area being a global sink for a range of Persistent Organic Pollutants (POPs) (Savinova et al. 1995).

POPs, such as poly-aromatic hydrocarbons (PAHs), are found in sediments and sea water all over in the Arctic. Common levels of PAHs in sediments in the Barents Sea area are 200–600 ng/g, while the levels close to coal mining towns, i.e. Barentsburg and Longyearbyen, are 10 times higher. Analyses of benz(a)pyrene, a PAH component, in sediments from the Barents Sea area show levels between 1 and 40 ng/g. This is 3–4 times higher than the background levels, indicating that use of oil and coal has increased the PAH levels in sediments in the Barents Sea area.

The largest concentration of DDT in the Barents Sea area has been detected off the Murmansk coast. In the open part of the Barents Sea and eastern coastal regions POPs are significantly lower, often merely at normal background levels.

The levels of HCHs in the same area were half as high as in sea water from the Canadian Arctic. The highest concentrations of HCHs have been measured in Russian waters. A gradient of decreasing HCH concentrations has been observed from the North Sea to Spitsbergen. This reflects the importance of European sources of HCHs. The HCH levels ranged from 4.8 to 6.2 ng/l in the North Sea to 0.9 to 1.5 ng/l in the Norwegian Sea south-west of Spitsbergen.

The Ob and Yenisei rivers are not part of the European Arctic, but they still influence the area. Their enormous water discharges bring contaminants from numerous industries, extensive oil extraction, river transportation etc. in the vast Eurasian catchment areas to the Kara Sea. Some of this may be transported to the region with ice and water in the trans-polar current. In the Nozhnevartovsk area mean annual concentrations of petroleum hydrocarbon usually reach 13–25 times the Maximum Allowable Concentration (MAC). The annual PHC flux in Ob and Yenesei during 1986 to 1990 is estimated to have been 0.4 million tonnes (Kimstach & Meybeck 1995).

Pollution levels in biota.

Published information on POP contaminants in sediments and in plankton from the Barents Sea is scarce. Studies have shown relatively low levels of POPs both in sediments and in plankton from the Barents Sea.

In liver samples from cod and polar cod collected from the Barents Sea, both PCB and DDT were detected. The highest levels were found in cod.

For seabirds, as with other organisms, the POP levels measured depend on which level

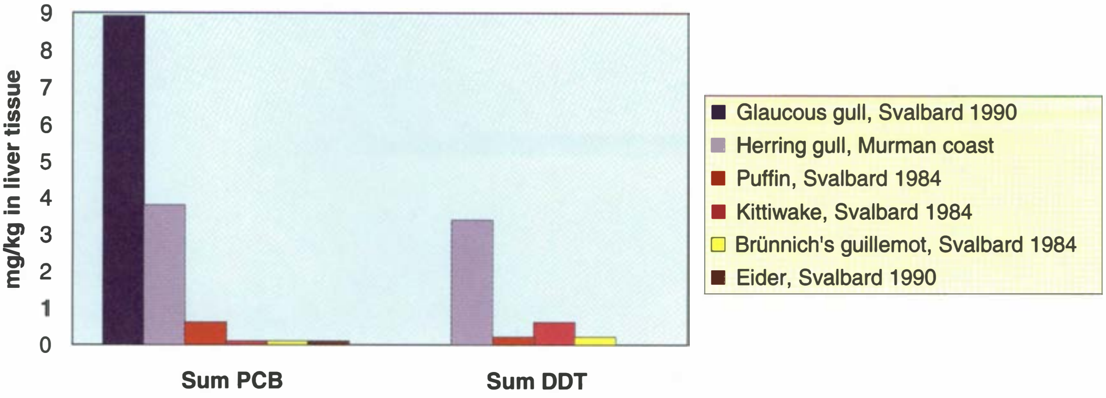


Figure 5.6
Bio-accumulation in predatory birds: Mean levels of Sum PCB and Sum DDT (mg/ kg wet weight) in liver tissue from common sea bird species in the European Arctic show how fat soluble pollutants are accumulated through the food chain to reach extreme levels at the top, in the predatory glaucous gull. (Data on DDT levels in glaucous gull not available). (Source: Norwegian Institute of Nature Research/ Norwegian Polar Institute).

of the food chain they are feeding (Figure 5.6). The lowest PCB levels (300–730 µg/kg) are found in benthic feeding birds, such as the common eiders. The highest PCB levels (400–13,000 µg/kg) are found in birds which feed on chicks and eggs from other birds, such as the glaucous gull. Recent investigations of POPs in different seabird species from the Barents Sea region indicate that the DDT level has declined 3–6 times during the last decade. For PCBs and chlordanes the levels in seabirds from the Barents Sea collected in the 1990s are generally lower than earlier.

The levels of DDT in ringed seals in the Svalbard area (1000–2000 µg/kg) are about twice as high as the concentrations found for the same species in the Canadian Arctic. PCB levels were also higher (1–3 µg/kg) in seals from Svalbard, while HCH levels were higher in seals from the Canadian Arctic. In minke whales from the Barents Sea area the DDT and PCB levels recorded were 1000–2000 µg/kg and 1000–3000 µg/kg, respectively.

Studies of POP levels in polar bears from the Svalbard area show PCB levels of 15 to 30 µg/kg, which is 3–6 times higher than the levels found in the same species in Alaska and in the Canadian Arctic

For most Arctic terrestrial species the POP levels are generally low when compared to similar species from temperate and tropical areas. However, the levels recorded for terrestrial species also reflect what they eat (Figure 5.7). For example the PCB levels in reindeer from Svalbard vary between 6 and 32 µg/kg while PCB levels in the Arctic fox, which feeds on blubber from seals and eggs and chicks of seabirds, vary between 3000 and 800 µg/kg.

Effects of POPs in biota

Knowledge of the effects of POPs on the Arctic environment is limited. In polar bears PCBs seem to reduce the level of thyroid hormones and retinol and they may effect their reproductivity (Kleivane et al. 1994). The PCB levels found in polar bears from the Svalbard area are higher than the values assumed to have had a negative effect on the reproductivity of seals from the Baltic.

Heavy metal contamination

Few studies have been conducted on heavy metals in the Barents Sea area, so our knowledge in this field is quite limited.

Levels of heavy metals in sediments and plankton are generally low in most parts of the Barents Sea area. High concentrations of some elements are found in sediments and vegetation close to rivers connected to indus-

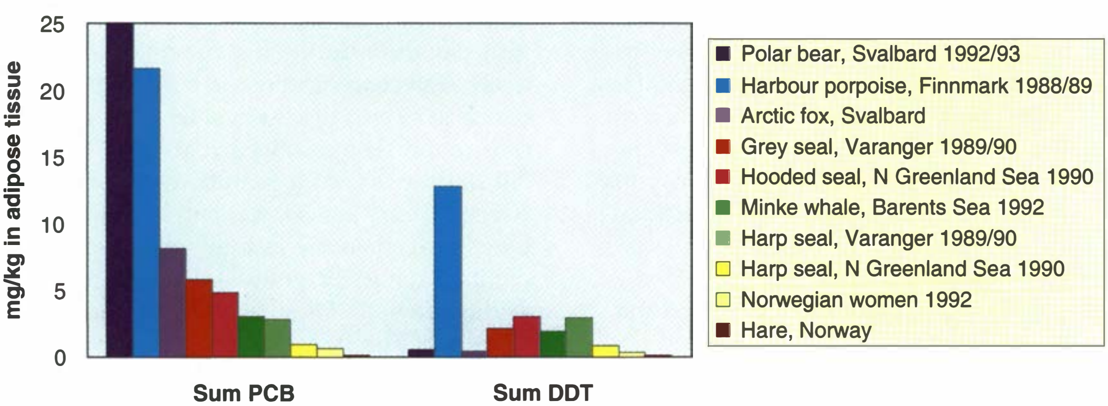


Figure 5.7
Bio-accumulation in marine mammals: Similar to the situation for marine birds, mean levels of Sum PCB and Sum DDT (µg/ kg wet weight) in adipose tissue from common marine mammal species in the European Arctic show very high contaminant levels in the top predator, the polar bear. Levels in northern hare and Norwegian women are included for comparison. (Skaare et. al. 1994).

Figure 5.8
Acidification:
Deposition levels of sulphur dioxide ($mg\ SO_2/m^3$) in the European Arctic. Sources are local (the Kola area) and long range transport (central Europe to southern Scandinavia). (Source: GRID-Arendal).

trial activities in Svalbard and on the Murmansk coast.

In most species of fish, seabirds and marine mammals the levels of heavy metals are low when compared to other northern seas such as Canadian and Greenland waters. However, in some species certain heavy metals are found in high concentrations, reflecting the feeding habits of the species. For example high concentrations of copper (1000 ppm) have been found in common eiders breeding in Svalbard. Since these birds feed mainly on mussels, snails and crustaceans, which have haemocyanin as their blood pigment, it is believed that they are able to tolerate high copper levels without developing liver injuries.

The heavy metal levels in terrestrial Arctic species are low compared with similar species in temperate and tropical areas. High concentrations of heavy metals have nevertheless been found in both birds and mammals close to industrial areas, both in Svalbard and on the Kola Peninsula. Mercury may be reommitted repeatedly, and gradually transported northwards where concentrations increase.

Sulphur pollution

The concentrations of sulphur dioxide and particulate sulphate show pronounced seasonal variations in the High Arctic. During the summer months, the concentrations of SO_2 are mostly below the detection limit of 0.1 $\mu g/m^3$ for Svalbard and somewhat higher for northern parts of Novaja Zemlja. Farther south the concentrations are considerably higher in local polluted areas on Kola (1.3 $\mu g/m^3$). In the winter season the concentrations of sulphur dioxide are close to 0.80 $\mu g/m^3$ in the High Arctic, and >1.7 $\mu g/m^3$ in the winter in northern parts of Sweden, Finland, the eastern parts of Finnmark county in Norway, and the north-western Russian Federation (Ottar et al. 1986) (Figure 5.8).

It is difficult to assess the impact of atmospheric sulphur on the Arctic environment, since only a few measures of wet deposition and even less of dry deposition have been carried out. During the summer, precipitation occurs mainly as fine drizzle from low stratiform clouds or during fog. In winter, the relatively high concentrations of sulphates are mainly confined to a 2-km layer of air next to the ground. As a result, current Arctic snowfall, at the peak of the pollution season between January and May, is only ~ 2 times more acidic than it is in summer at the time of minimum Arctic pollution. These levels of acidity are 5–10 times lower than those found in areas of Europe and North America receiving high levels of acid rain (Pacyna 1995).

Local pollution

POPs, heavy metals, and organic pollutants

On the mainland of the Norwegian Arctic, pollution problems related to POPs and heavy metals are mainly found in Ranafjorden and Vefsenfjorden in Nordland county, as well as outside Kirkenes in Finnmark county. These fjords have been severely polluted by mining and local industry. However, due to recent mitigation measures and reduced industrial activities, the PAH in sediments was reduced to half the previous levels by the early 1990s. The pollution level of PAH in benthos in these fjords is still high.

Many rivers in the Russian Arctic are strongly impacted by anthropogenic pollution of both local and long-range transport origin (YUSFQ 1992). High concentrations of industrial enterprises and population centres without adequate waste treatment are the main causes for the poor state of freshwater resources. For example 30 per cent (more than 100 million m^3), of waste water in Murmansk county are discharged into water bodies without any treatment. In Arkangelsk oblast only 6 per cent of waste water is treated to the normative levels (MCCEN 1993, ACCEN 1994).

Heavy metal pollution from non-ferrous industry is the most urgent environmental issue for rivers on the Kola Peninsula. Kolosyoki, Hauki-Lampoi-yoki, Nama-yoki and some other rivers have chronically high levels of contamination. In 1993, the mean nickel concentration in the Nyuduay river, into which waste waters of the Severonickel smelter are discharged, was 2.25 mg/l, or 225 MAC (Maximum Allowable Concentration) (MCCEN 1993).

Impacts of the pulp and paper industries are the most serious environmental threat to the North Dvina river. In some small rivers of the basin impacted by paper mills and pulp, concentrations of organic compounds reach extremely high levels. In Puska river in 1993, the mean concentration of lignosulphonates was 553 MAC. Due to two giant pulp and paper mills and Arkangelsk city, the mouth of the North Dvina is the most polluted part of the river; the water suffers from oxygen deficiency in the winter and spring.

The middle and upper parts of the Pechora river are affected by coal mining and oil extraction, where large accidental spills (like the Usinsk spill in 1994) are superseeded with chronic spills from regular production and transportation. The high content of suspended matter in the Pechora water promotes transport of the pollutants to the estuary zone.

Estuaries and narrow coastal zones, which occupy less than 10 per cent of the ocean surface and less than 0.5 per cent of its volume, trap up to 90 per cent of the sediment matter, metals and other compounds discharged from land (Gordeev 1983). At the same time the primary production in this zone is very large. Little is currently known about the fate of pollutants in these areas and about the potential transport further into the oceans, but the vast Russian estuary areas are obviously of particular importance to the situation.

Due to low population and little heavy industry, as well as modern waste-water treatment in most settlements, the nutrient and other pollution loads are low in most rivers and lakes in Iceland, northern Scandinavia, and Finland.

Oil and gas contamination

Due to the limited petroleum extraction at present in the Barents and Kara Sea, the main input of petroleum hydrocarbons (PHC) to the European Arctic is from river transport. There is, however, a serious lack of data on PHC-concentrations in Arctic rivers. Russian measurements indicate a four to 20 times higher concentration of PHC in the Ob gulf than in the Rhine or Elbe rivers. The pollution comes primarily from ship traffic and local industry.

Estimates indicate that the Arctic receives about 200,000 metric tonnes of petroleum hydrocarbons per year as pollution. About 60–70 per cent of this is discharged into the Kara Sea. Local pollution is observed in the Pechora Sea area, and the pollution is increasing steadily.

Radioactive contamination

Contamination from large amounts of improperly stored radioactive material is potentially an extremely serious threat to the European Arctic environment as well as to human health and to the economy. So far, however, the level of contamination both in sediment and biota in the region is generally much lower than for adjacent seas further south in Europe (Fig. 5.9).

Radionuclides in water and sediment. Global fallout from atmospheric nuclear weapon testing is still the major source of radioactive contamination in the Arctic.

BOX IV – OIL SPILL IN USINSK, KOMI REPUBLIC

During the autumn and winter of 1994 there were frequent oil spills from pipelines in the Vozey and Usinsk areas of the Komi Republic of the Russian Federation. The major concern regarding the spills was the potential for pollution of the Barents Sea via the Pechora river. Press reports suggested that the oil spill would cause an environmental disaster in the fragile arctic environment locally, as well as cause detrimental effects in neighbouring countries. Concern was also expressed for the environment of the Pechora basin.

The Pechora river basin is an important breeding ground for numerous species of fish, including Atlantic salmon (*Salmo salar*). Stocks of several fish species have declined in recent years because of heavy human pressure (illegal fishing, hydro engineering, pollution etc.). The annual catch of atlantic salmon, which in the period 1951–1960 was of 447 tonnes, was decreased to 157 tonnes in the period 1981–1988 (Kazakov 1994). Subsistence and recreational fishing, however, remains very important to the indigenous Nenets people in the area. The river delta is also a major breeding, moulting, and migration area for birds, including Bewick's swan (*Cygnus columbianus bewickii*). Up to 50 per cent of the western European wintering population of this swan visits this (WCMC Russian Arctic Oil Pipeline) extensive network of channels, pools and marshes making up the Pechora delta which constitutes a wetland of international importance.

According to a Russian consultancy report from GEOPOLIS the oil spill in the area was a result of several spills rather than a single one. The spills originated from numerous separate leaks both in the main Kharyaga-Usinsk pipeline and various field-gathering lines and facilities. It was estimated that some 93,000–97,000 m^3 of oil remained on the ground along the pipelines between Usinsk and Palnik Shore – a distance of some 50 km. Most of the oil was contained within a peatland area near Palnik-Shore.

A UN team studying the spill concluded that it was likely that some of the oil could reach the Barents Sea (UN 1994). However, dilution and absorption onto particulate matter in the water and along the river banks would cause reduced hydrocarbon concentrations along the river gradient. The major risks concerned birds along the shorelines, and migratory salmon which could be exposed to sunken oil deposits. The UN team concluded that it was "unlikely that a substantial amount of oil would reach the Pechora delta region, although tar balls could be expected. While this could have an impact on the bird populations, impact is likely to be localised". The oil polluted areas covered some 65 ha of land in the area. The UN team stated further that "the recent oil spill will have a serious, albeit extremely localised, impact in some areas in the immediate vicinity of the spill through a smothering effect".

A Norwegian consultancy (Akvaplan-Niva AS) sampled the Pechora delta sediments one month after the spill without detecting any oil pollution. A follow-up study by the same consultancy in late 1995 also unveiled no oil pollution of the Pechora delta.

There are widespread reports of massive spills occurring on a regular basis in the former Soviet Union. These spills are often due to corroded, poorly maintained pipelines and facilities, with inadequate safety or regular shutdown procedures or equipment. The resulting problem of chronic oil pollution across the Russian Federation is of crisis proportion. Between 5 per cent and 10 per cent of the oil production is generally thought to be lost to leakage, waste and theft (Annual Report of the Russian Ministry of the Environment, Moscow). It is therefore likely that the Pechora catchment will continue to be polluted by oil spills in the future.

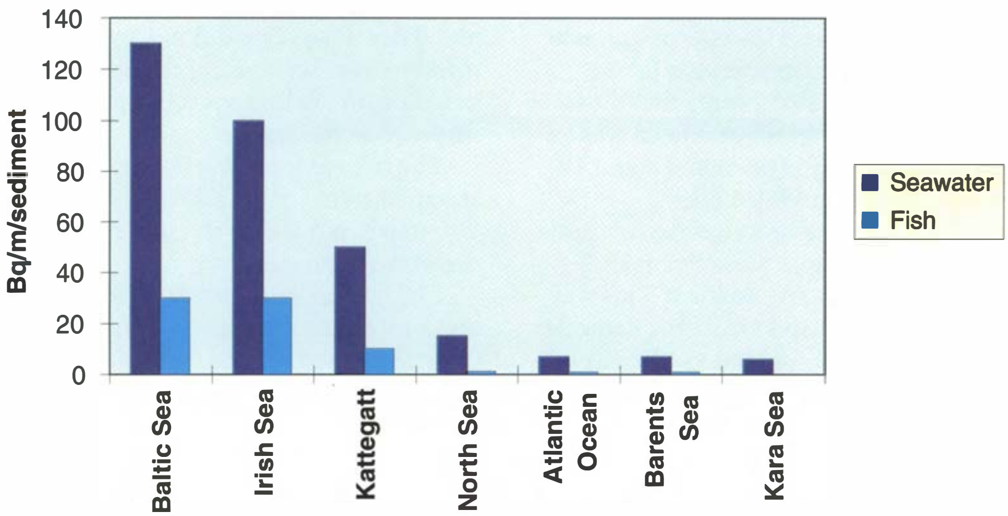


Figure 5.9 **Chernobyl fallout**: Levels of Cs-137 in sediments and fish from different European seas. (Source: Institute of Marine Research, Norway).

The major fallout occurred during 1955–66. At present, the deposition at the latitude of Novaja Zemlja is similar to levels of caesium reported for northern Sweden and Finland during 1964–1969 (NATO 1995).

The three underwater nuclear tests at Novaja Zemlja are assumed to have had a short-term impact on the surrounding waters, but longer-term impacts on sediments. The 45 underground nuclear tests at Novaja Zemlja seem to have had no impact on the level of contamination in the soil, air, or water, but local effects cannot be excluded (IRNC 1994).

Radionuclides in rivers usually come from drainage areas contaminated by global fallout, accidental releases, or discharges from nuclear installations. Information on the total input of radionuclides into the Arctic seas with rivers either lacking or inconsistent, and new estimates, are expected soon from

Laborious clean-up of oil spill outside Usinsk, Komi republic. (photo: Gunnar Futsæter)

ongoing joint Russian and Norwegian research programmes. However, rough estimates given by Russian scientists (at the IAEA Oslo meeting 1993) imply that the river transport from Ob, Yenisej and Lena was less than 300 TBq during 1949–61 and about 110 TBq of Cs137 during 1961–1991.

An increase in the concentration of caesium in the Kara Sea was observed in 1992 following the Chernobyl accident. This was probably due to transport from the Baltic Sea, North Sea, and from contaminated areas in central Norway.

The nuclear reprocessing plants in England and France are currently the main sources of fission products transported to the Arctic seas. The nuclear waste released from the reprocessing plant in Sellafield in England between 1971 and 1985 amounted to about 75,000 TBq. Much of this waste was transported via the North Atlantic Current to the Barents and Kara Seas. The transit time from this reprocessing plant to the Barents and Kara Seas is estimated to be four to six years. It is assumed that about 20 per cent of caesium and 30 per cent of strontium discharged from Sellafield are transported to the Barents Sea (JRNC 1994).

In the beginning of the 1980s, the concentration of caesium (Cs137) in the southern Barents Sea was 30 Bq/m^3 which is five to six times higher than levels detected previously. The discharges from Sellafield and Le Hague have now decreased significantly (Yablokov et al. 1993). The levels observed in the Kara Sea in 1992 were at their lowest since 1961.

Nuclear waste has been dumped in five defined areas in the Barents Sea since 1960, but it has also been dumped beyond these areas. The waste comes from the Russian northern fleet as well as from civilian reactors. There are approx. 100 active, and 60 decommissioned, nuclear submarines on the Kola Peninsula. Nowhere else on earth is there such a concentration of naval nuclear reactors (Yablokov et al. 1993).

The greatest concern is related to the 17 naval reactors dumped in a fjord on the east coast of Novaja Zemlja between 1965 and 1988 (MFAN 1994). The total nuclear radioactivity in the reactors at the time of dumping was 89,000 TBq. As a comparison, all other countries have dumped a total amount of 42,000 TBq at 15 different dumping sites in the north-east Atlantic.

Leakage from dumped reactors and solid radioactive waste is a potential source of future radioactive contamination of the Kara and Barents Seas. In addition, low and intermediate-level solid radioactive wastes from vessels with nuclear reactors, have also been disposed in the area.

The current Russian nuclear waste storage situation is first of all a threat to the local environment, but also to the larger surrounding ocean environments.

The nuclear installations in Majak, Tomsk and Krasnoyarsk represent a potential threat of increased radioactive contamination in the Barents and Kara Seas through the rivers Ob and Yenisey. In Majak a total activity of 4440 PBq are stored in artificial reservoirs. Approximately 100 PBq were directly released into the river system in the early fifties. Much of this contamination is still present in the immediate vicinity of the nuclear installations, and may potentially reach the river systems Ob and Yenisey.

The nuclear submarine "Komsomolets" which recently sank to a depth of 1658 m in the Barents Sea represents a potential source of contamination. Current estimates indicate that released radionuclides are expected to slowly mix with the huge water masses of the deeper part of the Norwegian Sea in such a way as not to pose a threat (NATO 1995).

Radionuclides in biota

Evidence from the time of nuclear bomb testing and the situation following the Chernobyl accident indicate that the marine environment is less vulnerable to radioactive contamination than freshwater and terrestrial ecosystems (JRNC 1994).

Measurements of radioactivity in cod and haddock caught in the Barents Sea during and after the Soviet atmospheric nuclear weapon tests indicate a fairly rapid decrease in the radioactive contamination of marine fish after 1963, when the highest values of radioactive fallout were reported (about 80 Bq/kg w.w.).

In 1968, the measured radioactive contamination was found to be below 10 Bq/kg w.w. Recent measurements in fish from the Barents Sea show values well below this.

Radionuclides in the marine food chain represent a minor source to humans. The concentration of Cs137 in fish in the Arctic seas has declined since the 1960s and is presently low (less than 1–5 Bq/kg w.w.). The intervention levels for food products applied in Europe after the Chernobyl accident are significantly higher, but vary according to dietary

Murmansk. (photo: Torfinn Kjærnet)

ingredient and country (e.g. 300 Bq/kg w.w. Cs137 in Sweden, 600 Bq/kg w.w. Cs-isotopes for foodstuffs and 6000 Bq/kg w.w. for reindeer meat in Norway).

Environmental issues of human health

The Russian Federation

The combination of environmental conditions with the present socio-economic situation in the Russian Federation strongly affects the health of the Russian population in the European Arctic. The most critical situation exists in the eastern part of the region (Arkangelsk oblast). The total mortality in this county is 12 per cent higher than the average value for the Russian Federation. Children in the area are particularly affected. Child mortality in this area was recently found to be almost 21 per cent higher than the Russian average (NEFCO/AMAP 1995).

Each third pregnant woman in Arkangelsk oblast suffers from anemia, which is 63 per cent higher than the Russian average. As a consequence of this and other diseases among pregnant women, new-born child mortality increased by 58.1 per cent from 1991 to 1993. In the same year, 3.34 per cent of the infants born in the area had anomalies, compared to 2.3 per cent which is the Russian average.

Increased immunological deficiencies have been registered in the Nenets Autonomous District in the eastern part of Arkangelsk oblast, especially amongst the local indigenous population (Nenets). Though there is no direct evidence, medical scientists connect this with the atmospheric nuclear tests on near-by Novaja Zemlja in 1955–1962. Such deficiencies are 1.6 times more common within the native population than among newcomers. In 1982–1992 the average annual increase of cancer mortality among Nenets was 9.8 per cent compared to 2.4 per cent in the Russian population (Tkachev et al. 1994).

BOX V
THE KOLA PENINSULA; A SPECIAL CASE

The greatest pollution effects on the European Arctic terrestrial ecosystems are locally induced, and their main sources are mining and heavy industry. The sources are found around the major cities in Sweden, Finland, and the Russian Federation . The Kola Peninsula, where metallurgical plants cause enormous emissions of air pollutants such as SO_2 and heavy metals, is the most polluted area in the European Arctic.

Because of lack of information, the emissions of toxic substances, the precision of pollution level measurements, and areas of affected land on the Kola Peninsula are not sufficiently documented. However, due to Russian-Finnish cooperation as well as to the Joint Norwegian-Russian Commission on Environmental Co-operation, the environmental impacts of the metallurgy plants in Zapoljarny and Nikel, close to the Norwegian border, are becoming well-documented. Annual emissions of SO_2 in Nikel were approximately 190,000 tonnes/year, and 2,400 tonnes/year of nickel, but the emissions have been somewhat reduced lately. In 1992, the emissions in Zapoljarny were about 67,000 tonnes/year, in Montsjegorsk 233,000 tonnes/year, in Apatity 32,000 tonnes/year, and in Murmansk 24,000 tonnes/year. In comparison, the greatest emissions of SO_2 outside the Russian Federation in the region are in Kemi, Finland (2310 tonnes/year) and in Sørfold, Norway (2200 tonnes/year) (Sivertsen et al. 1993). The environmental damage around Nikel and Zapoljarny is serious. Remote sensing has shown seriously damaged vegetation and environmental deterioration in 329 km^2 around these two plants. Pronounced effects on the vegetation are observed over an area of 4,400 km^2. Lichens and other vegetation are also damaged in nearby Norwegian and Finnish areas. High concentrations of chromium, cobalt, copper, nickel, argon, and selenium are found in lichens and moss along the Russian border to Norway in Sør-Varanger county. The concentrations of nickel and copper are about 10 to 20 times higher in the border areas than in southern Norway. Sulphur deposition rates due to emissions from the smelters are linked to vegetation injuries and exceedance of critical loads throughout the area (Sivertsen et al. 1994, Traaen 1995).

A 700 km^2 area on the Kola Peninsula is completely destroyed by sulphur deposition, and by an annual nickel, copper, manganese and zinc deposition of about 5–6 tonnes per km^2. In this area 900–1,000 km^2 of former birch forest-tundra is almost dead. In 48,000 to 55,000 km^2 of the taiga-ecosystems tree canopies are damaged (needle loss). On the peninsula there is also a larger zone of initial degradation where surface waters are slightly acidified and coniferous needles have high sulphur concentrations. The Kola region belongs mostly to the same granite-gneiss bedrock formation with thin soils as Fennoscandia, and these areas have low natural buffering capacity for acid rain.

Toxic substances have had a significant influence on surface waters on Kola. Lakes and rivers near the industrial plants are polluted and there are severe problems connected to toxic heavy metal contamination. Fluorine and nitrate pollution is decreasing in some rivers, but there has been a considerable increase in the concentrations of the same pollutants in other lakes. These pollutants have serious effects on the river and lake ecosystems, and all trophic levels are strongly affected.

The nuclear reactor in Polarnye Zori has recently had operational problems. Two of the four assemblies in the Kola reactor are of an elderly type, which western experts call 'high risk reactors'. These do not satisfy current safety requirements. In addition, the maintenance standards are not considered sufficiently high. As recently as in 1993, one of the reactors came close to a meltdown because of an electric failure.

Air pollution: The metallurgical industry in Monchegorsk and other cities in the Kola Peninsula, emits large volumes of air pollutants such as SO_2 and heavy metals. (photo: Torfinn Kjærnet)

The state of human health on the Kola Peninsula in general is close to average for the Russian Federation. However, in some cities with high levels of environmental pollution these figures are considerably higher. For example in Monchegorsk, heavily impacted by emissions and discharges from the "Severonickel" smelter, the total mortality in the adult population is 37 per cent higher than the average of Murmansk county, and 19.3 per cent higher than the average Russian value. Total child mortality on the Kola peninsula exceeds the average Russian levels by 39 per cent. Mortality among the Monchegorsk population is especially high, and grew by more than 75 per cent from 1989 to 1993. In 1989 this city was the city of the former Soviet Union with the 4th highest level of skin diseases (38.1 out of every 1000 were affected) (NEFCO/AMAP 1995, USCEP 1990).

The Nordic countries

The strong effects on human health of the integration of environmental and socio-economic elements in the north-western Russian Federation do not clearly manifest themselves in the rest of the countries in the region. Nevertheless, a study of asthma and allergic illness in Sør-Varanger in Finnmark, revealed relatively high occurrences of atopic illnesses among school children (Dotterud et al. 1993). This is connected with, among other factors, air pollution from the Kola smelters. A relatively high occurrence of nickel allergy was also found in the same study. A study among children and school children in 11 Finnish counties showed that the astmathic prevalence was higher in northern than in southern Finland (Pöysä et al. 1993).

A tendency of higher mortality caused by cardio-vascular diseases in Finnmark county than in other Norwegian counties are not expected to be connected to environmental factors.

Arctic science: Little auks (*Alle alle*) being caught for population studies. (photo: Ian Gjertz)

6 State of Action and Protection Arrangements

Prevention of pollution, and protection of arctic wildlife and habitats are keystones to preserving Arctic wilderness as a valuable heirloom for future generations. However, a wide range of policy instruments will need to be utilised if both conservation and sustainable development in the Arctic are to be possible. Currently, the gravest threats to the Arctic environment are of transboundary origin. International co-operation is vital for substantiating Arctic environmental values and for safeguarding the sustainable development of these last pristine wilderness areas in Europe.

A variety of international, national and regional organisations and institutions work with arctic environmental issues. These constitute an important framework for co-ordination and implementation of arctic research and development projects, and they constitute forums for national and international meetings and co-ordination of interests.

This chapter lists the most important organisations and programmes connected with protection of the European Arctic environment. (Main references: the Nordic Council of Ministers Report (NCM, 1995), and Bergesen and Parman (1995)).

International environmental programmes

The "Rovaniemi process"

The most extensive and structured international Arctic co-operative programme in progress is the Arctic Environmental Protection Strategy (AEPS). AEPS was signed in Rovaniemi in 1991 by Ministers from the Nordic countries, the Russian Federation, USA, and Canada. The following working groups were established to fulfill AEPS and to implement the recommended actions:

- Arctic Monitoring and Assessment Programme (AMAP).
- Protection of Arctic Marine Environment (PAME).
- Emergency Prevention, Preparedness and Response (EPPR).
- Conservation of Arctic Flora and Fauna (CAFF).

The AEPS programmes, working groups and other activities are carried out as approved by the Ministers, under the direction of the Senior Arctic Affairs Officials (SAAO). The third Ministerial meeting will be held in the spring of 1996.

The main objective of AMAP is, through co-operative monitoring to identify levels of contaminants and assess their effects in relevant components of the arctic environment. The programme documents the state of the arctic environment, with particular emphasis on pollution and contamination issues. AMAP provides recommendations on needs for further actions based on new knowledge or identified gaps in knowledge. The AMAP Assessment Report, which includes contributions from more than 150 international experts, is planned finalised in December 1996. AMAP is managed by a secretariat which is funded by Norway and is located in Oslo. References on all ongoing projects in the Arctic relevant to AMAP are stored and continuously updated in an AMAP project directory database. The actual data collected through these projects are handled and stored at AMAP's international data centres.

The main objective of the PAME is to assess the needs for further actions or instruments at the national and international level to prevent pollution of the arctic marine environment. Norway acts as lead country for the working group.

The main objectives of the EPPR is to analyse risks of accidental pollution (including radioactive pollution), to improve co-operation in emergency situations and in research, and to assess the need for further arrangements for prevention, preparedness and response in the Arctic. Sweden acts as lead country for the working group.

CAFF was established to facilitate circumpolar co-operation and implementation of initiatives to conserve arctic flora and fauna, their diversity, and habitats. CAFF's programme activities include:

- Habitat conservation.
- Species conservation.
- Regional implementation of the Biodiversity Convention.
- Integration of indigenous peoples and their knowledge.

An international strategy to improve habitat conservation in the circumpolar region through protected areas is currently being developed through CAFF. Other activities include international sea bird conservation strategies and listing of rare, vulnerable and endangered fauna and flora in the Arctic region. The various activities are handled by member countries according to a "lead country" system, and co-ordinated through a secretariat in Canada.

Other AEPS initiatives

The task Force on Sustainable Development and Utilisation (SDTF). The task force was established at the second Ministerial meeting (Nuuk Greenland 1993), to explore and propose additional steps to be taken to secure sustainable utilisation of natural resources, including their use by local populations and indigenous peoples in the Arctic. Canada acts as lead country.

The main objectives of the *AEPS Indigenous Peoples Secretariat (IPS)* are to ensure better co-ordination and information exchange among the indigenous people's bodies within the initiatives of AEPS. A board consisting of representatives from Denmark, the Russian Federation, Canada, the Inuit Circumpolar Conference, the Association of Small Peoples of the Northern Russian Federation, and the Nordic Saami Council assist IPS in its work. IPS is funded by Denmark and is located in Copenhagen.

In 1989, Canada proposed the establishment of an *Arctic Council* to strengthen co-operation between the arctic countries. The 1993 draft Declaration on the Establishment of the Arctic Council states that the Council should act as a forum for common interests in the Arctic while securing sustainable development and the interests of the indigenous peoples in the area. The AEPS is proposed to be included as one of the main strategies of the Council.

Other programmes

The Euro-Arctic Barents Region Environmental Action Plan.

The Barents Region covers part of north-west Russia and the northern parts of the Nordic countries, including the adjacent seas. The Action Plan was adopted in 1994 and is a part of the larger Barents Co-operation Programme. It embraces five main topics:

- Prevention of radioactive pollution and preparedness against nuclear accidents,
- environmental management and regional harmonisation of environmental standards and guidelines,
- reduction of pollution from industrial activities,
- protection of natural habitats and conservation of flora and fauna,
- co-operation between local and regional authorities.

A Task Force has been established to follow up the Action Plan.

The Oslo and Paris Conventions for the prevention of marine pollution (OSPAR)

A task team for the Arctic has been established under OSPAR (*Regional Task Team I*). OSPAR has decided to elaborate a Quality Status Report for the maritime area of the contracting parties within year 2000. The report will be based on data from national programmes and from a Joint Assessment and Monitoring Program (JAMP) under OSPAR. The regional task team for the Arctic will start its work in 1996, but the monitoring programme for this region will await the conclusions and recommendations from AMAP.

The Nordic Environment Finance Corporation (NEFCO)

NEFCO was established in 1991 by the Nordic Council of Ministers. Its task is to invest in actions that will reduce pollution in or to the Nordic areas. Focus hitherto has been "hot spot" areas in north-west Russia. The corporation is located in Helsinki, Finland, in connection with the Nordic Investment Bank (NIB).

Nordic Strategy for Co-operation in the Arctic

The strategy is is currently being developed under the Nordic Council of Ministers. It will cover several topics, including environmental issues.

Bilateral programmes. In addition to the mentioned multilateral programs there are bilateral programs including both environmental and scientific co-operative issues.

Research co-operation

International co-operation

In connection with international agreements and conventions, there is a substantial research activity in the Arctic. In 1990, the *International Arctic Science Committee (IASC)* was established as an international framework for co-ordination of research in the Arctic.

The IASC Council has representatives from the principal scientific organisations of the eight arctic countries, (Canada, Denmark, Finland, Iceland, Norway, Sweden, the Russian Federation, and the USA), and from the seven countries which conduct science in the Arctic, (France, Germany, Japan, The Netherlands, Poland, Switzerland, and the United Kingdom). In addition, IASC has a Regional Board, and working groups appointed by the national science organisations in the following subject areas: Global Change, Arctic Glaciology, Marine Geology, Geophysical Compilation and Mapping, and International Science Initiative in the Russian Arctic (ISIRA). The IASC secretariat is located in Oslo, Norway.

The priority research areas under 'Global Change' are:

- Atmosphere, Sea ice, and Ocean Interactions and Feedbacks.
- Terrestrial and Marine Ecosystems.
- Paleoenvironmental Records, Ice Sheets and Glaciers.
- Atmosphere Chemistry and Air Pollution.
- Human Dimension and Global Changes.

The IASC Global Change Working group (IACS-GCWG) secretariat is located in Rovaniemi, Finland.

Included in the work of IASC is also the *International Science Initiative in the Russian Arctic (ISIRA)*. This organisation is a co-operation programme supporting multi-national research projects of special relevance for the Russian Arctic.

The *International Union of Circumpolar Health* (IUCH) is an advisor on arctic health issues for IASC. Other important organisations working closely with IASC include the *International Arctic Social Science Association* (IASSA) and the *Arctic Ocean Science Board* (AOSB).

Three other major international research programmes also cover arctic research: *The World Climate Research Program (WCRP); The International Geosphere-Biosphere Program (IGBP), and The Human Dimensions of Global Environmental Change Programme (HDP).* The WCRP includes the *Arctic Climate System Study (ACSYS)*. Its secretariat is in Oslo, Norway.

International research in marine environment and fishery biology is co-ordinated by *The International Council for the Exploration of the Seas* (ICES). ICES works with the resources in the North Atlantic including the Baltic Sea and the areas east of Greenland. All coastal nations within this area, EU, Canada, and the USA participate in this co-operation. There is a close collaboration between ICES and the *North Atlantic Fisheries Commission* (NAFC) and the *North Atlantic Salmon Commission* (NASCO).

European co-operation

Within the (EU), the *European Science Foundation* (ESF) is the main co-ordinating organisation for research. The ESF acts as a forum for information exchange, as a co-ordinating organisation for the *ESF Networks*, for the European Research Conference (*EURESCO*), and for a number of the *ESF Scientific Programmes*. The most important programmes concerning the European Arctic are the *Polar North Atlantic Margin* (*PONAM*), the *Greenland Ice-core Project* (*GRIP*), and the *European Consortium for Ocean Drilling* (*ECON*); the latter is a project organised under the *Ocean Drilling Programme (ODP)*.

The EU provides considerable support to arctic research through the *4th Framework Programme (4FWP)*, especially within the *Marine Science and Technology (MAST)* programmes. In a collaboration between ESF and the European Commission, DG XII (CEC), the *European Committee on Ocean and Polar Science (ECOPS)* is planning the programme *Grand Challenge in Ocean and Polar Sciences*. The main activity within this programme is the *Arctic Ocean Grand Challenge.*

National Arctic research organisations

Numerous national organisations within the Arctic countries conduct arctic research.

Co-ordination of Arctic research in the Russian Federation is complicated. Until recently, the co-ordination was done by the *Russian Academy of Science (RAS)* with the *Arctic and Antarctic Research Institute (AARI)* in St. Petersburg as the main polar research institute. Now the situation is more complex. However, the *Kola Science Centre (KCS)* seems to continue to be an important research organisation in the northern part of the Russian Federation.

Swedish polar research is co-ordinated through the *Polar Research Committee* under *the Royal Academy of Science* with the *Polar Research Secretariat (PRS)* as the executive organisation. PRS works through the programme *SVEDARCTIC* which is particularly strong in the natural sciences.

In Denmark, the Commission for Scientific Investigations in Greenland is responsible for long term planning and priorities in Danish polar research. The Danish Polar Centre acts as a secretariat to the Commission. The actual research is carried out by various national agencies, universities and the Polar Centre.

In Iceland, polar research is organised through the Science Council of Iceland.

In Finland, arctic research is organised through the *Polar Commission*. The *Arctic Centre* in northern Finland is the secretariat for IASC, GCWG (GCPO), IASSA and the *Northern Forum Academy (NFA).*

In Norway, the *Norwegian Polar Institute (NP)* is the central agency for research and environmental management and mapping in the polar regions. The NP also has a long history of international involvement in these fields. The institute is currently strengthening its national and international role in these two fields, and as a provider of logistics and field support in the European Arctic. The institute is currently relocating from Oslo to Tromsø, and is concurrently expanding its presence and activity in Svalbard. The Norwegian *Institute of Marine Research* (IMR) is the national agency for research in fishery biology and management in temperate and arctic areas up to the marginal ice-zone in the Barents Sea. The IMR is the international co-ordinator of the marine part of AMAP.

Moreover, Norway has established the *Polar Research Committee* under the *Norwegian Research Council* which draws up the national strategy for Arctic research.

In Germany the *Alfred Wegner Institute* (AWI) is the central research institute for polar issues. This institute has an extensive activity in the European and the Russian Arctic.

In the United Kingdom, polar research is directed and co-ordinated by the *Polar Science Committee* under *The Natural Environmental Research Council* (NERC).

Also Poland, Italy, France, and Japan conduct polar research with platforms within the European Arctic.

Regional development programmes in the Arctic

The most important Nordic co-operative programme in the European Arctic is the *Nordkalott Committee* which organises activities of common interest in the Nordic areas. A relatively new area of interest is the *Euro-Arctic Barents Region.* The co-operation is based on the *Kirkenes Declaration* of January 1993, and is mainly connected to the land area in the region. The programme covers part of northwest Russia and the northern part of the Nordic countries, including the sea areas. The activities in the region are based on the *Barents Programme.*

The Barents Programme supports industrial and commercial development in the region. It is ,however, based on collaboratory activities which are meant to respect nature and the interests of the indigenous peoples.

International arrangements for the protection of the European Arctic environment

Prevention of pollution

Protection of the seas

The most important global conventions for the protection of the marine environment in the European Arctic are: The *Convention on the Prevention of Marine Pollution by Dumping of Waste and other Matter (London Convention 1972)*, and the *International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 relating thereto (MARPOL73/78).*

The London Convention is the primary international agreement regulating dumping of waste and incineration at sea. The convention sets forth minimum standards for all states on the basis of categories of pollutants and a system of permits for those substances that are allowed to be dumped. Amendments to the Convention of 1972 are: prohibition on the dumping of industrial waste, with limited exceptions; a ban on incineration at sea of industrial waste and sewage sludge; and a ban on dumping of low-level radioactive waste. The Convention is currently being revised.

Following up the UN conference on Environment and Development in 1992 (Rio Declaration), intergovernmental meetings have been held to adopt a global programme of action for the protection of the marine environment from land-based activities (the Washington-process). In Washington in 1995 an agreement was reached on the need to develop a global, legally binding instrument for the reduction and/or elimination of emissions and discharges (incl. appropriate manufacture and use) of persistent organic pollutants.

In May 1995 the *International Convention on Oil Pollution Preparedness, Response and co-operation, 1990 (OPRC)* entered into force. This is a global convention on preparedness and response to accidental oil pollution. It provides a framework for international co-operation in combating major oil pollution incidents and enhances existing national, regional, and global capabilities concerning oil pollution preparedness, response and co-operation. The Convention also provides for reporting procedures.

A regional agreement of importance is the *Convention for the Protection of the Marine Environment of the north-east Atlantic, 1992 (OSPAR Convention).* This convention resulted from the revising and merging of the 1972 *Oslo Convention* and the 1974 *Paris Convention.* Geographically, it applies to the north-east Atlantic, the Iceland Sea, the Norwegian Sea, the north Greenland Sea, and the Barents Sea. The OSPAR Convention regulates pollution from offshore- and land-based sources, ocean dumping, and ocean incineration. OSPAR includes the concepts of the precautionary principle and the polluter pays principle. Under OSPAR, the dumping of all wastes and other matter is prohibited, except for those wastes and other matter specifically listed. Incineration within the area where the Convention applies is prohibited. Dumping of all kinds of radioactive waste is prohibited for a minimum of 15 years (from January 1. 1993).

Air pollution

Among the most important conventions in this field are the *Vienna Convention for the Protection of the Ozone Layer*, including the *Montreal Protocol on Substances that deplete the Ozone Layer*, the *Convention on Long-Range Transboundary Air Pollution (LRTAP)*, and the Framework *Convention on Climate Change (FCCC).*

The objectives is to protect human health and the environment against adverse effects resulting or likely to result from human activities which modify or are likely to modify the ozone layer; to adopt agreed measures to control human activities found to have adverse effects on the ozone layer; to co-operate in scientific research and systematic observations, and to exchange information in the legal, scientific, and technical fields.

The LRTAP focuses more on general air pollution. The objectives are to protect man and the environment against air pollution, and to limit and, as far as possible, gradually reduce and prevent air pollution, including long-range transboundary air pollution. Three affiliated protocols to this convention are signed: the control of emissions of sulphur emission (1994 Sulphur protocol, *not yet in force*), the control of emissions of nitrogen oxides and their transboundary fluxes (NOx protocol), and the control of emissions of volatile organic compounds or their transboundary fluxes. To share the cost of a monitoring programme which forms the backbone for review and assessment of relevant air pollution, the *Protocol to the Convention on long-range Transboundary Air Pollution on Long-term Financing of the Co-operative Programme for Monitoring and Evaluation of the long-range Transmission of Air Pollutants in Europe (EMEP)* was signed in Geneva in 1984.

The FCCC's objectives are to stabilise greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous human interference with the climate system, within a time frame sufficient to allow ecosystems to adapt naturally to climatic change; to ensure that food production is

The biological resources of the European Arctic have been harvested for centuries: Remnants from white whale (*Delphinapterus leucas*) hunting in Van Keulenfjorden, Svalbard. (photo: Ian Gjertz)

not threatened; and to enable economic development to proceed in a sustainable manner. The Convention entered into force in March 1994.

Radioactive pollution

The *International Atomic Energy Association (IAEA)* has made several international agreements which concern nuclear safety. The most important are *the Convention on Early Notification of a Nuclear Accident (Notification Convention)* and *the Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency (Assistant Convention)*. The objective of the *Notification Convention* is to provide relevant information about nuclear accidents with possible international transboundary consequences as early as possible in order to minimise environmental, health, and economic consequences. The first objective of the *Assistant Convention* is to establish an international framework for facilitating the prompt provision of assistance in the event of a nuclear accident or radiological emergency. The second is to minimise consequences and to protect life, property, and the environment from effects of radioactive releases.

The Nordic countries have taken an initiative to arrange an international meeting regarding treatment and deposition of radioactive wastes and fuel cells from reactors, with a special emphasis on Russian problems.

The IAEA initiated *the International Arctic Seas Assessment Project (IASAP)* to address the health and environmental effects of radioactive waste which has been dumped in the Arctic. The projects are carried out by IAEA as a part of the bureau responsibility for the supervision of the London Convention. The Nordic countries initiated a resolution on *Nuclear Safety guidelines for Nuclear Powered* Vessels under the IAEA's general meeting in 1990.

Another organ for nuclear safety is OECD's *Nuclear Energy Agency (NEA)* which includes four special committees for nuclear safety, radiation preparedness and waste, statistics and prognoses regarding nuclear power, a scientist committee, and a committee which handles judicial questions regarding responsibilities and liability for compensation for a third party. The OECD *Co-ordinated Research and Environmental Surveillance Programme (CRESP)* might be a potential contributor to the studies of nuclear pollution in the arctic region.

In 1992, the G-7 countries decided to carry out a five year programme to strengthen nuclear safety in the Russian Federation and Eastern Europe with special emphasis on improving safety at the most vulnerable nuclear plants, improvement of the legislation regarding nuclear safety, evaluation of alternative sources of energy, and upgrading of newer nuclear plants.

Within NATO and *the North Atlantic Co-operation Council (NACC)* increased efforts have been made to stop the spread of mass destruction weapons and to prevent environmental damages as the result of the disarmament process.

Nuclear contamination from military activity is discussed under the NATO *Committee on the Challenges of Modern Society (CCMS)* and in the NATO *Science Committee.* Norway has taken an initiative to study transboundary chemical and radioactive pollution from military activity and installations in the Kara and Barents Seas. Moreover, an agreement has been reached between the Nordic countries and the Russian Federation for early warning and information in case of accidents and incidents linked to the nuclear power plants in the area. Under the Euro-Arctic Barents Region Co-operation an extensive mapping of radioactive pollution and dumping in the Barents and the Kara Seas is in progress.

Protection of arctic wildlife and habitats

The most important agreements on protection of arctic wildlife, habitats and protected areas are: the *Convention on Biological Diversity (CBD)*, the *Convention of International Trade on Endangered Species of Wild Fauna and Flora (CITES)*, the *Convention on the Conservation of Migratory Species of Wild Animals (CMS* or the *Bonn Convention)* , and the *Convention on the Conservation of European Fauna, Flora and Habitats (Bern Convention).* The objectives of the CBD, which entered into force in 1993, are to ensure the conservation of biological diversity and the sustainable use of its components; to promote a fair and equitable sharing of the benefits arising from the utilisation of genetic resources, including appropriate access to genetic resources and appropriate transfer of relevant technologies, and appropriate funding. It is expected that the provisions of the CBD will be an important tool to improve protection and monitoring of arctic ecosystems.

Of particular importance concerning wildlife in the Arctic is the *Agreement on the Conservation of Polar Bears and their Habitats* . The agreement was signed in 1973 by Canada, Denmark, Norway, USA and the USSR. The agreement has been instrumental in limiting the hunting of polar bears to sustainable levels, but has been of limited use in protecting polar bear habitats.

An important convention to protect vulnerable wetlands and waterfowl is the *Convention on Wetlands of International Importance especially as Waterfowl Habitat* (Ramsar Convention). Its objectives are to stem the progressive encroachment on and loss of wetlands now and in the future, recognising the fundamental ecological functions of wetlands and their economic, cultural, scientific, and recreational value, to encourage the "wise use" of the world's wetland resources, and to co-ordinate international efforts for this purpose.

The Agreement on North Atlantic Marine Mammal Commission (NAMMCO) from 1992, and the *International Convention for the Regulation of Whaling* from 1946, under which the International Whaling Commission (IWC) works, both aim to regulate harvesting of marine mammals.

The Convention on Environmental Impact Assessment in a Transboundary Context (ESPOO Convention, 1991) is aimed at preventing, reducing and controlling significant adverse transboundary environmental impacts (resulting in both pollution prevention and protection of wild life). It is open to member countries of the UN Economic Commission for Europe and states having consultative status with the Commission. All Arctic countries are eligible to become parties. The convention is not yet in force. Signatory parties are obliged to conduct environmental impact assessments on proposed activities that may have significant transboundary impacts. Parties that may be impacted must be notified of proposed projects and all impact assessment documentation must be made available with appropriate consultations carried out.

Over-harvesting: Fisheries represent the greatest impact on the marine ecosystem in the European Arctic. Unless international agreements on resource management are established, the resources may be seriously threatened. (photo: Trym Ivar Bergsmo/ Samfoto).

7 Threats and challenges to the European Arctic Environment

The main current threats to the European Arctic environment are:

- *Habitat fragmentation, degradation, or destruction*
- *Over-harvesting of biological resources*
- *The potential for radioactive contamination*
- *Persistent organic pollutants*
- *Oil pollution*
- *Tourism in vulnerable areas*
- *Introduction of alien species and diseases*
- *Cumulative impacts*
- *Long-range pollution transport*
- *Climate change*
- *Ozone depletion, UV-radiation*

There are in particular three characteristics of human activities that imply a future challenge to the European Arctic environment:

- *The need for development: Economy and industry in the north-west of the Russian Federation.*
- *The tragedy of the commons: Sustainability of national and international fisheries.*
- *"The last frontier" attitude: Obsolete and ageing practices and technologies.*

Threats

Current regional threats

➤ Habitat fragmentation, degradation or destruction

One of the most valuable and unique features of the European Arctic is its large areas of wilderness and natural wildlife habitat. Such habitats are the physical basis for all plant and animal populations. In the terrestrial environment, loss of suitable habitats is currently the single most important factor causing reductions in natural populations and loss of biodiversity. Agriculture, forestry, and other natural resource exploitation, road, construction, urbanisation, and other infrastructure development are all human activities that cause habitat destruction and fragmentation. Such activities continuously and increasingly affect wildlife habitats in the European Arctic (Table 7.1).

➤ Over-harvesting of biological resources

Several mammal and bird species have previously been over-harvested in the European Arctic, and both fish stocks and forest areas are being over-harvested today. Such over-harvesting not only depletes valuable populations and harms important economical interests. It can also directly or, for example through by-catches, depletion of the nutrient basis and through destruction of other species' habitats, reduce the total biodiversity of the system.

➤ Regional and local pollution

The pollution situation is severe in large parts of the Kola area (e.g. acidification, and heavy metals in air, soil and water), and in some areas further east (e.g. oil in soil and water). The environment is heavily affected by this pollution in these areas. Human health effects have not yet been clearly documented, but there are reports and strong indications of pollution-related health effects on large num-

	FIN	NOR	RUS	SWE	ICE
Climate Change	X	X	X	X	X
Mineral/Petroleum Expl. and Development	X	X	X		
Hydropower Development		X		X	X
Rapid Urbanization	X	X	X	X	X
Roadways/Infrastructure/Habitat Fragmentation	X	X	X	X	
Motorized Vehicles	X	X	X	X	X
Rapid Expansion of Tourism	X	X	X		X
Forestry Practices/Deforestation	X	X	X		X
Fisheries Practices/By-catch		X	X		X
Wetland Drainage	X	X	X		X
Erosion		X	X		X
Overgrazing	X	X	X		X
Introduction of Species	X	X	X	X	X
Over-Exploitation of Species/Hunting Pressures	X		X	X	X
Oil Spills		X	X	X	X
Ocean Dumping		X	X	X	X
Noise			X	X	
Airborne Contaminants	X	X	X	X	
Waterborne Contaminants			X	X	
Nuclear Waste			X	X	
Toxic Waste			X	X	

Table 7.1. **Threats**: CAFF list of current and potential threats to Arctic habitats and species. Source: Conservation of Arctic Flora and Fauna, Report No. 1.

bers of people in Murmansk oblast and in industrialised areas elsewhere.

➤ The potential for radioactive contamination

The large and increasing amounts of radioactive material in the Russian part of the European Arctic are to a large extent improperly stored and handled. The Kola nuclear power plant is relatively old. Nuclear material will have to stay in the area and in the current stores until new stores of satisfactory standard are provided. Until then, the potential for release of radioactive material from land-based and marine sources will increase with time. In addition, large amounts of radioactive material is stored along the Ob and Yenesey rivers east of the European Arctic. Radioactivity released into these rivers may be brought to the Kara and Laptev Seas and brought into the European Arctic by ocean currents. The current radioactivity levels in the European Arctic environment are low. Though small releases may only cause negligible health effects, they can easily cause large economic effects (fish export, reindeer meat).

➤ Persistent organic pollutants

Although the effects of POPs on the environment have not yet been studied in sufficient detail in European Arctic species, these pollutants are commonly considered the most serious environmental threat to animals high in the European Arctic food-chains. The current POP levels in glaucous gulls and polar bears are far higher in the European Arctic (Svalbard) than in other parts of the Arctic, indicating that the European Arctic receives more long range pollutants than these other areas. Continued POP emissions may cause serious consequences even in populations that live in an otherwise unaffected environment.

➤ Oil pollution

The potential for oil pollution is closely connected with the level of oil and gas prospecting and extraction activity, and will increase with the planned increase in such activity. Oil activity in areas with harsh and risky conditions (drift ice, cold, darkness, permafrost), long distances and lack of infrastructure and clean-up equipment increase this potential. Most probably, little can be done if an offshore oil spill happens in the European

Arctic. The use of obsolete technology and improper procedures, as well as the current lack of adequate regulations and standards, all add to the magnitude of the pollution problem.

➤ Tourism in vulnerable areas

The volume of tourism in Iceland, northern Scandinavia, Finland, and Svalbard is already large, and it is increasing rapidly in the eastern and High Arctic areas of the European Arctic. Wilderness tourism can be a positive factor through the educating effect on participants and because operators have economic interests in protecting their "product" – the Arctic nature – from degradation. On the other hand, large numbers of tourist visits to remote and fragile spots in the High Arctic may cause disturbance if not regulated. In some Kola rivers, tourist industries have bought fishing rights and blocked locals off from traditional resources.

➤ Introduction of alien species and diseases

Introduction or immigration of alien species to an area might cause impacts on resident flora and fauna. Only few species are registered as new to the European Arctic, and relatively few negative effects linked to the introduction or immigration of alien species are known. However, escaped salmon from Norwegian fish farms have infected wild salmon populations with parasites with detrimental and locally even disastrous results, and they have caused "genetic pollution" in such populations through interbreeding.

➤ Cumulative impacts

Although a single encroachment or activity is often without significant environmental effects, the impact may turn out to be serious if a series of such "harmless" encroachments are added. Examples are tracks and roads in wilderness areas, or small operational spills of oil or chemicals. The cumulative impacts of these and other activities may imply a long term environmental stress that is less conspicuous, but possibly more harmful, than short term, "spectacular" impacts.

Long term and global threats

➤ Long range transboundary pollution

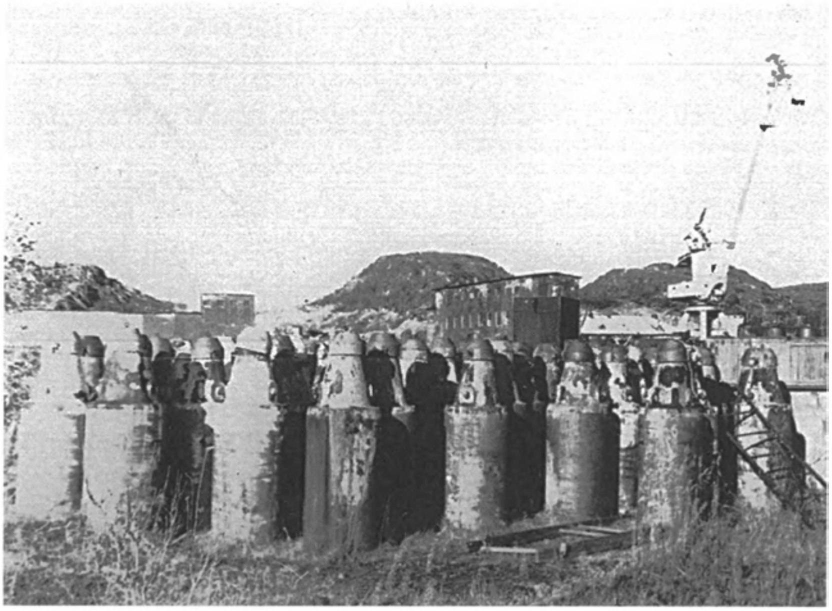
The one-way transport of pollutants to the European Arctic from Central Europe and other urban and agricultural areas has caused high levels of some pollutants in the region. Persistent substances are accumulated upwards in the food chain. Despite international regulations, several harmful substances are still produced and used extensively. Additionally, some of the many new substances introduced every year will probably also prove to be harmful to the environment. Unless production and use of such substances is stopped, the level of contaminants from long range transport in the European Arctic is likely to continue increasing.

The major environmental consequences of such pollutants in the European Arctic are expected to be:

- Organochlorines: Reduced fertility, increased mortality among young birds and mammals near the top of the food chain.
- Acidification: Reduced production, increased mortality in European coniferous taiga tree species, freshwater invertebrates and salmonid fish species.
- Accidental releases of radionuclides: Soil and plant contamination, bio-accumulation, increased frequency of diseases (cancer) and increased mortality in mammals, including humans, in affected areas.
- High levels of heavy metals: Poisonous effects on flora and fauna.

➤ Climate change

If the model predictions of a temperature rise in the Arctic twice that of the global average turn out to be correct, a complicated chain of events may be triggered. These potential multi-feedback loops may cause dramatic en-



Radioactive waste: 32 containers totalling 200–220 exhausted nuclear fuel cores from Soviet submarines, have been stored in an open field in Zapadnaja Litsa, close to the Norwegian border since 1961–62. The containers are in a very poor technical condition. (photo: Bellona)

Climate change:
A predicted effect of global warming is increased frequency of extreme weather situations. As in the rest of the world, extreme weather events have been unusually frequent in the European Arctic during the last decade, although these records are still disputed as scientific evidence of climatic change.

vironmental changes, but no reliable forecasts can be made for what the end result might be. The basic mechanisms involved are, however, strong arguments for complying with the precautionary principle in world climate politics.

The 1995 IPCC report document clear signs of global warming. The warming is expected to increase for several years even if emissions are reduced. At present, however, an international agreement on substantial reductions of greenhouse gas emissions does not seem close.

The major environmental consequences of climate change in the European Arctic are expected to be:

- Reduced sea ice cover, ice volume and albedo.
- Reduced deep water formation and storage of CO_2 in oceans.
- Changed thermal balance of permafrost systems; thermokharst erosion.
- Vegetation changes due to climate and substrate change.
- CO_2 and methane releases to the atmosphere.
- Positive feedback mechanisms between several factors.

➤ Stratospheric ozone depletion and increased UV-b radiation

The major effects of ozone depletion are expected to occur in the polar regions, since "ozone holes" are primarily formed over cold areas. Ozone depletion over the European Arctic caused by human emissions of ozone depleting substances has been demonstrated on Svalbard. Unless such substances are phased out world-wide, ozone depletion will continue to occur in the polar areas.

The major environmental consequence of ozone depletion in the European Arctic is expected to be:

- Reduced marine primary (phytoplankton) production caused by UV radiation, as demonstrated in Antarctic waters. This may reduce the annual nutrient basis for the marine ecosystem in the European Arctic.

Human activities; future environmental challenges

Besides the specific environmental threats currently caused by human activities, there are in particular three human development trends that imply important future environmental challenges.

The need for development: Economy and industry in the north-western Russian Federation

The Russian Federation is in strong need of a rapid economic and social development in order to strengthen national finances and administration and to counteract poverty. A primary basis for such development will be the large oil, gas, mineral, forest and other resources in the north-western part of the Russian Federation. In addition to Russian companies there is a heavy interest within international oil companies and other multinationals to develop activity in the area. This is expected to cause a dramatic increase in industrial, transport and other commercial activity in the area in the near future. In addition, as the new geopolitical situation has closed the Russian Federation off from almost all southern harbours, large export and import volumes to and from the rest of the Russian Federation may also pass through the north-western territories. This development is expected to include:

- Offshore and onshore oil and gas production facilities (in permafrost and drift ice areas).
- Offshore and onshore pipelines, storing and loading facilities, and possibly refineries.
- Increased ship transport of oil, gas and other products.
- New, deep sea harbour(s).
- Inland infrastructure development.
- Corresponding increase in secondary industries, services etc.
- Large scale forestry.
- Mining.

The presence of the navy and the army is likely to continue to be substantial in the north-western Russian Federation, and most existing and new nuclear materials and waste will have to be handled and stored locally. The current routines and management procedures in this area involves obsolete technology and is improper with respect to health and environmental safety.

The tragedy of the commons. National and international fisheries

Currently, the over-capacity of the fishing fleet and the lack of internationally accepted management regimes and quotas pose an acute threat to key species of the marine environment.

The large over-capacity in the fleet and the increasing degree of depleted fish stocks in the European Arctic cause an increased international demand for the marine resources of the European Arctic. Questions of jurisdiction, quotas, compliance and inspection in the European Arctic oceans may continue to be disputed for a long time. In addition to the large harvesting capacity of the European Arctic nations, a fleet of European Arctic and international fishing vessels may thus stay active in international or disputed waters, beyond national and international control and regulations, until these matters are settled. These factors may lead to:

- Uncontrolled harvesting of unregulated and poorly monitored stocks.
- Additional harvesting of managed stocks by nations without quotas.
- Over-harvesting of managed stocks caused by too high quotas or over-harvesting by the national fleet.

"The last frontier»: Obsolete and ageing technologies and practices

The vast and remote areas of the European Arctic are still seen as "the last frontier" where it is not always necessary or possible to "go by the book" with respect to environmental safety. Very few regulations ensuring particular concern for environmental safety are in force at the national or the international level in the European Arctic.

Despite political awareness and international regulations, prohibited POPs and other harmful substances continue to be produced and used in industry, for example within agriculture in developing countries. Since it may take time to alter such practices, such substances will continue to be transported to the European Arctic environment.

In the Russian Federation, old practices, lack of investments and a strong need for profits will promote the continued use of equipment and practices that are economically cheap on a short term basis, although environmentally detrimental.

These complex factors may lead to:

- Continued use of obsolete equipment and practices in management, industrial production, land and sea transport, military activities, construction, waste treatment, storage, etc.
- Continued transport of pollutants to the European Arctic, which acts as a "sink" for long range pollutants, and continued accumulation of persistent organic compounds and other substances in the European Arctic food chain.

Arctic summer night. (photo: Torfinn Kjærnet)

8 Objectives and Recommendations

The European nations should recognise the unique values of the European Arctic environment, it's ecosystems, biodiversity, wilderness areas and cultural heritage, and see it as their common responsibility to protect these values for the benefit of today's and future generations. Concerted action by European and other nations is needed to counteract current environmental problems, restore affected areas and resources, and ensure an environmentally sustainable future development.

It should be recognised that in order to achieve this, a different and higher level of environmental management is needed in the European Arctic than in most other parts of Europe.

Action is needed at all geopolitical levels. International co-operation can direct political focus and resources to the region, and facilitate co-ordinated responses to transboundary issues and problems. Such co-operation should primarily be based on existing conventions, agreements, programs and other co-operative efforts, such as the Arctic Environmental Protection Strategy/ Rovaniemi process (AMAP, CAFF, PAME, EPPR, TFSI), the Barents Region Environmental Task Force, the Nordic Council of Ministers' work on the Arctic Environment, the bilateral environmental co-operation in the area as well as the European Environment Agency and EU programmes.

Still, the main responsibility for actions lies with the individual nations. Most economic activity, management, development, and enforcement of regulations within the European Arctic is based on national law. As most important activities in the European Arctic are locally based action, information and education at this level are essential.

Long term goals

The following long term goals are proposed for management of the European Arctic environment:

- To protect and maintain the biological diversity and wildlife habitats of the area.
- To protect and maintain the biological productivity of the European Arctic ecosystems as a basis for sustainable development.
- To secure the long term environmental basis for local and indigenous peoples living in the area.

Objectives and actions

Based on the current threats, future development trends and long term goals, the following objectives and actions are recommended:

Objective I

Integrate environmental concerns into the economic and industrial activities in the area, in particular in north-western Russian Federation.

Both Russian and other European Arctic national legislation include environmental regulations and standards for most types of activities. It still remains a challenge to ensure that these are enforced and complied by, particularly in Russian Federation.

Actions needed:

1 Development of internationally agreed upon environmental management regimes, standards, impact assessment and reporting procedures, and mitigating measures.
2 Development and exchange of expertise on Arctic environmental management and science.
3 Improvement of information and scientific data bases on the European Arctic environment and impact factors.
4 Establishment of economic incentives for

environmentally safe operations and equipment (insurance, taxes etc.).
5 Improvement of information on European Arctic environmental issues to the public and to decision makers.

Objective II

Ensure sustainable management of European Arctic marine living resources and ecosystems.

Although the combined management tools and scientific knowledge of the European Arctic countries could probably provide a sufficient basis for sustainable management of the marine resources, these resources and regimes are insufficiently co-ordinated and partly disputed or inefficient.

Actions needed:

1 Establish internationally agreed upon management regulations, quotas, and inspection mechanisms in international and disputed waters.
2 Improve multi-species and ecosystem management models.
3 Enforce efficient countermeasures against over-harvesting, by-catches, and incorrect catch reporting.
4 Reduce or remove economic incentives for unsustainable practices.

Objective III

Protect European Arctic wilderness areas and important habitats.

Large parts of the European Arctic can still be characterised as wilderness. While the northern parts of the area have many established and planned protection regulations, wilderness areas are being challenged in the north-west of the Russian Federation and Fennoscandia, and partly in Iceland.

Actions needed:

1 Support the development and implementation of the Circumpolar Protected Areas Network (CPAN) strategy of the AEPS/Rovaniemi process.
2 Develop national and regional co-ordinated plans for environmental management and infrastructure development in non-protected areas.
3 Implement the provisions of the Biodiversity Convention at the national and regional levels in the European Arctic, including development of national strategies for conservation of biodiversity.

Objective IV

Reduce long-range transportation of pollution to the Arctic.

Some agreements restricting the production and use of some environmentally hazardous substances are in force, while others, (organochlorides, heavy metals, CO_2, ozone-depleting compounds), are being negotiated. Economic and political interests as well as insufficient scientific data slow the progress of this work.

Actions needed:

1 Research in order to identify sources, transport routes, mechanisms for, and biological effects of long range pollutants.
2 Contribute to reducing economic incentives for the production and use of harmful substances that may be transported to the Arctic.
3 Support the development of protocols under UN ECE Conventions on long-range Transboundary Air Pollution in order to contribute to the reduction of pollution transport to the European Arctic.
4 Consultation with non-ECE nations whose emissions and discharges of pollutants contribute to pollution of the European Arctic
5 Contribute to the improvement of testing and knowledge of the effect of new substances potentially harmful to the European Arctic environment.

Objective V

Ensure safe storage of radioactive waste and operation of nuclear facilities.

Radioactivity levels in the European Arctic environment are currently relatively low. Marine dumping sites and most land storage facilities and installations are recorded.

Actions needed:

1 Contribute financially and technologically to the improvement of currently insufficient storage facilities in the European Arctic to long term safety standards.
2 Contribute financially and technologically to maintenance, upgrading or decommissioning of unsafe nuclear facilities.
3 Support research in order to identify potential transport routes and mechanisms for radioactive pollutants

Objective VI

Utilise the relatively intact ecosystems and low impact levels in the area as a reference for regional *and global environmental monitoring, and for research to provide new knowledge on fundamental ecological processes.*

Several international long term monitoring programmes are operating or being established in the European Arctic. European and other nations are currently increasing their co-operative research effort in the area.

Actions needed:

1 Further develop long trend global and regional environmental monitoring programmes in the European Arctic, primarily based on existing and planned programmes:
   (a) climatic change (radiation, stratospheric zone, ocean, sea, ice, glacier, paleo-geology and vegetation changes studies);
   (b) High Arctic ecosystem state (marine and terrestrial);
   (c) Biodiversity mapping and monitoring (species, populations, distribution).

2 Basic studies of ecosystem function and individual adaptations:
   (a) Marine ecosystem function in ice-free and ice-covered waters and in estuary and coastal waters;
   (b) Vegetation and soil (permafrost) response to climatic change;
   (c) Effects of individual contaminants.

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Appendix

Red List of threatened animals and plants in the Euro-Arctic region

Sources: CAFF, IUCN, Icelandic Institute of Natural History, Norwegian Directorate for Nature Management, Swedish Threatened Species Unit.

The use of Finland, Iceland, Norway, Sweden and the Russian Federation below refers to the Arctic parts of these countries. Shaded cells indicate that the species do not inhabit the Arctic parts of the country.

The lists of mammals and birds are based on the 1995 CAFF and 1994 IUCN lists of threatened animals. The status codes for countries are similar to those used within CAFF, while the global status levels refer to IUCN standards.

The list of vascular plants is extracted from the 1994 CAFF list of vascular plants that are at risk in more than one country. Only species at risk in more than one of the countries within the European Arctic are included. The reader is kindly referred to CAFF for more detailed information about threatened vascular plant species in the Arctic.

In both lists we have included information about the abundance of the species in all countries. This information is given by "present" if the species inhabits the Arctic part of the country, and by a shaded cell if the species does not exist in the country.

IUCN codes	CAFF codes		Aditional codes
E = Endangered	Endangered	Present	= inhabits the country
V = Vulnerable	Vulnerable		= does not exist in the country
R = Rare	Rare		
K = Insufficiently known	Indeterminate		
	Need Monitoring		
	Not Classified (only used for Norway)		
	Extinct		

MAMMALS

SPECIES	Finland	Iceland	Norway - including Svalbard and Jan Mayen	Russian Federation	Sweden	IUCN Global state
Alopex lagopus (Blue (Arctic) Fox)	Endangered	Present	Present	Present	Vulnerable	-
Balaena mysticetus (Bowhead Whale)			Not Classified[s]	Endangered		V
Balaenoptera acutorostrata (Minke Whale)		Present	Present	Present		K
Balaenoptera borealis (Sei Whale)		Present	Present	Rare		V
Balaenoptera musculus (Blue Whale)		Rare	Endangered	Endangered		E
Balaenoptera physalus (Fin Whale)		Present	Present	Vulnerable		V
Canis lupus (Grey Wolf)	Vulnerable		Endangered	Present	Endangered	V
Delphinapterus leucas (White Whale)			Present	Present		K
Eubalena glacialis (Northern Right Whale)		Endangered	Present	Endangered		E
Globicephala melas (Long-finnedPilot Whale)		Present	Present			K
Gulo gulo (Wolverine)	Endangered		Vulnerable	Present	Vulnerable	V
Halichoerus grypus (Grey Seal)	Vulnerable	Present	Present	Present	Vulnerable	-
Hyperoodon ampullatus (Northern Bottlenose Whale)		Present	Present	Endangered		K
Lagenorhynchus albiostris (White-beaked Dolphin)		Present	Present	Present		K
Lutra lutra (Otter)	Need Monitor.		Vulnerable	Present	Vulnerable	-
Megaptera novaeangliae (Humpback Whale)		Rare	Rare	Endangered		V
Monodon monoceros (Narwhal)			Not Classified[s]	Rare		K
Odobenus rosmarus (Walrus)			Not Classified[s]	Vulnerable		-
Orcinus orca (Killer Whale)		Present	Present	Present		K
Phoca vitulina (Harbour Seal)		Need Monitor.	Not Classified[s]	Present		-
Phocoena phocoena (Harbour Porpoise)		Need Monitor.	Present	Present		K
Physeter catodon (Sperm Whale)		Rare	Present	Present		K
Rangifer tarandus (Caribou)	Present	Present	Present	Extinct	Extinct[1]	-
Ursus arctos (Brown Bear)	Present		Vulnerable	Present	Present	-
Ursus maritimus (Polar Bear)			Vulnerable[s]	Rare		V

[1] extinct as wild, common as tame

BIRDS

SPECIES	Finland	Iceland	Norway – including Svalbard and Jan Mayen	Russian Federation	Sweden	Global state – IUCN
Alca torda (Razorbill)	Present	Present	Vulnerable	Present		-
Alle alle (Little Auk)		Endangered	Present[5]	Present		
Anas acuta (Pintail)	Present	Rare	Rare	Present	Present	-
Anser erythropus (Lesser White-fronted Goose)	Endangered		Endangered	Indeterminate	Endangered	R
Anser fabalis (Bean Goose)	Present		Vulnerable	Present	Present	-
Aquila chrysaetos (Golden Eagle)	Vulnerable		Vulnerable	Present	Present	-
Aythya marila (Scaup)	Endangered	Present	Rare	Present	Present	-
Branta bernicla (Brent Goose)		*Need Monit.	Not Classified[5]	Rare		-
Branta leucopsis (Barnacle Goose)		*Need Monit.	Present[5]	Rare		-
Bucephala islandica (Barrow'sGoldeneye)		Rare				-
Calidris minuta (Little Stint)			Rare	Present		-
Circus cyaneus (Hen Harrier)	Present		Rare	Present	Present	-
Clangula hyemalis (Long-tailed Duck)	Present	Need Monitor.	Present	Present	Present	-
Crex crex (Corn Crake)			Present	Present	Extinct	R
Cygnus bewickii (Bewick's Swan)				Rare		-
Cygnus columbianus (Tundra Swan)				Rare		-
Eremophila alpestris (Shore Lark)	Endangered		Present	Present	Vulnerable	-
Falco peregrinus (Peregrine)	Vulnerable		Endangered	Rare	Present	-
Falco rusticolus (Gyrfalcon)	Vulnerable	Rare	Vulnerable	Vulnerable	Present	-
Fratercula arctica (Puffin)		Present	Vulnerable	Present		-
Gallinago media (Great Snipe)	Endangered		Present	Present	Present	-
Gavia adamsii (White-billed Diver)				Rare		-
Gavia immer (Great Northern Diver)		Rare				-
Grus grus (Crane)	Present		Vulnerable	Present	Present	-
Haliaeetus albicilla (White-tailed Eagle)	Endangered	Endangered	Vulnerable	Present	Present	V
Histrionicus histrionicus (Harlequin Duck)		Rare				-
Larus fuscus fuscus (North. LesserBlack-backed Gull)	Present	Present	Endangered	Present	Present	-
Limicola falcinellus (Broad-billedSandpiper)	Present		Vulnerable	Present	Present	-
Limosa lapponica (Bar-tailed Godwit)	Present		Rare	Rare	Rare	-
Lymnocryptes minimus (Jack Snipe)	Present		Rare	Present	Present	-
Melanitta nigra (Black Scoter)	Present	Rare	Present	Present	Present	-
Mergus albellus (Smew)	Present		Rare	Present	Present	-
Mergus merganser (Goosander)	Present	Vulnerable	Present	Present	Present	-
Nyctea scandiaca (Snowy Owl)	Vulnerable	Endangered	Rare	Present	Rare	-

SPECIES	Finland	Iceland	Norway – including Svalbard and Jan Mayen	Russian Federation	Sweden	Global state – IUCN
Oceanodroma leucorhoa (Leach's Storm Petrel)		Present	Rare			-
Pagophila eburnea (Ivory Gull)			Present[S]	Rare		-
Pandion haliaetus (Osprey)	Present		Vulnerable	Present	Present	-
Phalacrocorax aristotelis (Shag)		Present	Vulnerable	Present		-
Phalacrocorax carbo (Cormorant)		Present	Vulnerable	Present		-
Phalaropus fulicarius (Grey Phalarope)		Endangered	Present0	Present		-
Phalaropus lobatus (Red-necked Phalarope)	Present	Need Monitor.	Present	Present	Present	-
Phylloscopus borealis (Arctic Warbler)	Present		Rare	Present	Present	-
Podiceps auritus (Slavonian Grebe)	Present	Vulnerable	Present		Present	-
Rhodostethia rosea (Ross' Gull)			Rare[S]	Indeterminate		-
Sterna caspia (Caspian Tern)	Extinct				Present	-
Strix nebulosa (Great Grey Owl)	Present		Rare	Present	Present	-
Uria aalge (Common Guillemot)		Present	Vulnerable[N]	Present		-
Uria lomvia (Brünnich's Guillemot)		Present	Vulnerable[N]	Present		-
Xenus cinereus (Terek Sandpiper)	Endangered			Present		-

[S] species living in Svalbard (not in mainland Norway)

[N] for mainland Norway, common in Svalbard

* species resting in Iceland during their migration

VASCULAR PLANTS

SPECIES	Finland	Iceland	Norway – including Svalbard and Jan Mayen	Russian Federation	Sweden	Global state – IUCN
Arenaria humifusa			Present	At risk	At risk	-
Botrychium boreale		Present	At risk	At risk	At risk	-
Carex bicolor		Present	Present	At risk	At risk	-
Carex heleonastes		At risk	Present	At risk	At risk	-
Chamorchis alpina	At risk		Present	At risk	Present	-
Crepis paludosa		At risk	Present	At risk	Present	-
Gentianella tenella	At risk	Present	At risk		Present	-
Isoetes lacustris		At risk	Present	At risk	Present	-
Oxalis acetosella		At risk	Present	At risk	Present	-
Paris quadrifolia		At risk	Present	At risk	Present	-
Primula egaliksensis		At risk		At risk		-
Puccinellia capillaris			At risk	At risk	Present	-
Ranunculus sulphureus	At risk		Present		At risk	-
Sagina caespitosa		At risk	At risk		At risk	-
Salix arbuscula	At risk		Present	At risk	Present	-
Trisetum subalpestre	At risk		Present		At risk	-

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The European Arctic is clearly affected by human activity. The region has been seen as an area of unlimited harvesting, into which nuclear wastes and other contaminants could be deposited. The Kola Peninsula is affected by heavy industrial pollution and military installations. Intensive fisheries have resulted in over-exploited key stocks, and long-range pollutants threaten even High Arctic species. Still, the European Arctic is first and foremost an area with values unique in Europe. There are large, nearly pristine wilderness areas and nearly intact ecosystems. Many habitats and animal populations are far less affected by man than elsewhere in Europe, and the marine ecosystems are highly productive.

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