European Environment Agency

Europe's biodiversity

- biogeographical regions and seas

Biogeographical regions in Europe

The Arctic biogeographical region

- **warming up and changing?**

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Summary

- The Arctic biogeographical region has a highly varied landscape and contains some of Europe's few remaining large wilderness areas.
- The climatic conditions put extreme pressure on plants and animals, and large parts of the region are still under glaciation. Permafrost is widespread.
- There are few winter-active species, but very large populations of summer-active plants and animals.
- Large numbers of many migrating birds and fish species link arctic ecosystems inextricably with the conditions of circumpolar ecosystems as well as with Europe, northern Asia and Africa.
- Large parts of the region are dominated by coastal habitats and interchange with the sea is a dominant feature.
- Predicted increases in temperature of some degrees may change conditions radically in many areas and shift plant and animal communities towards more boreal types. Distributions of existing species and habitat types would shift northwards to higher latitudes and upwards to higher altitudes. Some species may become extinct.
- There are significant anthropogenic impacts from long-range air pollution, and in some areas from long-term overgrazing and recently from tourism.

1. What are the characteristics of the Arctic biogeographical region?

1.1 General characteristics

Table 1: Statistics for the Arctic biogeographical region

Surface Area (km^2)	Number of countries in region	National makeup of region by area	Population (people/km^2)	Main habitat type
670 000	3	RU 63% NO 22% IS 15%	Less than 10	Grassland and tundra around 60%[1]

Sources: compilation from various sources by ETC/NPB and EEA.

Note: RU: Russian Federation; NO: Norway; IS: Iceland
1. The data from Iceland are not fully comparable with data from Norway and the Russian Federation due to different definitions of tundra and grassland.

The area considered in this chapter is the European Arctic biogeographical region as defined by the European Commission and the Council of Europe for evaluation and reporting on nature conservation. It includes Iceland, northern Norway, the northern Kola Peninsula, the north-west Russian Federation and islands further north, such as Svalbard, Franz Joseph

Land and Novaya Zemlya. The Norwegian and Russian parts of the region are part of the Barents region as defined by the Barents Council and used by GRID-Arendal in databases and maps.

1.1.1 Topography and geomorphology

The region contains a wide range of landscapes, from bare rock to swamp, glacier to meadow, mountain to lowland plain. While some parts of the region were not covered by ice during the last Ice Age, most terrestrial ecosystems are the result of colonisation during the 10 000 years since then. Vegetation colonisation is continuing in some of the volcanic areas of Iceland and in areas all over the region where the ice is retreating.

Glaciers are important features of the region; they range in size from the small glaciers in small mountain recesses to the enormous glacial caps topping extensive mountain ranges. Vatnajökull ice cap in Iceland covers an area of about 8 288 km^2 and is about 914 m deep at its thickest point.

Fluvio-glacial activity has been and continues to be a determining element in the formation of the landscape. In the north, in the tundra and polar deserts, the ground is permanently frozen below the surface. This prevents water from penetrating into the ground. The active layer, the soil overlying the permafrost, is constantly saturated in summer over wide areas. In spite of low precipitation, boggy landscapes are therefore common. Discontinuous areas of permafrost occur further south in the transition zone between the tundra and the boreal forest. With the present changes in climate, the border of the permafrost is shifting to higher altitudes and northwards, creating new conditions for grazing and forest growth. The precise extent of this change is unknown.

The continuing cycles of freezing and thawing contribute to intense erosion and an ever-changing topography with wide local variability in soil and surface patterns, including polygons, circles, sorted and non-sorted stripes and mounds of soil with ice cores such as pingos.These patterns create great variations in moisture and temperature which enhance biodiversity by providing a great range of habitat types in a small area.
The coasts vary greatly, but are mostly rocky with archipelagos. In some areas, though, large plains roll to the sea with moors and large deltas such as around the Russian River Pechora and in southern Iceland. The tides vary, from 4 to 6 m along the Russian coasts to around 2-5 m in Iceland.

The region still has large wilderness areas, remote from human settlements, but increasing mobility (off-road driving, air transport) for residents as well as for tourists is radically changing this situation.

1.1.2 Soils

Much of the region has soils with a frozen layer at the base (cryosols). Permafrost conditions exist where the arctic soil layer in summer only thaws out down to 1 metre (low arctic) or less (high arctic polar deserts). Arctic soils are generally young, infertile and poorly developed. Tundra soils have a thick layer of largely undecomposed organic matter or peat. In contrast, polar desert soils are often of pure sand and gravel with only traces of organic material. The most developed and fertile soil is arctic brown soil, or brunisolic cryosols, found in sheltered areas on warm, well-drained sites with a deep active layer. Parts of the region were not covered by ice during the glaciation and these tend to have deeper organic soils, especially in wetter areas. New soil formation over lava and volcanic ash and on newly deposited or exposed sand and gravel is slow because of the low temperatures.

Iceland has suffered the strongest soil erosion in Europe, having lost around 50 % of its vegetation cover due to overgrazing and felling of the original woods and scrub. More than

40 000 km^2 show considerable-to-extremely severe erosion and only 11 % show no or little erosion. Erosion has been stopped in the most severely affected areas.

1.1.3 Arctic climate

Living conditions are generally controlled by the climate, with low temperatures, extreme annual variation in sunlight and short intensive growing seasons; however this varies from west (milder, humid) to east (colder, dryer).

Table 2: Main factors controlling life processes

	Winter	Spring	Summer	Autumn
Intense growing season	8–10 months winter	2–4 months summer		
Sunlight	Up to 3 months continuous darkness	Extreme increase rate	Up to 3 months continuous sunlight	Extreme decrease rate

The limit to the productivity of the region is the short growing season, although continuous summer daylight makes growth in this season intense. The simultaneous influence of warm water from the Gulf Stream and cold arctic waters affects the climate in all but the easternmost parts of the region.

The variability in the climate includes differences in temperature and precipitation, as well as differences in the annual patterns of both. This causes major fluctuations in access to food and limits the possibilities for reproduction. Weather patterns can shift very suddenly, producing many freeze-thaw cycles in a short period. Adaptability to such variations is essential if plants and animals are to survive.

The region is characterised by large changes in climate over short distances. In northern Norway annual precipitation drops from more than 1 000 millimetres (mm) along the coast to less than 300 mm only 100 km inland. Coastal areas of Iceland and northern Scandinavia have a marine sub-arctic climate with persistent cloudy skies and strong winds, high precipitation and frequent east-moving storms. Average temperatures in the winter are often mild and summers relatively cool (-3 °C in winter to 11°C in summer). A more continental sub-arctic climate is found inland, or along the Russian coast, where winters are much colder and drier, and summers slightly warmer (-11 ºC in winter and 13 °C in summer). Svalbard has a very cold and dry climate (winter -14 ºC and summer 5.5 ºC).

Evaporation is very low in the whole region. However, in large areas precipitation is so low (below 200-300 mm per year) that polar deserts develop, such as on Franz Joseph Land, Svalbard and in central Iceland.

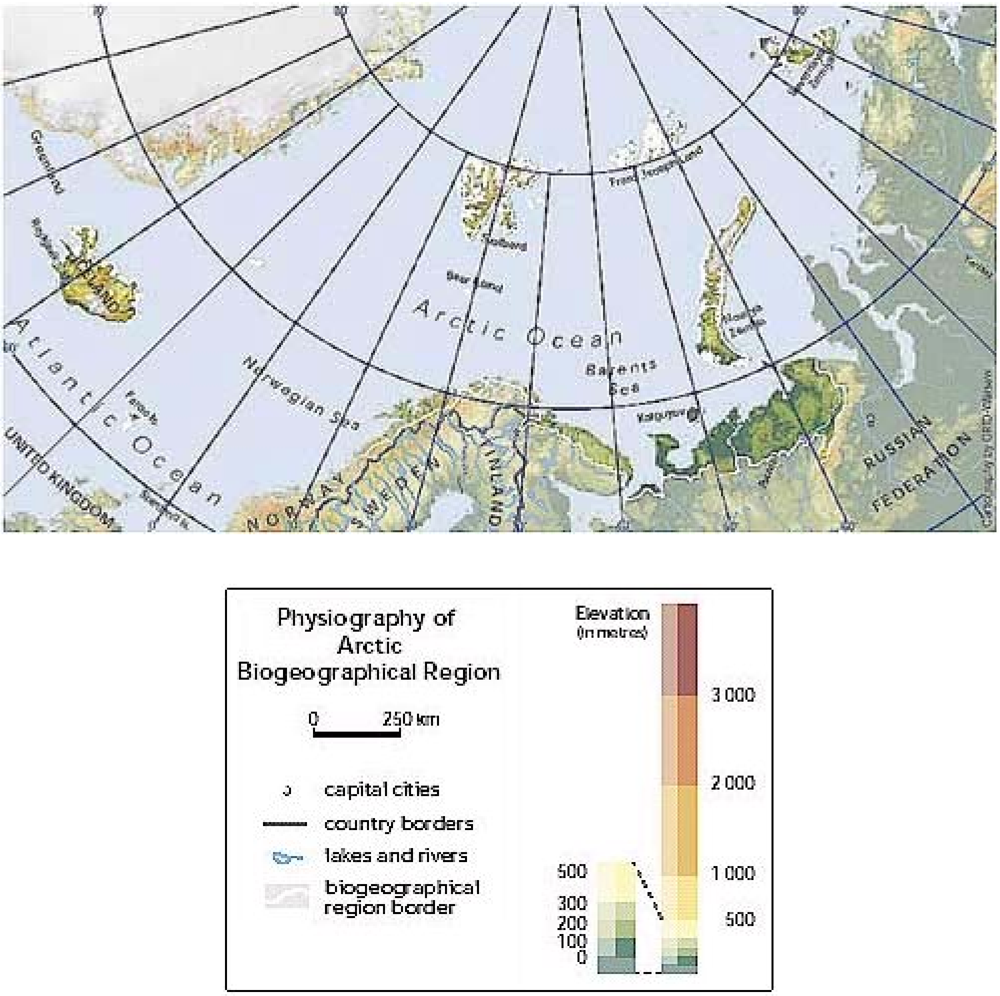
1.1.4 Population and settlement

Despite the relatively small and sparse population, nearly all of the land area (except for the ice-bound areas) is in use, or has been in recent years or decades.

With the exception of the Russian Federation, where present economic conditions have compelled many people to move from remote areas towards cities, populations are slowly increasing. However, whereas a large part of the population used to migrate seasonally with the reindeer or for fishing and hunting, most of the population is now sedentary and urban. Most settlements are along the coasts or in valleys.
Tourism is growing rapidly in value and bringing a greatly increasing number of tourists into the area, mostly during the summers, and, to a much lesser degree so far, for winter

sports. Tourism provides access to formerly undisturbed wilderness areas by terrain vehicles and helicopters and creates new settlement nuclei and infrastructure.

Map 1: The Arctic biogeographical region physiography (elevation pattern, main lakes and rivers)



Source: EEA. UNEP/GRID Warsaw final map production.

1.2 Main influences

Main influences
The main influences on biodiversity are:

- climate change
- economic use of species
  - hunting
  - berry harvesting
  - fur trading and fur farming
  - freshwater fishing
  - forestry
  - grazing activities

Other important influences are:

- draining of wetlands
- hydroelectricity
- mining, oil and gas development
- tourism
- contaminants
- alien species.

1.3 Main political instruments

Main political instruments
The main political organisations and instruments of direct importance for biodiversity of the region are:

- the Arctic Council
- the Barents Region Council
- Nordic Council and Council of Ministers
- the Bern Convention (Convention on the Conservation of European Wildlife and Natural Habitats)
- the Ramsar Convention (Convention on Wetlands of International Importance especially as Waterfowl Habitat)
- the Bonn Convention (Convention on the Conservation of Migratory Species of Wild Animals)
- the Convention on Biological Diversity (CBD)

1.4 Biodiversity status

1.4.1 Ecosystems and habitat types

The Arctic remains the largest area of true wilderness in Europe. At first sight many parts of the region are polar deserts without soil or vegetation. Closer inspection shows that some plant life is always present, and even on and in permanent ice there are often algae.
Two main vegetation zones are found:

- in the southern part (sub-arctic): the northern sub-zones of the circumpolar boreal forest;
- in the northern part (the Arctic proper): tundra vegetation (from the Finnish word for an open rolling plain).

Between forest and tundra lies the tree line: the absolute northern limit of tree-like species, although even beyond it the same species may be found in low shrub and dwarfed forms. Some areas under glaciation are treated in the chapter on the Alpine region.

Table 3: Main habitat types of the Arctic biogeographical region, definition according to EUNIS (European Nature Information System) Habitat Classification (by top categories)

Forest	Grassland and tundra	Polar desert	Permanent water bodies
Russian Federation and Norway 10–15 % Iceland 1 % (mostly birch shrubs)	Russian Federation and Norway around 60 % Iceland 46%[1)]	Russian Federation and Norway 2 % Iceland > 30 %[1)]	Russian Federation and Norway around 2 % Iceland 12 %

Sources: Compiled from various sources by EEA.

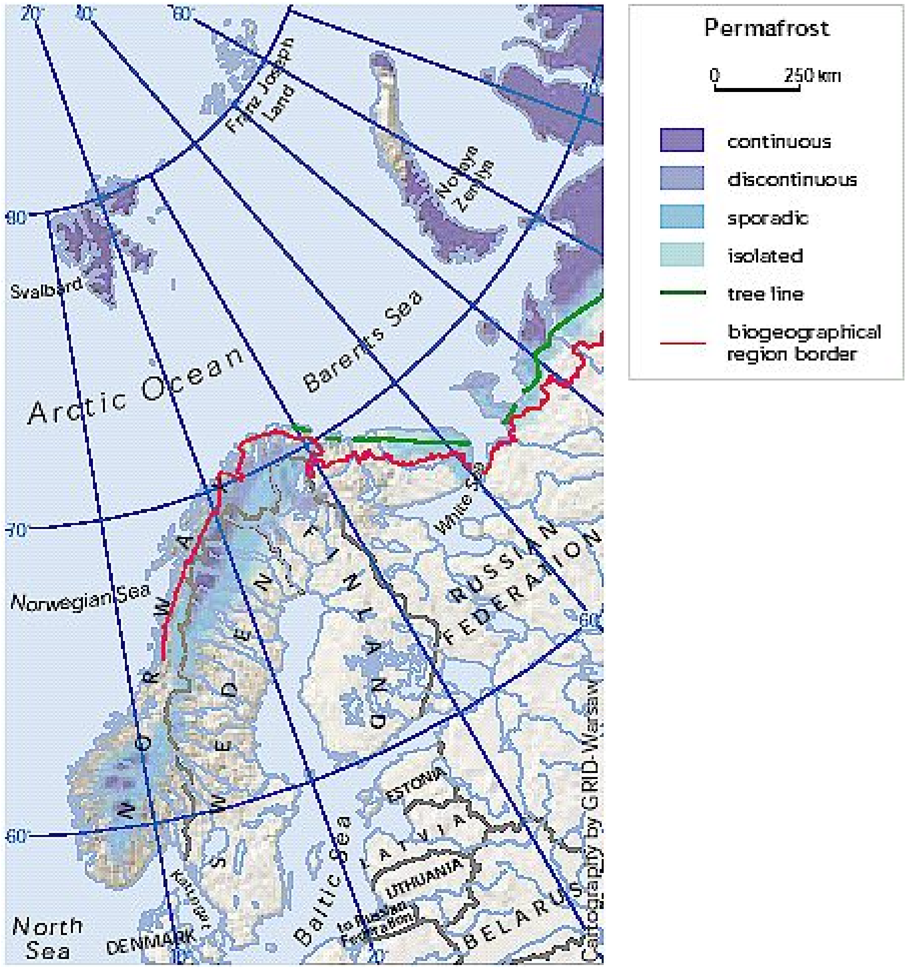
Note: 1) The data are not fully comparable between countries due to different definitions of tundra and grasslands.

- **Forests at the limit**

Forests and other wooded land cover 10-15 % of the region in Norway and the Russian Federation, while only around 1 % in Iceland. The forest occurs between the continuous forest line to the south and the tree line (the limit for the occurrence of trees more than 2-3 m tall). The arctic forests are either sparsely covered by trees, or composed of a mosaic of tundra and forest. The plant species composition is relatively uniform throughout most of the arctic forest which basically consists of one canopy layer with an under-vegetation of dwarf shrubs, mosses and lichens. The predominant tree species in Iceland is birch (*Betula pubescens*),while in the rest of the region birch occurs together with spruce (*Picea abies*), pine (*Pinus sylvestris*) and larch (*Larix sibirica*). In Iceland the shrubs are dwarf shrubs, mainly willows (*Salix spp.*), heather, *Vaccinium* and crowberry (*Empetrum nigrum*). The proportion of tundra in the forests increases northwards. The northernmost trees are as a rule short and stunted. The breadth of the transition zone varies from some hundreds of kilometres in the eastern Russian parts to only a few kilometres in the western parts. Altitude, which often creates differences in climate similar to those produced by changes in latitude, also affects the transition zone.

Permafrost is mostly discontinuous in the forest-tundra and continuous under the tundra. The climate restricts the generative reproduction of the trees more than the vegetative growth. Mature trees can live for hundreds of years without regenerating, and several tree-line species can reproduce vegetatively. Generative reproduction is often possible only after a series of favourable years. Increasing temperatures and longer activity seasons are expected to change this.

Map 2: Permafrost and tree line



Source: From CAFF web map (modified for EEA by UNEP/GRID Warsaw).

The arctic forest has fewer plant species than either the tundra north of it or the boreal forest south of it. The true tundra species and true forest species do poorly in this intermediate zone, where more ecologically flexible species survive. Fungi play an especially important role. Stresses such as a cold climate and nutrient-poor soils make trees more dependent on mycorrhiza. Many insects thrive in the arctic forest zone, foraging on trees and other plants and finding refuge from wind and storms. These insects are, in turn, food for insectivorous birds. Accordingly, the arctic forest and the tundra can support large numbers of birds during the summer months. In some areas, the insects can devastate a region as effectively as fire, which itself may spread through the dry, dead timber left by the insects. Many migratory species such as reindeer spend some part of the year in the forest-tundra, or at least pass through it as they move from the tundra to the closed forest south of it. As the marginal range of many species, the forest-tundra provides a refuge in case of catastrophe and an evolutionary area for adaptation to the Arctic. It also serves as an east-west channel for exchange of animals with similar areas in Siberia.

Regeneration of former forest is occurring in Iceland where decreased sheep grazing allows the suppressed low arctic birch forest and shrub vegetation to reappear in a relatively short time, though the acreage is still small. There is also increased active afforestation, mostly with acclimatised alien conifers from Europe or North America, with hardy poplars from the same regions gradually coming into use also. The long-term plans call for afforestation of ca 5% of the lowlands of Iceland.

The downy birch forests of the Arctic: A unique forest ecosystem

Most of the lower parts of the coast of northern Norway and the Kola Peninsula are covered by birch forests, dominated by the downy birch (*Betula pubescens*). These occur as tall trees (up to 20 m) in most of Europe; in the Arctic they stay around 2 m in many places. The pure birch woods of the Arctic are characterised by unique ecological processes affecting their structure and functioning. The most important of these is the regular fluctuations of two moth species, the winter and autumnal moths, which every 10 years or so reach outbreak densities severe enough to wipe out birches over significant areas, creating a natural patchy structure in addition to the topographical fragmentation.

The fluctuations have direct consequences for the ecosystem with effects over more than just one season:

Direct influence:

- Large moth outbreaks with many moth caterpillars provide large amounts of food for many bird species, which increase in number and improve their chances of survival.

Indirect influence:

- The same large outbreaks reduce the vitality of birches in subsequent years.

- **Tundra**

The tundra is circumpolar. In the Arctic region it occurs on the vast treeless plains, covering around 55 to 60 % of the region. It has an annual production period of only 1.5 to 3 months. The annual growth or biomass increment of tundra plants is very low, and they are thus capable of supporting only a limited number of herbivorous animals. Bacterial activity is low and invertebrate soil fauna are nearly absent. Biological material is only slowly decomposed.

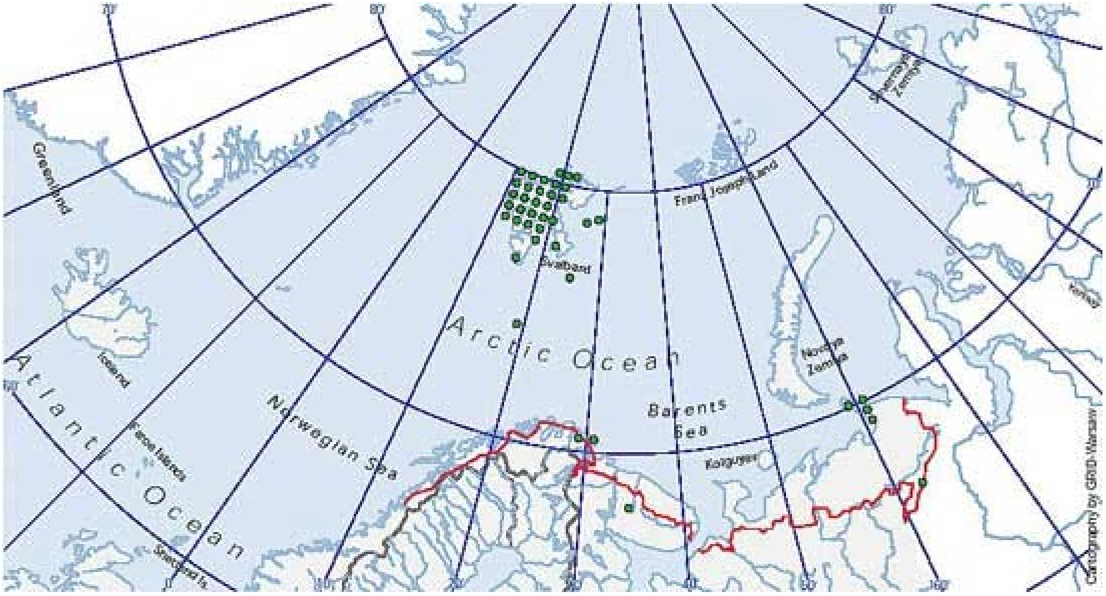
For much of the year, the tundra is covered in snow and is relatively inactive. Some resident mammals hibernate and most if not all insects are dormant during winter. Resident non-hibernating species such as lemmings (*Lemmus lemmus*) and arctic fox (*Alopex lagopus*) spend the winter trying to survive, living off fat reserves and the little food that is available. In summer, however, the tundra bursts into life. Migratory birds arrive in huge numbers from far away, and plants take advantage of the daylight to initiate a hectic growing season.

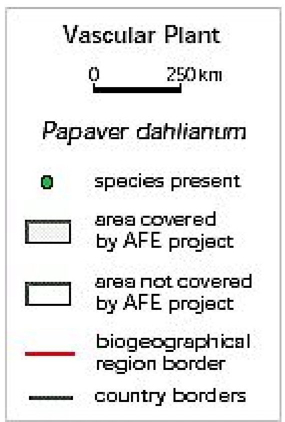
The tundra has fewer plant species than the boreal forest, and the number of species decreases northwards, with decreasing July temperatures. Mosses, lichens, dwarf shrubs and shrubs dominate. The moss flora is abundant and rich (150-200 species in some research plots). The number of vascular plants can be upwards of 250-300 species per 100 km^2, 70-100 bird species and 20 mammal species. Shrubs are sporadic and often with prostrate forms. Prostrate forms of willows (such as polar willow *Salix polaris*) extend far into the polar desert.

Several 'nunatak' areas, (mostly mountainous areas not covered by ice during glaciations) offered refuge to a number of species during glaciations and some still exist with such species such as in the Vatnajökull ice cap area. The bright yellow Svalbard poppy (*Papaver dahlianum*) is typical of high arctic flora. This may be a relic species which survived glaciation and spread from nunataks.

Reindeer favour areas with a dense cover of reindeer moss (which, despite the name, is a group of lichens) as grazing grounds. However, heavy grazing pressure reduces the slow-growing lichen cover in favour of grasses.

Map 3: Svalbard poppy (*Papaver dahlianum*)





Source: ETC/NPB (based on Atlas Florae Europaeae)

While reindeer herds may be large, their ranges cover vast areas with an overall density of animals far lower than in the grasslands of temperate and tropical regions. Berry production on the tundra is vital to many vertebrate and birds during the winter as well as to migrating bird species.
At the southern edge along the tree line, arctic tundra vegetation forms a narrow belt of tall shrubs, mostly erect, which gradually changes to a low-shrub tundra with semi-erect willows (*Salix spp.*), alder (*Alnus sp.*), and dwarf birch (*Betula nana*) along with heather vegetation (*Cassiope sp., Vaccinium sp., Ledum sp., Arctostaphylos sp.*).

- **Polar desert**

The polar desert is largely bare ground or rock, lacking moisture and warmth to sustain extensive plant cover. Precipitation is around 200-300 mm per year. In Iceland natural deserts have spread because of intensive sheep grazing and erosion. The plant composition in polar deserts is unique in that it is of relatively recent origin, representing a stage of primary succession. In many areas this has been gradually established over centuries, but in volcanic areas or areas with retreating ice cover or sheltered conditions it is of much more recent origin. Plant cover is currently expanding more rapidly than before.
Many arctic plants are good at colonising bare ground, relying on nutrients absorbed from the exposed rocks and soils or from the air. Spore plants are dominant: lichens grow, extremely slowly, on stable surfaces; mosses compete with vascular plants for favoured

habitats. A few vascular plants, such as moss campion (*Silene acaulis*), thrive even in undeveloped polar desert soils, provided enough moisture is locally available. Once plants are well established, they can alter the character of the local environment and the entire landscape. In the Russian polar desert areas, vascular plant species typically number no more than 20-30 species per 100 km^2.

Oases in the arctic desert

In high arctic regions such as Svalbard, which are dominated by desert conditions (low precipitation, low nutrient availability, low water content), combinations of favourable conditions that occur in limited areas allow abundant plant cover, and robust growth during the short arctic summer. These areas, known as arctic oases, are often located in low-lying sheltered areas. They enjoy higher temperatures than their surroundings since the warmth of sunlight is retained in the plants and soil. They are often linked to the presence of seabirds. Seabirds need arctic islands to reproduce; they nest in dense colonies on cliffs or screes where they are safe from predators such as arctic foxes. Their excrement provides a large amount of nutrients, and the slopes below are often unusually green and lush, harbouring plant and animal species seldom found in surrounding areas. The arctic oases may become centres for the spread of vegetation under warmer climate conditions.

- **Arctic wetlands - bogs, lakes and rivers**

Wetlands, from peat bogs to marshes, dominate vast stretches of the tundra and are found throughout much of the arctic woods. Ponds and lakes are common and some areas of the tundra appear in summer to be nearly as much water as land. The lakes are mostly shallow and of a limited size: no lake or reservoir is larger than 100 km^2. The largest natural lake is Lake Thingvallavatn in Iceland (84 km^2).

Many parts of the region are rich in small streams and rivers. The biggest rivers are the Russian Dvina and Pechora. The Dvina brings vast amounts of water from the boreal region north through the Arctic region into the Arctic Sea, keeping the top layers of the Arctic Sea far less salty than most ocean water, while the migrations of fish from the ocean to freshwater bring significant quantities of nutrients back from the sea.

Generally the water quality of the rivers and lakes is good. Iceland has the highest proportion in Europe of rivers classified as being of good quality (around 99 %). However, in areas with mining industries, such as in the arctic part of the Russian Federation, rivers and lakes can be very heavily polluted. Several rivers are fed by glaciers and have large annual fluctuations in water discharge. When drainage from glaciers is blocked, melt water is stored inside the glacier. When water is finally released, large glacier outburst floods (jökulhlaups) occur. The largest occur in Iceland (the latest major incident was in 1996).

There are many extreme habitats for freshwater life in the Arctic: permanently ice-covered lakes, saline lakes and ponds, perennial springs, naturally acid lakes, meltwater lakes, ponds and streams on glaciers and ice shelves, and hot-water springs and ponds. These environments often contain complex communities of microscopic life forms such as viruses, bacteria, cyanobacteria, micro-algae, protozoa, nematodes, rotifers and tardigrades, that are highly tolerant of the extreme environmental conditions. The biodiversity and functioning of these so-called extremophiles is attracting increasing interest among ecologists because of their biotechnological potential and their importance for understanding the fundamental biological processes of adaptation, survival and evolution. Thus freshwater systems in the Arctic support a great number of species of bacteria, protists, algae and micro-invertebrates. Many of these small-cell species form a complex microbial food web that provides the biomass and energy that support larger animals.

1.4.2 Species groups

There are few winter-active species, but populations of summer-active plants, insects, rodents and incoming migrating birds and fish are very large. With few species compared with other parts of the world, genetic diversity is of particular importance, reflecting adaptations to local, often extreme conditions.

The presence of relatively few species also means that certain key ecological functions depend on only one or two species, rather than several with overlapping roles as might be found in lower latitudes. While individual species may be very resilient to changing conditions, the system as a whole may be vulnerable to catastrophes if key functions are disrupted by the disappearance of a few species or by occurrence of new species (by invasion, introduction or as a result of changing temperature). There are few endemic species.

- **Plants**

The arctic environment has only a small number of dominant plant species. One of the most widely spread is the cotton grass (*Eriophorum vaginatum*) on humid tundra. A similarly small number of accompanying plant species such as cowberry (*Vaccinium vitis-idaea*) are present. Plant composition is more or less identical from one region to another around the Arctic, which as a whole contains only 0.4 % of the world's vascular species.

Arctic plants produce large numbers of seed, but very few of them germinate. Insect pollination is rare, while self- (auto-) pollination is very common. One striking aspect of the arctic flora is the relatively small number of annual species. In spite of harsh living conditions, perennial arctic species can be very long lived: up to 80 years for dwarf birch, more than 100 years for dwarf azalea and even more than 500 years for *Diapensia lapponica*.

- **Mammals**

Mammals are the group of terrestrial animals with the largest above-ground biomass. Important groups are small rodents and insectivores (lemmings, voles, shrews), small predators such as weasel, marten and fox, ungulates like deer, moose and reindeer and larger predators. Several rodent species are found all over the southern parts, except in high alpine areas. The oscillations of the populations of rodents in many areas set the conditions for the size of the predator populations both among mammals and birds: high rodent populations allow high predator populations.

The arctic vegetation cover is heavily impacted and maintained in an open condition not only by climatic conditions, but also by grazing, mostly by herbivorous rodents and ungulates but also in some areas by ducks, swans and geese. The characteristic ungulate species are the reindeer of the tundra and the moose (*Alces alces*) in the arctic forest. The moose is widely hunted but the populations are large and even increasing.

Predatory mammals are rare in most of the region, largely because of competing land uses by humans and extermination campaigns designed to remove animals capable of harming livestock such as reindeer. There are four big land predator species in the region: the brown bear (*Ursus arctos*), lynx (*Lynx lynx*), wolverine (*Gulo gulo*) and wolf (*Canis lupus*), for which the largest populations are found in the Russian Federation. The arctic fox (*Alopex lagopus*) is found throughout the region in alpine or tundra habitats. The mainland populations of this predator are very small, some of them so small that their existence is threatened. In Iceland the Arctic fox has a viable population of some 3 000 - 6 000 animals in autumn despite persistent persecution since medieval times. The polar bear (*Ursus maritimus*) is a maritime species that regularly visits some of the most northern of the arctic islands such as Svalbard. The coasts harbour large numbers of seal and walrus, reproducing in the shore-belt ice. Retreating and thinning sea ice may change the pattern of movement and living conditions of the polar bear.

Photo: Arctic fox (*Alopex lagopus*)

Source: Sune Holt/Biofoto.Danmark (SH2119)

Table 4: Species in the Arctic biogeographical region, number of vertebrates

	Total	Amphibians[2]	Reptiles[2]	Mammals[3]	Breeding birds
No of species in region[1]	271	3	1	37	230
No of species threatened at European level[1]	44	0	0	2	42

Source: EUNIS from European Atlases, compiled in June 2000.

Note: 1. Only present species are taken into account, extinct or introduced species are excluded.
2. Based on data from only 82 % of the total region as covered by the European Atlas of Reptiles and Amphibians.
3. Excluding cetaceans - only 37 % of the total area of the Arctic region is covered by the European Atlas of Mammals.

- **Birds**

Resident birds are few, but the number of migrating birds is high. The migrating bird populations link the arctic ecosystems inextricably with the conditions of circumpolar, European, northern Asian and African ecosystems.

The open wetlands of the Arctic are a primary breeding habitat for large populations of waterfowl, such as swans (*Cygnus spp.*), brent goose (*Branta bernicla*), greater scaup (*Aythya marila*), eider (*Somateria sp.*, *Polysticta stelleri*), several species of geese, and the calidrid waders (*Calidris sp.*). In the arctic forests, a rich bird fauna with singing birds, woodpeckers, and several species of grouse, raptors and owls are found. There are large seabird colonies along the sea coasts of the Russian Federation, Norway and Iceland. On the Murmansk coast and in Novaya Zemlya alone there are more than 80 colonies. In Iceland an estimated number of ca 8 million pairs of seabirds nest in hundreds of colonies. In the shallow lake Myvatn (Iceland) a uniquely rich duck fauna has developed, allowing the gathering of around 10 000 eggs per year. At least 43 of the breeding species and sub-species protected in EU Member States under the EU Birds Directive Annex I are also present in the Arctic region (March 2000 based on data from BirdLife International).

Where large bird numbers congregate, the influence from their grazing or berry eating may be very significant, as is the subsequent deposit of droppings and thus the fertiliser effect.

- **Freshwater fish**

The freshwater fish fauna contains more than 30 species. Very few of the freshwater species are restricted to the Arctic, but many fish species have genetic and behavioural adaptations for life in arctic waters. For example, dwarf forms of whitefish and of the arctic char (*Salvelinus alpinus*) in Lake Thingvallavatn in Iceland are genetically distinct from southern strains of the same species. In addition to resident fish species, freshwater is essential to the life cycles of anadromous fishes, which spawn in freshwater but live part of their lives in the ocean. Salmon (*Salmo salar*) is the best known but a number of whitefish (*Coregonus spp.*), arctic char (*Salvelinus alpinus*), brown trout (*Salmo trutta*) and other species follow similar patterns. The pink salmon (*Onchorhynchus gorbuscha*) has been introduced from the Pacific Ocean.

As with migrating birds, migrating fish populations link the arctic ecosystems with the conditions of circumpolar, European and American ecosystems.
Races (gene pools) of indigenous fish such as salmon and trout are influenced and threatened by introductions of non-indigenous races.

- **Invertebrates**

The diversity of invertebrates is low. However some insects, such as mosquitoes, midges and blackflies, appear in summer in extreme densities over large areas in connection with the widespread standing freshwater. The grasslands around Lake Myvatn are fertilised by masses of midges (*Chironomidae*) emerging from the lake and dying after mating. Insects are a severe plague to reindeer in some areas. In the Russian Federation the most numerous group is beetles (*Coleoptera*) with more than 250 species. In the soil of the Russian tundra the group of *Annelida* (segmented worms) produce the highest biomass.

Climatic adaptation of plants and animals

The ability of animals and plants to last through the winter, and to take advantage of the summer, is critical to their survival. A number of adaptations make this possible.

Plants store nutrients over winter so that they can grow rapidly when spring arrives, making full use of early spring sunlight to extend the growing season. Arctic species must be able to survive long periods when food is limited or unavailable, and must respond quickly when conditions are right. Because sunlight reaches the plants before the ground is thawed, some plants store nutrients in their roots so that they are ready to begin growing as soon as spring arrives. This strategy also allows plants to maximise the benefits of good years by providing reserves for bad years, evening out the year-to-year unpredictability of the climate. In this respect, arctic, high alpine and steppic and arid zone plants show many similarities.

Animals store energy in the form of fat or blubber, or change their metabolic rate to minimise energy use during winter months. Fur and feathers that insulate against the cold allow even small animals such as lemmings and songbirds to survive in the depths of winter. Animals, too, must be ready to breed rapidly in good years and to live long enough to survive through bad years. Many insects spend most of their life cycle underground or under water and emerge only for the brief mating period. Others take a long time to mature, such as the woolly-bear caterpillar (*Gynaephora groenlandica*) which takes 14 years to develop from a fertilised egg to a mature adult. For many birds, long life spans allow them to select favourable years for reproduction rather than investing energy in producing eggs and rearing chicks when they are unlikely to survive. Mammal populations vary greatly. Small mammals such as lemmings (*Lemmus lemmus,* absent from Iceland) are able to reproduce rapidly when conditions are good, and their populations can soar in good years (2001 was a lemming year). When this happens, the populations of their predators, such as stoats (*Mustela erminea*), snowy owls (*Nyctea scandiaca)* and skuas (*Stercorarius spp.),* also rise rapidly. The lemming population cycles with high population peak years has been considered one of the most striking biological events in the mountain areas. However, in recent decades the phenomenon seems not to have been so evident. The reasons and the impacts are not fully clear. Many animals are able to move great distances to seek favourable conditions. A significant number of bird species migrate between the Arctic and temperate and tropical regions.

2. What is happening to biodiversity in the Arctic biogeographical region?

2.1 Climate change

Climate change is already recognised as affecting the distribution of moisture, expansion of forest, and consequent shifts in distribution of most plants and animals of the region.

With a predicted 2-4 ºC increase in temperature, mainly in winters, and a possible 20 % higher precipitation in many areas, climate-change models indicate a major reduction in the area of tundra as the forest moves northward towards the Arctic Sea, as well as a shift in the position of the tree line. Higher temperatures are predicted to push the snowline upwards by 150 m for every 1 ºC rise and to move vegetation main belts upwards and northwards at rates of 150–550 km and 150–550 m respectively during the coming century. Some terrestrial ecosystems cannot move further upwards or northwards as the climate gets warmer and are therefore threatened with future extinction. The rate of migration of major vegetation components such as trees depends on their life cycles and production and spreading capacities and may be slower than the rate of climate change, leading to completely new compositions of vegetation types based on the fastest migrating species, normally wind-borne. Animals with long-range migration patterns will be able to adapt quickly.

Oceanic birch forests, for example, represent a highly restricted ecosystem, with the largest area to be found in northern Norway. This is considered one of the most threatened ecosystem types. The Norwegian lemming, a keystone species of the tundra ecosystem, may also be threatened by climate change, which in turn may influence the populations of arctic carnivores and raptors. Sufficient depth and duration of snow cover are essential for successful hibernation of the polar bear.

2.2 Economic use of biological resources

Cross-boundary data based on statistical surveys on the economic use of biodiversity in the Arctic biogeographical region do not yet exist as such, though much information and data relevant for this region are being collected through the work of the Arctic Council or to be found via GRID-Arendal.

2.2.1 Traditional hunting, fishing and harvesting of berries and mushrooms

The importance of food from local land and waters remains high, although harvesting methods may change and become more effective. Hunting, fishing, and gathering of berries and mushrooms are still a mainstay of indigenous communities and many other local settlements throughout the region, although only very few people survive solely on this. With the exception of the smallest mammals and birds, most animals of the tundra are hunted for meat or fur. Such hunting takes place across a broad area: land used by a single settlement may encompass thousands of km^2 of tundra. Egg collecting (eider, geese, guillemot) is prohibited in many areas. In Iceland egg-collecting relates principally to seabirds, although some collecting still takes place at Lake Myvatn. Many varieties of plants are gathered: berries, roots, mushrooms and greens for food, herbs for medicinal purposes, and grasses used to weave baskets or insulate footwear. Such uses have at times depleted the local populations of some species, but the majority of traditional uses of the tundra have had little lasting effect. While domestic use may decline, emerging harvesting for wider trade (berries, mushrooms, lichens) may lead to depletion in some areas.

2.2.2 Fur trapping and fur farming

Fur trapping was commonly practised for centuries in the forest, in pursuit of bear, lynx, wolverine, wolf and a variety of smaller mammals such as ermine (*Mustela erminea*). The skins taken were and still are traded, as well as used locally. Fur trading was an important factor in establishing transportation routes through the Arctic and introducing manufactured goods to the region.

In the Russian Federation, fur farming along the arctic coast was a large enterprise satisfying a high demand for furs in central Russia. Large numbers of marine mammals were hunted to provide food for the foxes. In the Scandinavian part of the region, ptarmigan (*Lagopus mutus*) trapping was one of the most important sources of income as late as the 1950s.

Today, trapping and fur farming are smaller in scale but still important in many areas.

2.2.3 Freshwater fishing

Freshwater fishing is still the most widespread use of freshwater resources in the region. Arctic waters provide substantial quantities of fish each year from subsistence, sport and commercial fishing. The number of species is relatively low, but many, such as salmon (*Onchorhynchus spp.* and *Salmo salar*) and whitefish (*Coregonus spp.*), are an abundant and valued source of food and income. Others, such as lake trout (*Salvelinus namaycush*), char (*Salvelinus alpinus* and *S. malma*) and grayling (*Thymallus arcticus*), attract sport fishermen from around the world while also providing for commercial fisheries. The most common impacts from fishing are local declines in some species through over-harvesting. The high economic interest in sport fishing has led to the introduction and spreading of cultivated stocks of salmon and trout.

There is an emerging biotechnological interest in the genetic coding for arctic survival mechanisms (cryo-genes), for example in fish.

2.2.4 Forestry

Although arctic forests have only been under human influence for a few centuries, few areas remain unaffected today. However, arctic forests are generally less exploited than the boreal forest to the south, largely because tree growth is slow and the trees are smaller and thus less adapted for wood products, regeneration is very slow and access is often difficult.

Local use of wood for timber and firewood has declined in recent decades with better access to imported materials. However, as the timber industry expands, more interest is being shown in these areas, especially in the north-west Russian Federation, where an increasing proportion of the rich, productive forest areas along the southern border of the region is being used for spruce (*Picea abies*) plantations. This results in fragmentation of the remaining birch forests, and may lead to disruption of important ecological processes such as population fluctuations of small mammals and moths.

Deforestation by the early settlers in Iceland, followed by heavy grazing by sheep led to the virtual disappearance of the forest and extensive erosion. Similar patterns have been seen elsewhere in the region, where heavy grazing by sheep and reindeer have prevented the regeneration of birch forests.

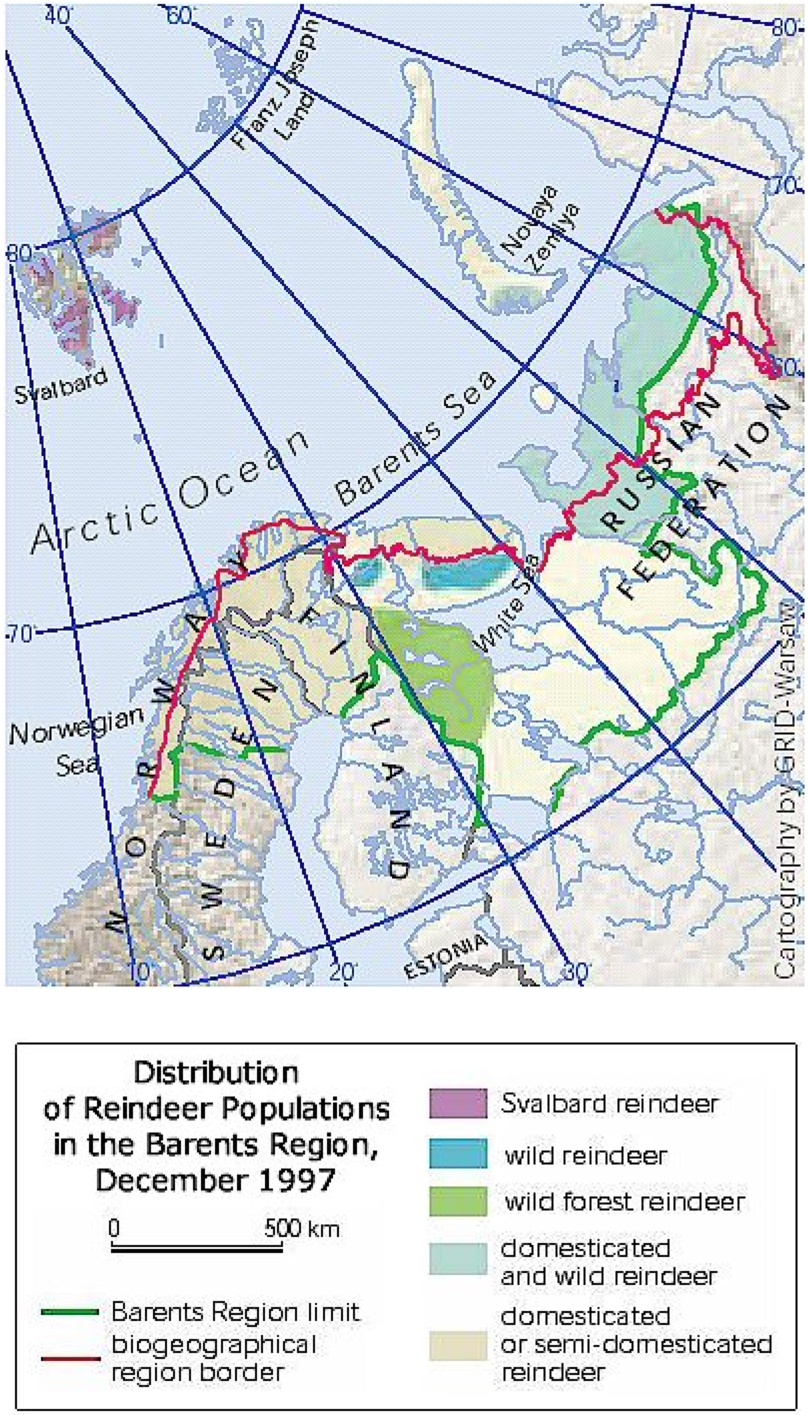
Afforestation is still at a very low level, though Iceland has had forest programmes for several decades, mainly with alien species.

2.2.5 Reindeer grazing

Reindeer herders still move their domesticated animals between summer and winter grazing areas, but movement patterns and distances have changed considerably over recent decades as numbers have increased markedly as a result of winter feeding. In the region of Norwegian Finmarksvidda numbers have also increased, though not from winter feeding.This has had severe consequences for vegetation in many areas. In Russia, reindeer herds used to be spread across northern areas, dispersing the impact of their grazing. This was possible because the collective farms had helicopters and other means of supporting the distant herders and giving them access to settlements and manufactured goods. Such support is now largely gone. The herders tend to stay closer to the settlements, and the herds are concentrated into smaller areas, resulting in localised overgrazing.

The several wild populations of reindeer that still exist are under pressure from the managed herds or are being intermixed with them.

Map 4: Distribution of Reindeer Populations in the Barents Region, December 1997



Source: From CAFF web map from UNEP/GRID Arendal website 2001 (modified for EEA by UNEP/GRID Warsaw).

2.2.6 Sheep grazing

Sheep are highly important in Iceland, and overgrazing was until lately a serious problem, contributing to the severe erosion. Grazing has been reduced in selected areas and is becoming more intensive in others. Winter stabling is common and the total stock, which peaked during the period between 1955 and 1985 at 900 000 head has now returned to about 450 000 head.

Land reclamation in Iceland
Erosion control and land reclamation was initiated in 1907 in Iceland. The main means used are control of grazing intensity and vegetation management. Around settlements forest belts are erected. In eroded areas, seeding of Icelandic varieties of grasses (*Leymus arenarius, Festuca rubra, Poa pratensis*) and nitrogen-fixing Alaskan lupine (*Lupinus nootkatensis*, introduced in 1945) are the main sand binders, while a small number of other indigenous leguminous plants are coming into focus also. Seeding in combination with fertilisation is conducted from low-flying airplanes.

2.3 Other major pressures on biodiversity

2.3.1 Drainage

Drainage has been a major problem in Iceland and large areas are still under drainage. However, with the land reclamation and soil erosion control activities, draining has levelled off.

2.3.2 Hydroelectricity

Several hydroelectric dams have been built in the Arctic, primarily in Norway and Iceland. This has led to alteration of hydrological regimes in rivers with potentially negative consequences for fish as well as other wildlife associated with the river systems. By restricting water flow and placing a physical barrier across the river, fish movements may be greatly limited; for example salmon may be blocked from their spawning grounds. The lakes created behind dams flood large areas and can create barriers to migrating land mammals. Where they flood wetlands, they may release contaminants such as mercury that are otherwise bound to soil particles, causing problems particularly for predators such as white-tailed eagles and osprey as well as for humans who eat fish from these watersheds. These impacts are no different from similar effects in other regions.

2.3.3 Mining, oil and gas development

The 20th century saw the beginning of the large-scale industrial use of tundra and polar desert areas, particularly for mining and oil and gas development. The search for minerals led to the exploration and development of large areas of the Arctic (for example metal mining on the Kola Peninsula and coal mining on Svalbard). This caused severe damage to the forest-tundra in the areas surrounding the large mining complexes in the northern Russian Federation. Trees and other vegetation over large areas have been killed by heavy metals, sulphur dioxide and other contaminants released from smelters, with consequent problems of erosion and further environmental damage. The damage caused by the mining areas of the Kola Peninsula includes the loss of needles on Scots pine (*Pinus sylvestris*) and other species. Acid rain caused by the emissions of sulphur dioxide has severely damaged lichens and other species.

Vast reserves of oil have been found in the Russian Federation. On-shore petroleum exploitation and production has substantial environmental impacts. The infrastructure of oil development, from drilling platforms and processing plants to pipelines, extends through large stretches of the arctic landscape. In Svalbard advanced equipment and careful procedures reduce these impacts and the potential for accidents. More recently, development has begun to extend into offshore areas. The possible impact on the land area in the region from offshore oil activity is primarily related to accidental oil and chemical spills affecting the coasts. For example, oil from the ruptured pipeline in the Komi Republic, Russian Federation in 1994 and 1995 caused severe environmental damage along the coasts. Pipelines may act as barriers to the movement of larger animals, leading to fragmentation of their territories.

2.3.4 Tourism

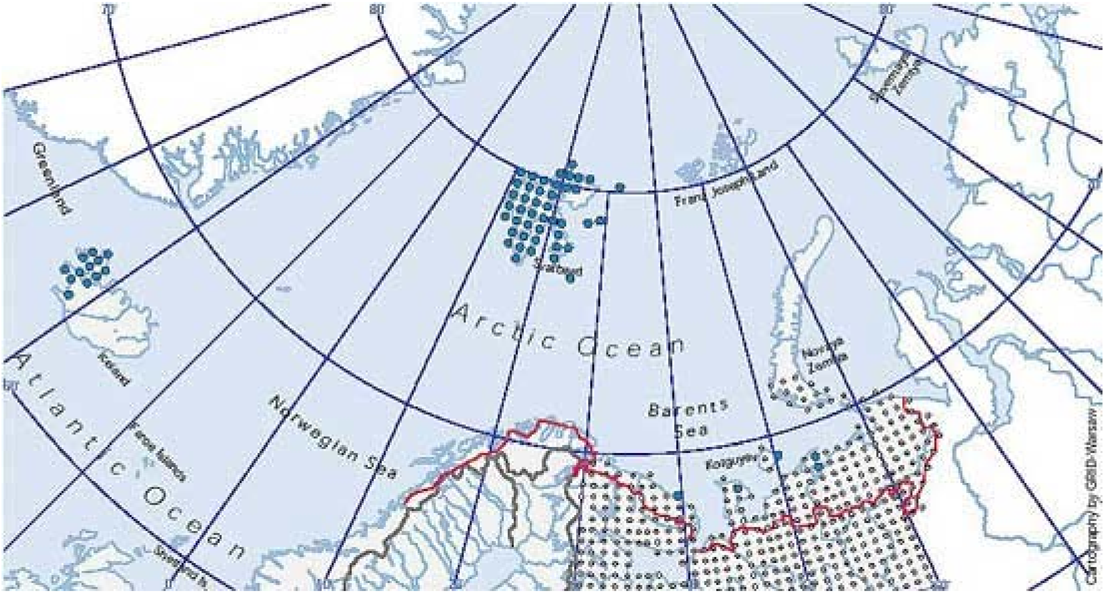
In recent decades, tourism has become a major industry in some areas of the region. Northern Scandinavia, with relatively easy access from population centres in western Europe, attracts the most visitors, up to 500 000 per year. 250 000 tourists visit Iceland each year, a figure which is increasing by 10 % per year. For some services such as whale-watching with 30 % per year. The increased number of tourists can benefit local economies, but concerns arise from disturbance of fragile vegetation and animal life in ecologically sensitive areas. The growth in tourism requires more land-based infrastructure and increases the volume of ship and aeroplane traffic, the need for freshwater and the production of waste. Regeneration of vegetation after mechanical impacts (human trampling, snow or off-road vehicles) is in general very poor, often leaving lasting effects. The animals that attract tourists may be greatly disturbed (nesting birds, resting walrus). Efforts are under way to develop effective management policies for tourism in the Arctic, focusing on minimising impacts and respecting local cultures.

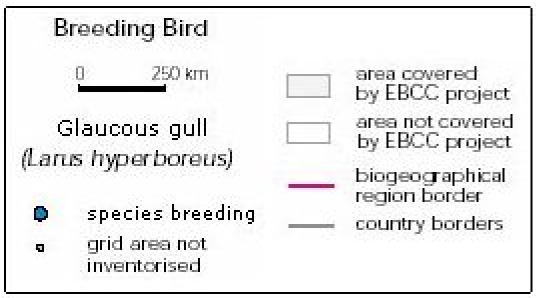
2.3.5 Contaminants

Compared to most areas in the world, the environment in the region remains clean. However, the area faces serious environmental risks and problems associated with contaminants from far distant and, in some areas, local sources. Depending on geographical location, weather conditions and the physico-chemical properties of the contaminants, they can be carried via the atmosphere, water currents, sea-ice drift and the great arctic rivers to and within the region.

Persistent organic pollutants (POPs) originate mainly in the temperate and tropical latitudes and are carried to the Arctic by air and water. Although the concentrations are typically higher in the marine food web than the terrestrial one, these substances are found in tundra plants and animals. Some POPs and heavy metals are present in concentrations high enough to pose threats to the health of arctic wildlife. Contaminant levels in some arctic animals exceed thresholds associated with reproductive, immunosuppressive and neuro-behavioural effects in laboratory animals and some studied wildlife species. Such effects have been documented in top predators such as the polar bear (*Ursus maritimus*) in Svalbard and the glaucous gull (*Larus hyperboreus*) on Bear Island. The polar bears in the Norwegian Arctic have been found to have a high concentration of PCBs (20 times higher concentration than in Alaskan polar bears). Pseudohermaphrodism has been found in the bears since 1996. Of the around 13 000 bears in the Norwegian Arctic area more than 1–2 % are now thought to be affected. Similar findings have also been reported from Greenland. The degree of exposure can be explained as a result of the global circulation pattern of both air and water, transporting pollutants into the Arctic from southern latitudes and accumulating in the polar bears which are at the top of the food web (Norwegian Polar Institute, 2001).

Map 5: Breeding distribution of Glaucous gull (*Larus hyperboreus*)





Source: ETC/NPB (Based on data from European Bird Census Council)

Photo: Glaucous gull (*Larus hyperboreus*)

Source: Sune Holt/Biofoto. Danmark (SH834)

Acid deposition is lower than in most of Europe. However, there is particularly low tolerance of acid deposition (acid rain) in Norway and the Russian Federation. When the acid is stored in snow, the spring runoff can carry a concentrated pulse of acidic water through the ecosystems, with severe impacts. After a period with declining acidification, there have been reports of levels in Norway increasing again.

Radionuclides from the fallout of atmospheric testing of nuclear weapons from the 1940s through to the early 1960s and from industrial accidents, especially at Chernobyl in 1986, have spread across the entire Arctic. In the tundra and polar deserts, lichens, mosses and cushion plants draw heavily on air and precipitation for their nutrients and are thus exposed to much of the radioactive contamination that comes to the Arctic. Reindeer in turn are exposed through the lichens that make up most of their winter diet, and show some of the highest concentrations of radionuclides among arctic animals. The remaining nuclear material and waste around the port of Murmansk on the Kola Peninsula and the presence of marine nuclear-powered vessels in the adjacent ocean continue to cause concern.

Ozone depletion occurs primarily over the polar region. The increased exposure to ultraviolet radiation that results may cause changes to the chemical structure of plant and animal cells and genes. It can also harm the eyes and skin of animals. International conventions to eliminate ozone-depleting chemicals appear to be having some effect, but more monitoring is needed.

2.4 Alien species

Biological disturbances have occurred in many areas through the introduction of alien species. In Norway, brook and rainbow trout (*Salvelinus fontinalis* and *Onchorhynchus mykiss*) have been introduced in streams to benefit sports fishing. Norwegian electric companies introduced the opossum shrimp (*Mysis relicta*) to mountain lakes to replace invertebrates that had been lost due to changes in water levels from damming. The shrimp was intended to provide prey for fish and thus support fish populations. Some fish such as burbot (*Lota lota*) and brown trout (*Salmo trutta*) do benefit, but the opossum shrimp eats the zooplankton that arctic char (*Salvelinus alpinus*) and whitefish feed on, and those species have declined, leading to an overall decline in fish production in these waters.
In Iceland the feral mink (*Mustela vison*) has had severe effects on some wetland and seabird species. The introduction of some alien tree species and especially the Alaskan or Nootka lupine (*Lupinus nootkatensis*) is gradually changing species richness in some areas. Biological consequences include a reduction in the genetic diversity of species. If a discrete population of a species is lost, its distinctive genetic characteristics may also be lost. Such problems are especially prominent with species such as salmon, which have separate stocks in each river system. Genetic contamination is another problem, for example through programmes to stock salmon streams by releasing smolt taken from other places. The genetic identity of the original stock may be lost, along with the special characteristics that have adapted it to that particular stream.

3. Policies at work in the Arctic biogeographical region

3.1 Nature Protection

3.1.1 International collaboration

The Arctic biogeographical region is integrated through circumpolar, Nordic and wider European collaboration:

- **The Arctic Council**
  Iceland, Norway and the Russian Federation are all members.

- **The Nordic Council and Council of Ministers**
  Includes Iceland and Norway and collaborates with the Russian Federation.

The main conventions with direct influence on biodiversity in the region are:

- **The Ramsar Convention**
  The Convention on Wetlands of International Importance especially as Waterfowl Habitat, is signed by Iceland, Norway and the Russian Federation and has led to major designations of areas for water birds.

- **The Bonn Convention**
  The Convention on the Conservation of Migratory Species of Wild Animals (CMS) is signed only by Norway, while the Russian Federation is associated.

- **The Bern Convention**
  The Convention on the Conservation of European Wildlife and Natural Habitats, is signed by Norway and Iceland.

- **The Convention on Biological Diversity**
  The Convention on Biological Diversity (CBD) is signed by all countries of the region.

3.1.2 Protected areas

Areas designated for nature protection may be protected by national instruments alone or under both national and international instruments.

Internationally protected areas

In the Arctic biogeographical region there are several internationally protected areas, mostly large and connected to wetlands and migratory species, such as Ramsar sites. Since the countries of the region are not members of the European Union no areas are designated under the Birds and Habitats Directives. So far no areas have been designated according to the Bern Convention. In the Introduction to the report a map shows the internationally designated areas in Europe.

The Circumpolar Protected Areas Network (CPAN) is an undertaking under CAFF. After a period of little progress the initiative is now being revitalised. Information is accessible via the UNEP/GRID Arendal web site.

Nationally protected areas

The countries in the region have a wide number of nationally protected areas. In the Russian Federation approximately 4.3 % of the total arctic area is protected. This includes 190 000 km^2 of tundra, including arctic tundra, moss-lichen tundra and bush tundra, 27 500 km^2 of mountain tundra, forest tundra and northern taiga, along with 42 000 km^2 of glaciers and polar deserts on Novaya Zemlya, Franz Joseph Land and the other high arctic islands.

In Norway a total of 41 611 km^2 of arctic land area is protected, which constitutes 25.4 % of the total Norwegian Arctic. The largest protected areas in the Norwegian Arctic are found in Svalbard, where 22 000 km^2 of glaciers and 12 900 km^2 of tundra are protected. On the Norwegian mainland the protected areas consist mainly of treeless mountain areas (2 940 km^2). Some birch forests (797 km^2), and only minor amounts of coniferous forests (99 km^2), fjord and coastal areas (60 km^2), and freshwater (168 km^2) are protected.

In Iceland more than 10 % or some 12 100 km^2 of the area is protected by law; about 25 % is protected seascapes or landscapes and 20 % is national parks. The main habitats protected are geological formations, relict birch forest, shallow bays, intertidal zones and volcanic craters. Vatnajökull (glacier and adjacent areas) is foreseen to become Europe's largest national park in 2002, doubling the protected area in Iceland.

3.1.3 Red List species

There are no Red Lists of threatened species developed directly for the Arctic region, but arctic species and habitat types are part of national Red Lists in all three countries.

3.1.4 Protected species

International conventions
Several Arctic species are protected under international conventions.

Botanical and zoological gardens - ex-situ conservation of genepools
There are no zoological gardens in the region. However, there are 2 botanical gardens in Iceland.

3.2 Research and monitoring programmes

AMAP
The Arctic Monitoring and Assessment Programme (1991, Arctic Council)) has responsibility for monitoring the levels of, and assessing the effects of, anthropogenic pollutants in all compartments of the arctic environment. Since 1997, AMAP has had a ministerial mandate to continue 'monitoring, data collection, exchange of data on impacts, assessment of the effects of contaminants and their pathways, increased ultraviolet-B (UV-B) radiation due to stratospheric ozone depletion, and climate change on arctic ecosystems'.

CAFF
The Programme for the Conservation of Arctic Flora and Fauna (1991) under the Arctic Council addresses the special needs of arctic species and their habitats in the rapidly developing Arctic. CAFF developed a Strategic plan for the conservation of arctic biological diversity in 1998, and the plan identifies monitoring as one of the key objectives. The Circumpolar Protected Areas Network is an activity under CAFF.

SCANNET
is a network of field bases, research station managers and user groups that are collaborating to improve comparative observations and access to information on environmental change in the North.

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Bonn Convention:
http://www.wcmc.org.uk/cms/

CAFF (Conservation of Arctic Flora and Fauna):
http://www.caff.is

GRID-Arendal:
http://www.grida.no

Information on jökulhlaups (large glacier outburst floods):
http://center.ess.ucla.edu/davidson/research/grimvotn/home.htm

HALO ehf, Laboratory for Oceanic and Atmospheric Sciences:
http://halo.is/ (tidal information)

Ministry for the Environment, Iceland:
http://brunnur.stjr.is/interpro/umh/umh-english.nsf/pages/front

Icelandic Institute of Natural History:
http://www.ni.is

Icelandic Agricultural Research Institute:
http://www.rala.is (soil erosion)

Norwegian Ministry for Environment:
http://odin.dep.no/md/engelsk/

Nordic Council and Council of Ministers:
http://www.norden.org/start/start.asp

Norwegian Polar Institute:
http://www.npolar.no/

Ramsar Convention:
http://biodiversity-chm.eea.eu.int/convention/other_conv.html

Russian Conservation Monitoring Centre:
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